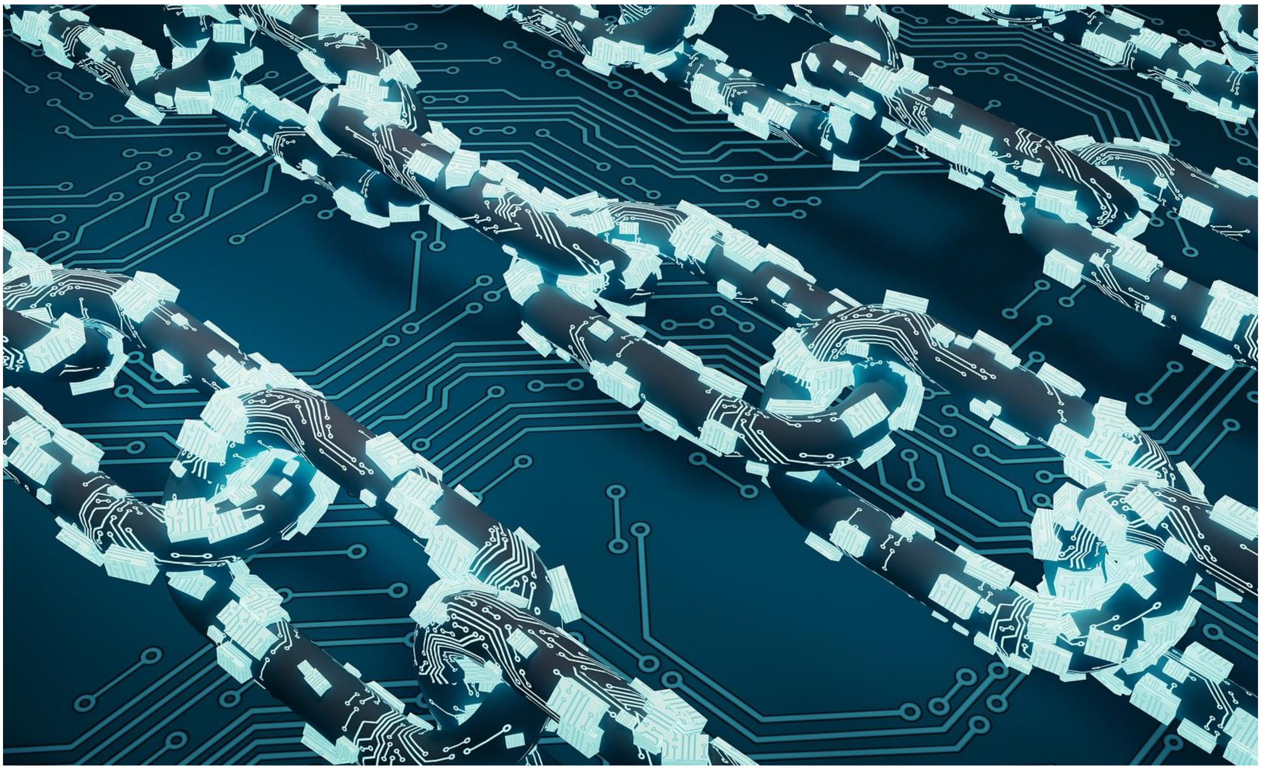
UNIVERSITY OF COPENHAGEN
DEPARTMENT OF COMPUTER SCIENCE



PhD Thesis

Karim Jabbar

Infrastructural Entrepreneurship in the Context of Blockchain

Supervisor: Pernille Bjørn

Submitted on: 6 December 2019

Name of department:	Department of Computer Science
Author:	Karim Jabbar
Title and subtitle:	Infrastructural Entrepreneurship in the Context of Blockchain
Topic description:	This PhD thesis investigates how entrepreneurial activities unfold in the context the Blockchain information infrastructure. Through a research approach based on ethnographic and interventionistic methods, the thesis introduces *infrastructural entrepreneurship* as a framework for better understanding the complexities of activities taking place in a context that is simultaneously entrepreneurial and infrastructural. The thesis presents empirical accounts of Blockchain-focused entrepreneurial actions in the areas of Bitcoin ATMs, cryptocurrency trading, the energy sector, as well as in various projects within the shipping industry.
Supervisor:	Pernille Bjørn
Submitted on:	6 December 2019

Table of contents

Abstract

In this PhD thesis I aim to define entrepreneurial activities taking place in the context of the emerging Blockchain information infrastructure. Through a research approach based on ethnographic inquiry and interventionistic approaches, I investigate the entrepreneurial actions performed by entrepreneurs and other infrastructuring agents in selected domains of Blockchain application. These domains are education, shipping, cryptocurrency, and energy. The empirical accounts emerging from these participant-observant investigations, are the basis for an article collection consisting of 4 peer-reviewed publications, that have been published over the course of the PhD process, as well as a thesis essay bringing together the contributions of the papers into an overall framework for understanding entrepreneurship in the context of the Blockchain information infrastructure. More specifically, I introduce *infrastructural entrepreneurship* as a concept emphasizing how entrepreneurship is performed in a context that is simultaneously entrepreneurial and infrastructural. This framework unpacks the entrepreneurial drive inherent in the sustaining and growing the Blockchain information infrastructure. It explains how this drive is simultaneously contributing to infrastructural creation, and how entrepreneurship performed in this context involves an ongoing and iterative creation of Blockchain *assemblages* that are used in relational alignments with stakeholders in the targeted domains of application. Finally, the framework also explains how this engagement will take the shape of a *growing* of new infrastructures, or *grinding* against established infrastructures.

Chapter 1: Introduction

In the early fall of 2013, I stumbled across a colleague at a bar in Copenhagen. This encounter, as it happened, turned out to be the beginning of a rather unexpected journey. Other than being in a very chatty mood, and being obviously assisted in his outgoingness by a few drinks, my colleague, who shall remain anonymous, was celebrating good times with his friends from a Danish meetup circle. This all-male group, was rather loud and outspoken, and didn't miss an opportunity to shout out the name of their newly found passion: Bitcoin! … As an outsider, I did not have the first clue about what they were talking about, but I was fascinated. As rounds of drinks were generously handed out to the patrons of the bar, I recall getting bits and pieces of what seemed like a rather convoluted and incoherent story, which however had one important punchline. This is the opportunity of a lifetime. Get in now, and you will become rich!

The recollection exposed above, while rather peculiar and stereotypical, is probably something that a lot of cryptocurrency amateurs can relate to. It was a trigger that started a journey down a rabbit hole that kept getting deeper and more complex. In my case, it led to a simple internet search, that expanded into spending every single waking hour for 3 weeks straight exploring this phenomenon, and trying to wrap my head around its implications at large. Particularly, I was intrigued by the promises that were already at that time being articulated by enthusiasts regarding the use of the technology for other purposes than cryptocurrency, such as records of all sorts, as well as self-executing contracts. Just as I was getting confident with the basics, however, and had located the right online fora and message boards to keep up with the rapid changes in the deployment of the cryptocurrency, the first Bitcoin speculation bubble burst. The value of Bitcoin had momentarily surpassed the value of gold at slightly over USD 1200, and then went on to crash all the way down to a couple of hundreds. This was the beginning of the long so-called crypto-winter, which ended up lasting three years. During this time, the first hype wave surrounding Bitcoin and cryptocurrencies had settled, and my personal interest in the phenomenon had similarly started to slowly fade. In fact, it remained that way until 2016, when I was at the very early stages of the PhD project that I am now completing.

As I reconnected with Blockchain, as part of the present thesis, it was very interesting for me to see what had happened in the couple of years that I had not keeping up with Bitcoin and cryptocurrency news. Indeed, what I realized, was that the narrow application of the technology that I knew from a few years prior, had been replaced by a much broader and kaleidoscopic area of application, with much more diverse stakeholders, and multifaceted technical solutions. Blockchain had become a high-level term, used vernacularly by diverse self-proclaimed experts, evangelists, technologists, and everyday users. It was no longer the exclusive property of underground movements of cypherpunks and libertarians, but had become a generic term used casually, and interchangeably with bitcoin and cryptocurrency. Interestingly, I seemed to be able to identify waves of "newcomers" to this emerging area, from people with a finance background, to specific industry experts, professional consultants, lawyers, and so on. Everyone seemed to see something special in the technology, that could be introduced in their respective areas and fundamentally alter the status-quo, with efficiency and/or competitive gains as a consequence. Blockchain had gained universalistic aspirations, and was increasingly seen as a cross-cutting technology that could, with small adaptions, be implemented in a whole range of industries.

Observing this, it became clear to me that Blockchain was far more than a simple protocol, unleashed on the internet a decade ago (Nakamoto, 2008), but actually an emerging information infrastructure (Bowker & Star, 1999) in the making. Seen in such a way, Blockchain is a *"shared, evolving, heterogeneous installed base of IT capabilities among a set of user communities"* (Hanseth and Lyytinen, 2004). It is a dynamically evolving installed base, which has not been fully developed at inception, but rather unleashed in an embryonic state, allowing for others to engage with it, grow it (Zimmerman & Finholt, 2007), extend it (Ribes, 2014), and introduce it in new and unpredictable settings.

Blockchain, which at its core is a peer-to-peer technology that enables transparency and trust through a design (Zohar, 2015) that emphasizes (i) a shared distributed ledger, (ii) cryptography, and (iii) consensus algorithms, is indeed much more than these features. In order for anyone to engage with such a protocol, there needs to be extensions available that interface with the core of the system. In the case of Blockchain, applied as a cryptocurrency for instance, there needs to be gateway services (Bietz, et.al., 2013) (Zimmerman & Finholt, 2007) in place allowing users to acquire, store, and sell the coins in a user-friendly fashion. Creating such a network of gateway services, such as point-of-sales systems (PoS), bitcoin telling machines (BTMs), software wallets, online exchanges and brokers, hardware wallets and vaults, is taken on by a large number of geographically distributed actors that manifest these gateways through their entrepreneurial activities. Similarly, the attempts made at applying Blockchain technology into existing industry domains, are also being performed by distributed corporate and/or start-up actors, that act in an entrepreneurial fashion, and that through their actions impact the proliferation of the technology into other realms. In other words, I observed that the evolution of Blockchain technology, and its emergence as an information infrastructure seemed to be closely linked to the multiplicity of activities performed by entrepreneurial actors in all of its domains of application.

When looking into the specific entrepreneurial activities in question, it became clear to me that there seemed to be something particular about pursuing entrepreneurship goals in a context characterized by early-stage infrastructural emergence. The entrepreneurs in question are indeed operating their business venture in a context where they simultaneously contribute to manifesting and sustaining (Paper no. 1: Jabbar & Bjørn, 2017) the Blockchain infrastructure, but also relying on the features of this large-scale and uncoordinated infrastructure (Hanseth & Lyytinen, 2010) to build a profitable business. Through their actions they are actively infrastructuring (Pipek & Wulf, 2009) the Blockchain information infrastructure, addressing its kernel in order to sustain the availability of its cache (Ribes, 2014), and synergizing relational networks (Bietz, 2010) in order to succeed in their endeavours. These activities are challenged by the fact that Blockchain technology is still at the very early stage of infrastructural development. More specifically, the entrepreneurial actors involved in Blockchain find themselves confronted by multiple intertwined uncertainties. The core technology itself is still in its infancy, and its developmental pathways are still uncertain, particularly considering that much Blockchain development takes place in distributed open source settings. The embedding of the emerging Blockchain infrastructure into pre-existing relational networks (Star & Bowker, 2002) is only starting to happen, making the opportunities and constraints faced by the entrepreneurial actors more unpredictable. Finally, the domains of application of Blockchain are themselves in an early-stage emergent state, particularly when it comes to introducing Blockchain into establishes industries. Entrepreneurship performed in such a context of uncertainty, and ambivalent socio-technical entanglements between business drive and infrastructural emergence is the overall interest of this thesis.

1.1. Research question

The above considerations lead me to formulate the below research question, which structure and guide my PhD research – and which I particularly will examine in this thesis essay, by connecting the contributions of the four papers which serve as the ground for my thesis work:

What defines entrepreneurship in the context of the Blockchain information infrastructure?

In order to address this research question, the present thesis essay will first theoretically unpack how Blockchain is evolving as an information infrastructure, then expand on how entrepreneurial activities of globally distributed actors contribute to this evolution, and finally define the entrepreneurial activities in question as manifestations of *infrastructural entrepreneurship*, which is a concept emphasizing how entrepreneurship is performed in a context that is simultaneously entrepreneurial and infrastructural.

1.2. Paper collection

This thesis is a paper collection comprised of 4 papers, which are introduced and connected by a thesis essay. The empirical data that I have collected, and which is the foundation of these papers is based on ethnographic and interventionist investigations within four distinct domains, each demonstrating a part of the emerging Blockchain information infrastructure. These are: (i) the education domain, (ii) the shipping domain, (iii) the cryptocurrency domain, and (iv) the energy domain. Each domain was explored with a specific combination of ethnographic inquiries, and interventionist approaches. The results from the explorations of these domains are captured in the collection of papers and are connected in this thesis essay, which together make up the PhD dissertation. The research contribution of each of the included papers has been published in peer-reviewed conferences and journals (see below).

FIG 1: Overview of the peer-reviewed papers in this article collection

#	Title	Topic	Publication status
1	Growing the Blockchain Information Infrastructure	Establishes how infrastructuring activities in the context of the blockchain infrastructure can be characterized as *Entrepreneurial Actions.* Cases from Bitcoin governance, and Bitcoin ATMs (BTMs)	CHI '17: Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (Published)
2	Blockchain Assemblages:	Shows how entrepreneurial actors in the context of	CHI '19: Proceedings of the

	Whiteboxing Technology and Transforming Infrastructural Imaginaries	Blockchain use Blockchain Assemblages constituted of technology, practices and imaginaries, in their engagement with stakeholders. Cases from cryptocurrency trading and distributed energy.	2019 CHI Conference on Human Factors in Computing Systems (Published)
3	Infrastructural Grind: Introducing Blockchain in the Shipping Domain	Introduces the concept of Infrastructural Grind to explain the process whereby Blockchain gets introduced to the shipping Domain. Cases from the shipping industry	GROUP '18: Proceedings of the 2018 ACM Conference on Supporting Groupwork (Published)
4	Permeability, Interoperability and Velocity: Entangled Dimensions of Infrastructural Grind at the Intersection of Blockchain and Shipping	Unpacks Infrastructural Grind into constituting elements that influence the permeation of Blockchain into the shipping domain Cases from the shipping industry	ACM Transactions on Social Computing, Volume 1 Issue 3, December 2018 (Published)

For the sake of clarity, I should point out to the readers, that papers 3 and 4 of this article collection, are based on the same empirical data on the intersections between Blockchain and the shipping industry, the latter paper being a journal extension of the former. The original paper was presented at the GROUP 2018 conference in Sanibel Island, Florida, where it was selected as one of the top papers to be invited to submit an extended version for a then upcoming special issue of Transactions on Social Computing. The extension in question was done in accordance with ACM rules requiring at least 25% new content. More specifically, the journal paper further developed the contributions of the original conference paper, and added new theoretical concepts, in particular permeability, interoperability, and velocity, as dimensions of infrastructural grind at the intersection of Blockchain and shipping (Paper no. 4 Jabbar and Bjørn, 2019).

For the sake of clarity, I propose that the reader goes through this thesis sequentially, by first reading the present thesis essay, where I frame the whole PhD project, and then subsequently reads the four individual paper contributions, which go into details with specific empirical accounts. Reading the papers in the presented order will better tie them to the framing that is set out by the thesis essay.

1.3. Structure of the thesis

The thesis is structured in two main parts: Part I: The thesis essay and Part II: Paper collection of four published papers. Part I contains 5 additional chapters after this introduction. In Chapter 2 of this thesis essay, I present the ethnographic and interventionistic methods that I base my research on, as well as the specific artefact design that I have developed in order to better engage with collaborators and informants. In Chapter 3, I theoretically introduce Blockchain as an information infrastructure, hereunder the carrying concepts of kernel and domains. By doing so, I address the second part of the research question, and make it clear to the reader how Blockchain relates to the existing literature on information infrastructures, and how it is conceptualized in the context of domains. In Chapter 4, I shift my focus to theoretically unpacking entrepreneurial activities seen in the context of the Blockchain information infrastructure. By so doing I address the first and pivotal part of the research question, and present the reader with an overview of how the current literature addresses the issue, and how the theoretical contributions from my papers extend this literature. In Chapter 5, I answer the research question, and present *Infrastructural Entrepreneurship* as a concept that helps define entrepreneurship in the context of the Blockchain information infrastructure. In Chapter 6, I conclude.

Part II comprises the full text of the four papers which presents the main findings of this PhD work. Paper no. 1: *Growing the Blockchain Information Infrastructure* presents empirical cases about entrepreneurs involved in the areas of Bitcoin ATMs and Bitcoin governance. The paper is connected to the research question by framing entrepreneurship in the context of Blockchain as a form of infrastructuring. In other words, it helps unpack the "what is it?" of Infrastructural entrepreneurship. Paper no. 2: *Blockchain Assemblages: Whiteboxing Technology and Transforming Infrastructural Imaginaries* presents empirical cases that illustrate how entrepreneurial actors in the context of Blockchain develop, and iteratively reconstruct, socio-technical assemblages constituted of technology, practices and imaginaries. The paper is connected to the research question by emphasizing the importance that Blockchain entrepreneurs put on imaginaries about current about current and future states of the technology and areas of application. In other words, the paper emphasizes the "how is it performed?" of infrastructural entrepreneurship. Paper no. 3: *Infrastructural Grind: Introducing Blockchain in the Shipping Domain* presents various empirical cases of how entrepreneurial actors work at proliferating Blockchain technology into specific use cases within the shipping industry. The paper is connected to the research question by showing that the pattern of introduction of Blockchain into the shipping domain by various entrepreneurs is not linear and sequential, but rather iterative, in the making, and involving various instances of push-back from established practices and legacy systems. In other words, it addresses the "where does it take place?" of infrastructural entrepreneurship. Paper no. 4: *Permeability, Interoperability and Velocity: Entangled Dimensions of Infrastructural Grind at the Intersection of Blockchain and Shipping* presents an extended version of Paper no. 3, in which the concept of infrastructural grind is further unpacked.

Chapter 2: Ethnographic inquiry and interventionist approaches

2.1. An eclectic research strategy

Since the aim of my research was to explore what defines entrepreneurship in the context of the Blockchain information infrastructure, I quickly discovered that the nature of these entrepreneurial activities are not well-established and clearly defined practices. Instead, they are an aggregation of diverse emerging practices in-the-making, distributed globally, that would be difficult to examine in a comprehensive way by stringently applying a single traditional research method. This realization gave rise to fundamental conceptual and methodological questions that I needed to address: What constitutes the relevant sites and locales for my investigation? Which cases are specifically relevant to dive into in my research? How do I engage constructively with informants and stakeholders, who are geographically scattered and connected to the emergence of the Blockchain information infrastructure in a multitude of different ways? And finally, how do I ensure that I remain self-critical and reflexive enough in my shifting roles as observer, participant, researcher, and fully-fledged entrepreneur?

Based on the consideration highlighted above, I ended up framing my research methodologically by two separate yet interlinked methodological approaches: Ethnographic inquiry (Marcus, 1995), (Blomberg, 2013), (Forsythe, 1999, 2001), and Interventionistic approaches (Zuiderent-Jerak, 2007, 2016), (Karasti, 2010), (Mesman, 2007). Below I will briefly introduce my methodological approach as well as how I applied these diverse sets of perspectives differently in each of my empirical cases, depending on the nature of the sites, the relational networks available to enter domains and get access to data, and the opportunities that emerged from engaging with the case.

2.1.1. Ethnographic inquiry

Ethnographic inquiries are commonly used within the HCI/CSCW research literature (Blomberg & Karasti, 2013; Forsythe, 1999, 2001), and are often referred to as an *"eclectic methodological choice which privileges an engaged, contextually rich and nuanced type of qualitative social research, in which fine grained daily interactions constitute the lifeblood of the data produced"* (Falzon, 2009, p. 1). At the core of ethnographic inquiry is an element of immersion in which the researcher participates in the daily interactions of a practice, and makes sense of what is observed. While ethnographic inquiry can take many different forms, there are fundamental principles which must be observed. <u>Firstly</u>, it is critical for ethnographic inquiry that we study phenomena in their natural settings, which means that to study something, we have to go where it ‘takes place’. This is particularly challenging when you study entrepreneurship in the context of Blockchain, because it is not always clear, where and how it takes place. A key methodological challenge for my work was therefore to identify the ethnographic sites relevant for my investigations. Secondly, ethnographic inquiry requires the researchers to take a holistic point of view on the addressed area of inquiry. This means that it is fundamental to this kind of work, to keep the perspective broad while zooming in on certain details, since we can only understand the individual part as part of a larger endeavour. Concretely, this means that through my work I had to constantly zoom in and out from the empirical details of concrete entrepreneurial activities to the large information infrastructure of Blockchain. Thirdly, ethnographic inquiry should provide a descriptive understanding of the complexities of a given practice. Concretely, this means that in my work, I had to go beyond attempting to make sense of Blockchain entrepreneurship by relying on documentation provided by the start-ups in question, and by formally interviewing the relevant stakeholders. Instead, I also had to go a level deeper in my investigation, and get a more nuanced “thick” description of the everyday routines of these stakeholders. Finally, ethnographic inquiry should aim at taking a members’ perspective, which means that by participating in the everyday routines of the informants, one should be able to present and analyse issues that are of particular relevance to the informants. In the case of entrepreneurs active in the area of Blockchain, this implied that I had to become part of the various settings that I was investigating, in order to better see the situation from the perspective of these entrepreneurs. (Blomberg et al. 1993; Blomberg and Burrell 2012; Blomberg and Karasti 2012).

Traditionally, ethnographic inquiries were carried out by anthropologists studying the customs and everyday practices of peoples living in distant geographies, and whose ways were very different from western culture broadly speaking. A prototypical example of this is Bronislaw Malinowski’s *Argonauts of the Western Pacific* (1922), which is broadly credited with redefining ethnography as an “off the verandah” method that is very much juxtaposed to the “armchair anthropology” of previous researchers. These ethnographic accounts of distant cultures usually relied on a single site of investigation, in which the researcher spent long periods of time, getting fully immersed in all the minute details pertaining to the examined social grouping, and collecting thick descriptions of their daily activities. This type of single-sited ethnographic research, applied to a workplace setting, was introduced to HCI though Lucy Suchman’s “Plans and Situated Action” (1987), and further expanded into a variety of specific single-sited workplace studies. These investigations emphasize the study of specific work practices as they take place in a special kind of profession, and highlight the use of artefacts in the work coordination within such profession-based work practices. Examples of this are control centers in the London underground (Heath and Luff, 1991), air traffic control (Harper, 1991), and emergency service centers (Petterson et.al 2004), among others.

When it comes to ethnography performed in the context of global information technology (Rode, 2011), however, this single-sited focus becomes difficult to sustain, since it is evident that the interconnections between sites through increased mobility, and enhanced forms of communication, is as important to examine as the activities taking place in the confined single-site. In the context of the present thesis, where I set out to define entrepreneurship as it takes place in the emerging Blockchain information infrastructure, my choice of sites of investigation was primarily determined by tracing the ongoing activities of specific entrepreneurial actors in the Blockchain domain (writ large), and following various patterns of *"mobility, intersection, and flow; with a focus on connections, associations, and relationships across space and time"* (Blomberg and Karasti 2013, p. 384). This aligns well with Marcus' view that ethnographic reports are constructions formed out of choices about focus area, opportunities and recourses available, reporting style, and conceptual and epistemological conviction (Marcus and Cushman 1982; Marcus 1998).

Specifically, this means that the modes and techniques that I used to define my objects of study were pragmatically defined as variations and combinations of the tracing techniques highlighted by Marcus (1995). Those are: follow the people, follow the thing, follow the metaphor, follow the plot, follow the life (journey), or follow the conflict. Examples of such pragmatic tracing choice are: 1) when I got more immersed in my ethnographic engagement with a particular group of informants, I was able to trace their personal connections to other potential informants and sites of Blockchain practice (follow the people/life/journey). 2) I was, in some cases, similarly able to trace artefacts that my informants were working with, across specific supply chains, leading to specific connected sites of activities (follow the thing). Similarly, other tracing techniques also influenced my choice of sites and cases.

The presentation of findings gathered through ethnographic inquiries often comes in the shape of reflexive ethnographies. Referring to Burawoy (1998), Rode (2011) summarizes reflexivity as follows: "*First, reflexivity, unlike positivism, embraces intervention as a data gathering* *opportunity. Second, reflective texts aim to understand how data gathering impacts the quality of the data itself. This approach "commands the observer to unpack those situational experiences by moving with the participants through their time and space". Third, reflexive practitioners attempt to find structural patterns in what they have observed, and fourth, in doing so they extend theory" (Burawoy, 1998, p 14)*. This being said, one can further distinguish between various types of ethnographies commonly resulting from HCI research: Rode (2011) proposes three such ethnography types, of which I will highlight two, namely formative ethnographies, and summative ethnographies (Rode, 2011). Here, formative ethnographies refer to accounts investigating practice with the explicit goal of developing new technology, i.e. informing design (Dourish, 2006). Summative ethnographies, on the other hand, refer to studies that investigate the divide between *"what we know we must support socially and what we can support technically"* (Ackerman, 2000, p. 1), in a way that does not attempt to close this socio-technical gap. Rather than prescribing implications for design, summative ethnographies investigate the socio-technical gap for its own sake. While this does not contribute directly to design, it strongly emphasizes the ways in which practice brings technology into being. Furthermore, unlike the other forms, summative ethnographies do not require the ethnographer to manage two separate relationships with the informant—that of the peer required for participant observation and that of critic for design (Rode, 2011).

The kind of ethnography applied in the present thesis, and constituting papers, uses both of the approaches highlighted above, with a propensity for favoring summative ethnographies. All the papers clearly avoid making explicit implications for design, and are mainly focused on getting a very granular understanding of the entrepreneurial activities taking place in the sites of investigation. In my particular case, however, the relationship with my informants did not completely avoid ambivalence. Not so much in the sense that design expectations were projected onto me, but rather because my simultaneous role as fellow entrepreneur tended to project an expectation of peer participation that goes beyond my research mandate. In other words, the designer/ethnographer ambivalence that a lot of the HCI literature highlights, was in my case more expressed as an entrepreneur/ethnographer ambivalence.

A final element worth pointing out before moving on to the second methodological approach that I am leaning on, pertains to the fact that conducting ethnography can sometime be perceived as being menial, and unstructured. The researcher is after all "just hanging out" in the site of practice. Diana Forsythe (1999) refers to this as "ethnography as invisible work", where the very unobtrusiveness required to conduct good ethnography goes unnoticed by informants and research colleagues that have a more positivistic approach to scientific methods. She goes on to highlight and critiquing six misconceptions that perpetuate a view that ethnography is a method that can easily be borrowed by any researcher. In the present PhD project, I wanted to make sure that I did not get tainted by the misconception that the method lacks rigor, simply because one might not able to see the intricacies of the trade a priori. More explicitly, this means that I was very aware of my own role as a researcher, and particularly reflective when it came to ambivalent roles, power dynamics, and everchanging perceptions of being inside or outside the practices (Bjørn and Boulus-Rødje, 2015) that I was simultaneously observing and actively participating in. This leads me to introduce interventionistic methods, which emphasize precisely that need for self-awareness in situations of on-site intervention.

2.1.2. Interventionistic approaches

It is today increasingly accepted in the HCI/CSCW community that ethnography and intervention are interlaced practices (Mesman, 2007), where intervention is an essential part of doing ethnography in the first place. This implies that the chronological separation of "*first "doing fieldwork" and only then "informing design" or "intervening" is problematic"* (Zuiderent-Jerak, 2018). Intervention should, as a consequence be included as a fully-fledged part of the ethnographic process from the beginning, while being clearly aware of the challenges that this implies. As Marcus (1995) puts it in connection with conducting multi-sited research:

> *"[…] one finds oneself with all sorts of cross-cutting and contradictory personal commitments. These conflicts are resolved, perhaps ambivalently, not by refuge in being a detached anthropological scholar, but in being a sort of ethnographer-activist, renegotiating identities in different sites as one learns more about a slice of the world system."* (Marcus, 1995, p. 113)

An illustration of this, is my participation in a Danish start-up called Blockchain Labs for Open Collaboration (BLOC), which was initiated through a round of interviews of Blockchain entrepreneurs in Denmark. My meeting with the founder of the start-up resulted in an ongoing relationship where there was a clear alignment between my research objectives and the mission of the start-up. I was thus invited to participate in numerous events, and meetings, and I eventually became a more trusted part of the team (disclaimer: I never had any equity in the company). This allowed me a much better understanding of the intricacies and complexities involved in performing entrepreneurship in the context of Blockchain, than what I had been able to gather through more traditional interviews and observations. Furthermore, I was able to navigate the mobility, intersections and flows that my relationship with BLOC afforded me, in order to conceptualize broader and more distributed domains of intervention.

For instance, I became a regular visitor to the Copenhagen Fintech Lab, where the start-up was housed. This Lab is a physical co-working space in central Copenhagen run by Copenhagen FinTech, an organization created with the purpose of connecting all members of the financial technologies' ecosystem in Denmark. The organization aims at being a catalyst for incubation in the FinTech sector allowing start-ups to grow and scale. While spending much time at the FinTech Lab through my association with BLOC, I rapidly became involved in activities run by the team managing the Lab. In this connection, I was given the opportunity to join a delegation of Danish FinTech start-up on a promotional tour to Singapore. This opened the doors for relevant interviews, meetings, and an exploration of problem areas related to Blockchain seen from the perspective of government officials, institutions, and other entrepreneurs participating at the events organized by Copenhagen FinTech. The promotional tour to Singapore allowed me to expand my network of relevant contacts, and made it easier for me to reach out to these contacts subsequently, as my PhD project evolved. I was furthermore chosen as the representative of Copenhagen FinTech in the Danish standardization committee working on developing an ISO standard for Blockchain. Here I had access to detailed information about how the global standardization work on Blockchain is proceeding, both in a processual sense as well as it pertains to the subject matter being discussed.

These two examples of new pathways, made possible by immersive participation in Copenhagen FinTech, did not explicitly result in academic papers included in this thesis, but they did however allow me to broaden my analytical and interpretative knowledge as it relates to Blockchain and its emerging manifestation in various social contexts. This immersive process was guided by the reflexivity embedded in my methodological choice, yet continuously evolving, and as such my research agenda was more one of emergence and constant repositioning than one of thorough long-term planning.

This interventionistic approach to data collection, however, also forced me to reflect on my role as a researcher. In several cases, my association with start-ups virtually wiped out the distinction between myself and the rest of the team, from an outsider perspective. At meetings and events, I was introduced not as the “inhouse researcher”, but as a member of the team, responsible for this or that particular project. This ambivalence in having to fulfil my research aim, and at the same time contributing to the ongoing operations of the start-up, did indeed create a shady area, that I needed to be aware of, and that I had to reposition myself within as my relationship with the start-up dynamically evolved. Specifically, this meant that I had to be aware of how my time was spent, and ensuring that whatever operational activity I was engaged in in connection with the start-up at all times retained an academic angle, and could be simultaneously conceived of as empirical data collection. At times this meant distancing myself from the start-up team, to work on my collected data, and ongoing paper writing, and at other times it meant re-engaging with the start-up and trying to negotiate new projects to handle, which could be of interest to my academic pursuit. I will now give some brief explicit examples from my journey as a researcher that had me questioning the various roles that I was simultaneously enacting.

In the case of BLOC, I experienced a general sense of mutual collaboration from the actors that I got involved with in an interventionistic fashion. Unlike in the case of Mesman (2007), and her intensive care experience, there was no interest from my collaborators to attempt to influence my academic research. Generally, they seemed less interested in the outcome of my papers, than in the ability to be associated with a researcher from the University. Furthermore, there were fewer hierarchies, political pecking orders, and less conflicting interests within the start-up, than what was the case in Mesman’s account. In other words, I became the token academic, that indirectly, merely through my presence, gave some legitimacy to the start-up in question at selected venues. This meant that I was essentially involved in a collaborative engagement, where my access to all the company’s data was allowed without objection, while it was implicitly expected that I also spend time contributing to the start-up through select daily activities aimed at better positioning the company within its field. This particular alignment of expectations and interests worked out well for me, as there was not any indication that the outcome was tainted by more subjectivity, that what can be expected in any situation where the researcher is also a “circumstantial activist”.

In a separate instance, where I was investigating a group of investors working at setting up a cryptocurrency trading fund, my dual role as participant and observer evolved differently. Here the balance of interests did tilt over an invisible line, making me sense that further academic work in that setting would have me conflicted to a higher degree that what I could justify. More specifically, I initially engaged with the small community of investors, through an old high school fried, who had set up the endeavour. I quickly became part of the process leading to the creation of the crypto-fund, which was based on an algorithmic trading model, and got to participate in all the public and confidential meetings that were held in than connection. At several meetings I did small presentations contextualizing the fundraising initiative, and positioning it within the broader Blockchain landscape that I was investigating. My reasons for proposing to do such presentations, was to get closer with the team running the fundraising initiative, and also get to know the prospective investors that were invited to join such events. By giving high level introductions to Blockchain technology, and framing the current developments in the domain, I was able to be perceived as a trustworthy expert and to be included in relevant further discussions with investors. This would serve the fundraising initiative well, as I added technology expertise to their initiative, as well as serve my research agenda, in the sense that it opened up avenues for more data collection. So far in the process, I had no issues maintaining the dual roles as participant and observer. At a particular point however, I was given the opportunity to invest some of my private money into the fund. At this point, as I weighed the pros and cons of the opportunity, I realized that I would not be able to represent the data collected in a fair and impartial way. I already had “skin in the game”, and this only increased as I accepted the offer to invest. The result was that I chose to abandon my plans to write a paper explicitly examining the fundraising activities of the cryptocurrency trading fund, and in the process, I decided to discard many hours of data, collected over several months. This was in order to avoid a potential conflict of interest, since my co-investment in the initiative might have influenced me to unintentionally portray the fund in an overly positive manner. While I abandoned the paper explicitly addressing the particular cryptocurrency trading fund, the many contacts and relationships that I had made in connection with my engagement, however remained extremely useful. They allowed me to trace further connections to new sites and groups that I could engage with, and I ended up using one of these informants as a key source for another paper (Paper no. 2).

As we can see, my role as a researcher, simultaneously engaging in observation and intervention evolved differently in various cases. Through my ongoing reflexive work, and specific choices and decisions, I managed to navigate the emerging challenges in a way that allowed me to keep a dual focus, and not compromise on either of them. In the following sub-chapter, I will introduce, and reflect on a specific way that I chose to engage with several of the new communities and stakeholders that I was seeking out, namely through the use of a technological artefact, that acted as a prop, or a probe of sorts, aiming at facilitating rapport (Rode, 2011) with selected future informants.

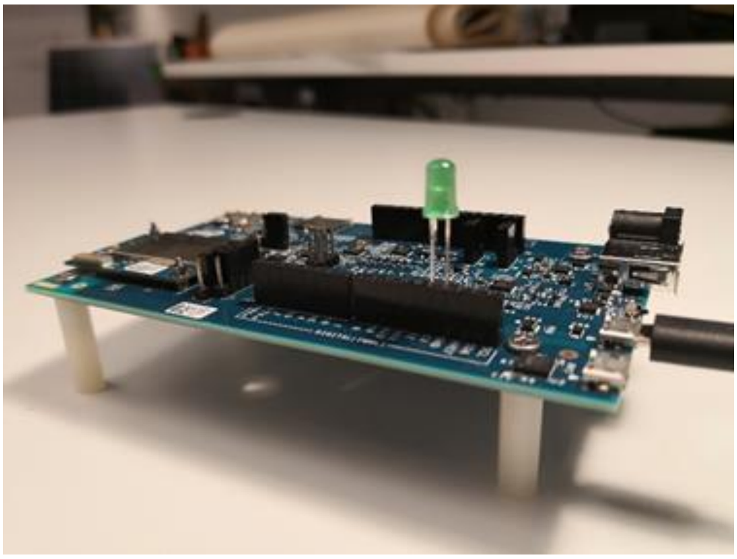
2.1.3. Designing artefacts for intervention

In order to facilitate my engagement with the entrepreneurs whose activities I was interested in investigating further, I decided to build a technical artefact that encapsulates the complexities of Blockchain in a material and tangible way. The purpose was to spark curiosity of potential informants, and to use the artefact as a point of convergence for initial talks about the technology and its affordances. Depending on the case, the artefact either acted as a door-opener for further contact and involvement, or as a direct constituting component of collaborative entrepreneurial planning with the stakeholders that I engaged with.

The artefact in question was named OpenBlock. The OpenBlock artefact is a stand-alone software/hardware Blockchain network that is fully functioning and comprised of 8 Intel Edison computers-on-module (COM), which are complete embedded computers built on a single circuit board and including integrated WiFi connectivity. Each one of the COMs is attached to an Arduino extension board and mounted on simple pods leaving the whole board exposed and visible. On the board, a simple LED lamp is attached. OpenBlock operates a real-life implementation of the Ethereum blockchain protocol using a private router for WIFI. Each device runs a modified Ethereum script, which was named Architect (it is based on Ethereum Geth 1.6. – Puppeth - and requires Node V4+ instead of Docker). The Architect script handles the set-up and configuration of the devices. (https://github.com/drouillard/openblock). An app called Fing (fing.io) is used to detect the active devices on the network, and a customized dashboard based on the public Ethstats interface (https://ethstats.net/) shows the status of the network and the blocks being mined. Finally, a browser-based graphical user interface allows users to interact with the network.

The role of OpenBlock in the various cases covered in the papers that comprise this thesis took different forms, and also shaped my role as researcher in different ways from active, participatory, and interventionist towards observing, ethnographical, and analytic. In the cryptocurrency trading case presented in paper no. 2 for instance, I used the OpenBlock artefact to stir up a conversation with my informant which appealed to his interest in blockchain-related hardware. This led to mutual examination of the hardware that we had developed and that we were utilizing for different purposes. This served as an icebreaker for better trust building and getting a sense of being accepted as part of the crypto-community. In the distributed energy case presented in the same paper (paper no. 2), on the other hand, the OpenBlock artefact took on a more tangible role in the strategies of the start-up that I was involved in. Here, the artefact became an anchor for the development of a pragmatic strategy pertaining to one of the projects that the start-up was contracted to work on. More precisely, the OpenBlock artefact in this context turned into a tangible potential component in a larger Blockchain system composed of hardware sensors, solar panels, and smart meters. While the project did not materialize, the OpenBlock artefact served as tool in the ongoing reconfiguration of imaginaries that made up the start-up's mission. Thus, by introducing the OpenBlock artefact, in different ways at different venues, I was able to explore the interconnectedness of entrepreneurial activities and dynamically evolving material artefacts in the context of the emerging Blockchain information infrastructure.

FIG. 2: One of the connected OpenBlock devices



2.2. Empirical domains

When I applied ethnographic inquiry as the ground for interventions, in various Blockchain sub-domains, the ways in which I gathered data over time, allowed me to gain insights into the manifestations of diverse topics, cases and accounts of entrepreneurial activities. When these topics started emerging, they in turn informed further investigation into more narrowly-focused areas of the Blockchain information infrastructure. In that sense, my choice of focusing on certain specific domains, industries, cases, and sites was guided by a combination of manifested opportunities and an ongoing conceptual framing that placed these potential domains and cases into a broader mapping of the Blockchain information infrastructure. The opportunities, which manifested themselves through my research approach, acted reflexively with the evolving patterns of interpretation, and further informed ongoing data collection and analysis. Over time, the chosen domains and cases became interconnected by a meta narrative tying them together in a broader framework, which allowed me to better understand the complexities of entrepreneurial activities in Blockchain. More specifically, the domains that I ended up focusing on are: 1) Education, 2) Shipping, 3) Cryptocurrency, and 4) Energy.

FIG. 3: Approaches employed in each investigated domain:

Domain	Ethnographic methods	Interventionistic methods	Duration (overlaps occur)	PhD stage
Education	Formative ethnographic approach. The engagement with students was explicitly to inform technology design	In-class interventions. Student feed-back iteratively informed technology development	6 months 2 3-hour workshops	Months 6-12
Shipping	Summative ethnographic approach. The purpose was to better understand the intricacies of technology deployment into the shipping domain. No prescriptive design implications were drawn.	Ongoing interventionistic approach in relation to the startups that I dealt with. e.g. leading a workshop in Singapore for industry experts on behalf of BLOC	26 months	Months 4-30
Cryptocurrency	Summative ethnographic approach. Two separate cases: 1) Investigating the development of a Bitcoin ATM infrastructure 2) Unpacking the practices within cryptocurrency trading. No prescriptive implications for design.	In case 1: More traditional participant-observer role. Not entangled with work practices of the start-up that I was investigating. In case 2: strongly interventionistic. Using the OpenBlock artefact to build rapport with the informant.	20 months	Months 1-12 + 26-36
Energy	Summative ethnographic approach. Focus on examining a municipal project in Copenhagen aimed at implementing Blockchain in the context of renewable energy. The design practices of the	Interventionistic approach. Participant on the project as a representative of BLOC. Use of the OpenBlock artefact in ongoing discussions about systems design.	14 months	Months 22-36

	stakeholders was in focus. This did not however lead to broader implications for design.			

While the data collection and analysis undertaken in this PhD project largely exceeds the specific narrow cases illustrated in the papers in this article collection, I found it necessary to delimit the empirical data presented in each one of the papers to specific agent-centric cases that illustrate complex connections while having broader implications. In this connection, the most promising and versatile cases were chosen and iteratively worked on as new data got added to my overall understanding of the underlying connections and blockchain deployment patterns. As this took place the main findings of each paper slowly emerged from the data, as the data was iteratively classified and analysed until it reached the format presented in the papers that constitute this thesis. The particular method employed in each paper, expressed as a specific variation of ethnographic inquiry, and interventionistic approaches, is introduced in more details in each of the papers. Likewise, the scope of the data collection and the specifics of data analysis as it pertains to each paper is also best presented in the final versions of the paper manuscripts presented in this thesis.

To summarize my research approach, I can say that in order to best investigate what defines entrepreneurship in the context of the Blockchain information infrastructure, I combined ethnographic inquiry and interventionistic approaches. This allowed me the flexibility in adapting my research methods to the specific cases, which then again created opportunities for diverse types of engagement. This was critical for me to gather very detailed accounts from multiple stakeholder perspectives, as well as to explore the characteristics of entrepreneurship as and when it takes place, in the making, within the emerging Blockchain information infrastructure.

Chapter 3: Blockchain as an Information Infrastructure

In order to give a proper background to the empirical topic of my research in this PhD project, I will start by broadly introducing Blockchain technology and its emergence as an information infrastructure that is entangled with the entrepreneurial activities that are contributing to its manifestation. More specifically, I will unpack the developments of Blockchain from an obscure digital protocol shared on the internet, to the broader emerging infrastructure that is currently in the making. Furthermore, I will expand on the main characteristics of Blockchain both in terms of technological features, as well as the more abstract principles that are being manifested by the technology, such as trust, transparency, decentralization and so on. This introduction to the technology will serve to underscore that Blockchain is a particular kind of emerging technology, that is reliant on large-scale distributed collaboration, and that yet is very loosely coupled and driven by independent entrepreneurial activities enacted by heterogeneous actors. Blockchain is an infrastructure in the making, yet it is not designed nor implemented from the top. Instead it grows, consolidates, proliferates, and permeates into the installed bases of other infrastructures through pervasive activities that are simultaneously entrepreneurial and infrastructural in nature.

3.1. Blockchain: What is it, and how does it work?

The first implementation of Blockchain was Bitcoin, which was introduced by an anonymous person or group under the name Satoshi Nakamoto in the early aftermath of the financial crisis. The agenda of Bitcoin, very much driven by a libertarian agenda, was to disintermediate financial institutions and to introduce a system for peer-to-peer transaction of digital cash (Nakamoto, 2008). It aimed at creating a computational system through which globally distributed peers (users) would be able to transact a native digital currency freely and instantaneously across the world in a trusted manner, while ensuring that double spending of units of this currency is impossible. Validation of the monetary transactions, and settlement between accounts on the system would happen through a codified consensus mechanism that would remove the need for a trusted third party such as a bank, or a clearing house.

The basic constituting parts of Bitcoin, and other later derived blockchains are <u>firstly</u>, the element of a shared distributed ledger. This ledger, which is replicated on all participating computers on the network (called nodes) stores the history of all transactions taking place in sequential transaction blocks that are connected to previous blocks through strings of cryptographic hashes. Cryptography, is indeed the <u>second</u> main feature of blockchain systems, and it is used to secure the transactions through public/private key pairs. The third and final feature is the so-called consensus protocols that validate the transactions on the ledger, and simultaneously incentivize the actors performing this validation through rewards in the shape of newly created units of cryptocurrency. While all these constituting parts of blockchain have been around for decades (Zohar, 2015), it is their particular configuration that is credited for being the innovation of Bitcoin in particular and Blockchain in general.

In bitcoin, as in many cryptocurrencies, the consensus protocol is referred to as proof-of-work (or mining). Mining is a computationally intensive process incentivizing the nodes on the network to compete against each other for the right to validate all the transactions having taken place over the previous 10 minutes increment, and posting these transactions as a block to the chain of previous bocks. The competing takes the shape of a puzzle that all miners attempt to be the first to solve. Winning this puzzle gives the right to broadcast the block, and results in being rewarded by newly created bitcoins. Without going into too many technical details, the "cryptographic puzzle" works as a race to find a specific number, called a "nonce", which combined with the transaction data to be validated as well as the header of the previous block of transactions results in a cryptographic hash that falls below a certain threshold. This threshold is represented by a particular number of consecutive zeros at the beginning of the generated hash (referred to as the difficulty level). The only way to find the nonce is through brute force, meaning that the more powerful one's processor(s), the more tries one gets at solving the puzzle. The system is self-adjusting so that the more aggregate hash-power there is on the network, the more difficult it becomes to find the nonce (i.e. the number of zeros in the beginning of the target hash is increased). Conversely, if the aggregate hash rate decreases, the difficulty level also decreases, so that the average time needed to solve the puzzle remains very close to 10 minutes. It is because of this proof of work process, that works in 10-minute increments, that the distributed ledger is divided into consecutive blocks. In other words, proof-of-work is fundamentally linked with Blockchain as it originally was the reason why there are blocks in the first place, rather than for instance just having a streaming of transactions on a shared ledger. This is reflected in the fact that the word Blockchain itself does not appear in Nakamoto's seminal paper, but is rather referred to as a "proof-of-work chain" (Nakamoto, 2008). Blockchain, as the concept we know today emerged after the publication of Nakamoto's whitepaper on various message boards discussing the features and applicability of Bitcoin.

Proof-of-work as described above, contributes to creating a very secure and robust system that so far has never been hacked. The structure of connected blocks, in which each block has a cryptographic residue of the previous block implies that attempting to retroactively change a transaction record would imply having to crack the hash of the block containing the transaction in question, as well as every single consecutive block (since editing one would completely alter the hash of the subsequent blocks). Furthermore, the change would also have to be recorded on all the distributed servers running a Bitcoin node. This would have to be done within 10 minutes, after which time the network synchronizes, and the corrupted transactions would be discarded by the system.

While this short overview summarizes the basic functioning of the Bitcoin protocol, which permits the validation of monetary transactions, the settlement of these transactions in a tamper resistant distributed ledger, and the issuing of new units of currency, it misses an important point: Bitcoin wouldn't be of use to the peers it targets unless there is instances in place that make the utility of the system available to its users. Bitcoin's manifestation in the real world is, in other words, completely contingent on the emergence of translational actors and boundary objects that act as gateways connecting the protocol to prospective users, and that in the process of so doing unlock the affordances of the protocol. These varied instances of protocol extensions, making core cryptocurrency protocols (not just bitcoin, but many others) available to users can be seen as a constituting part of the emerging Blockchain information infrastructure, which I am going to unpack and critically reflect on in the following sub-section.

3.2. An information infrastructure in the making

The information infrastructure that is emerging in the context of the development and deployment of Blockchain clearly has a technological dimension. Essentially the elements that I started out by unpacking in the section above, with a focus on the core protocol of Bitcoin, and by extension other similar protocols. The information infrastructure also, however, has a "social" dimension, in this case referring to all the gateway services, and related human activities needed to manifest the core protocols in the world, and give users access to the affordances of these protocols, i.e. services allowing the users to partake in the transparency, encoded trust, and anonymity that cryptocurrencies afford. Since my aim in this thesis is to focus analytically on the entrepreneurial activities taking place in the context of the emerging Blockchain information infrastructure, I need to bring the social dimension of the infrastructure to the front in a way that highlights the mundane activities, social practices, and potential conflicts of interest taking place as the infrastructure grows and gets sustained over time. Here, Susan Leigh Star's seminal work on information infrastructures (1996, 1999), which has laid the foundations for a growing body of literature within HCI/CSCW, as well as Geoff Bowker's notion of infrastructural inversion (1994) has been an inspiration to me. Through the process of infrastructural inversion advocated by Bowker and Star, the complex and entangled socio-technical fabric of infrastructures can be turned around, so that it becomes evident that "substrate becomes content. The inversion in question has been framed as a figure ground gestalt shift, which makes what was the ground 'emerge' as focus. Through the lens of infrastructural inversion infrastructure becomes a "fundamentally relational concept".

This way of conceptualizing information infrastructures forces the focus of attention onto the mundane socio-technical activities that otherwise would have been backgrounded i.e. remained invisible, had it not been for the infrastructural inversion. In the cases that I have investigated, this particular infrastructural lens has allowed me to frame the Blockchain information infrastructure as a broader and more composite socio-technical complex with a primary focus on the entrepreneurial activities that help grow and maintain the infrastructure. This being said, however, the infrastructural inversion introduced by Bowker and Star comes at the price of losing precision in the terms used, or as Charlotte Lee and Kjeld Schmidt imply in their 2018 paper tracing the concept of information infrastructures, the relational concept tends to become relativistic resulting in it not being intelligible (Lee & Schmidt, 2018). Infrastructure in the narrow sense employed by Star tends only to "emerge" in relation to organized practices for which it would have been invisible had the inversion not taken place. Infrastructure emerges in relation to use as it ceases to be invisible for the user, as for example when a consumer of grid electricity is made aware of the electrical infrastructure when power cuts occur. But what then is infrastructure outside of its relation to user-centric practice? What is infrastructure for an electrician whose everyday work it is to maintain the grid in question? Can infrastructure still be seen as substrate, or a bedrock for other applications to be built upon? Or is it purely relational in all its aspects? Critics, hereunder Lee and Schmidt (2018), as well as Schmidt and Bansler (2016), highlight that attempts of viewing information infrastructures as a fundamentally relational concept inevitable get caught up in difficulties addressing the essential technological system in question. If it is purely relational, then it should not exist outside its use, and seeing it as technical substrate would then imply a reversal away from the relational. I found that this ambiguity is quite widespread in the HCI/CSCW literature on information infrastructures, even among the writings of Star, Bowker and Ruhleder. Lee and Schmidt (2018) summarize this as follows:

> *"The result is ambiguity in almost all sentences in which the word 'infrastructure' occurs in the very text by Star and Ruhleder (1996). If it is accepted that 'infrastructure appears only as a relational property, not as a thing stripped of use' (p. 112), or that 'Information infrastructure is not a substrate which carries information on it, or in it, in a kind of mind-body dichotomy' (p. 118), what then is meant by 'infrastructure' in expressions such as 'a large-scale information infrastructure' (pp. 112, 131), 'very large scale systems such as the US National Information Infrastructure' (p. 117), 'largescale information and communication infrastructures' (p. 129), or 'computing infrastructures, including gophers, FTP sites, etc.' (p. 131)? — Having deprived themselves and the rest of us of using 'infrastructure' in the ordinary sense, they obviously cannot cope without using it in exactly that way." (Lee & Schmidt, 2018, p. 15)*

Considering the above, how do I then avoid the possible pitfalls and ambiguities when analysing the Blockchain information infrastructure through the lens of infrastructural inversion?
When I look at Blockchain, the answer to this question, is that the infrastructure clearly has a technical protocol. However, this protocol has no value on its own, unless seen in the context of the entrepreneurial activities (and other socio-technical activities) that contribute to manifesting the information infrastructure. It therefore makes sense to see infrastructural inversion as a lens, and not as a gestalt shift. It is in other words, not the infrastructure that "emerges", or the ground that shifts, as I perform the inversion, it is rather my attention as an analyst that has shifted. While my attention is focused on uncovering mundane activities pertinent to the emergence of the Blockchain information infrastructure, such as entrepreneurial activities, my attention is in "relational mode". When I then zoom out and reflect on the overall architecture of the information infrastructure being built, I fall back on viewing the infrastructure as something that can exist outside of organized practice by a user community. In other words, while infrastructure may become visible to some as the focus of attention shifts, it is simultaneously in place for others to engage with in various capacities. *"That is, one group's support structure is another group's everyday work of design, maintenance, and upgrade"* (Ribes and Finholt, 2007). For the group relying on the infrastructure as a support function, a shift of focus (an inversion) may uncover the hidden mundane tasks and processes of organized practice that contribute to

materializing the infrastructure. Simultaneously, for other groups of designers, and system maintainers the same infrastructure means something entirely different. In other words, infrastructure at large scale can be both relational and technological system at the same time. By viewing information infrastructure is this pragmatic way, we can see how it is the sum of this diverse work, performed by various groups, that materializes the Blockchain information infrastructure and keeps it afloat (Jabbar & Bjørn, 2017).

3.3. The kernel of the Blockchain information infrastructure

The diverse work tasks alluded to above, which are performed by distributed heterogeneous individuals and groups, and which contribute to growing and maintaining the Blockchain information infrastructure need to be unpacked. How do these actors work to make the affordances of the Blockchain available to users and related stakeholders? Applying a Kernel approach (Ribes, 2014) to uncover the answers to this question makes sense, particularly since this approach has a focus on the regeneration of the access to key resources and services afforded by the "Kernel" of an information infrastructure. Kernel, in this sense, is an analogy taken from the world of software, where the kernel is the main component of an operating system. The job of the Kernel is to intermediate the user interfaces and the software applications with the computational logic blackboxed into the lower levels of the tech stack. This is done by seamlessly performing key tasks, e.g. memory allocation, which make the applications available to users that are otherwise unaware of the processes taking place at the back-end of the system.

In this context, the Kernel of an infrastructure is made up of its *cache*, which is the resources and services made available to the users, and well as *addressing*, which refers to the complex socio-technical activities that are performed to sustain the availability of the cache. The cache of the Kernel of the Blockchain information infrastructure consists of the many different affordances gained by users in taking part in a Blockchain-based system. Among others these are: access to permissionless transactions, trusted verification of these transactions, transparency of the transactions, anonymity as a user, security, as well as more specific affordances that have emerged as the cache has been extended over time (e.g. access to a funding tool – here referring to so called Initial Coin Offerings or ICOs). Making this cache available to users, as well as ensuring its regeneration as the information infrastructure evolves, is the role of addressing activities. In line with the relational approach to information infrastructures covered above (Bowker and Star), the cache of the Blockchain information infrastructure should be seen as entangled with the addressing activities that sustain and regenerate it.

The trajectory that the Blockchain information infrastructure has followed since the Bitcoin protocol was shared online in 2008, has led to an ongoing repurposing, elaboration, and extension of its kernel. These ongoing changes to the kernel of the infrastructure is the result of entrepreneurial activities that are performed by globally distributed heterogeneous actors, who through their work (i) validate transactions, (ii) develop commercial services (gateways), (iii) maintain core protocols, (iv) ensure governance of the infrastructure, and (v) embed the Blockchain information infrastructure into pre-existing relational networks, often through mundane activities.

The entrepreneurial activities performed in the context of the Blockchain information infrastructure are both enabled and constrained by the constituting features of core protocols. One the one hand, the proliferation of cryptocurrencies and blockchain-based solutions is broadly enabled by the open source nature of many of the existing projects, hereunder the two largest, Bitcoin and Ethereum. On the other hand, this same openness can also act as a constraint for these entrepreneurial activities. Since Bitcoin and Ethereum are open and public, they rely on governance consensus mechanisms that prevent unilateral decision making by any group. In the case of Bitcoin an intricate system of implementation proposals (BIPs) are debated and voted on in an open yet hierarchically structured governance system, where decisions need to ultimately be agreed on by a handful of core maintainers (Jabbar & Bjørn, 2017). The fundamental changes to the protocol are then rolled out as code forks that in turn need to be accepted by the mining community, who must move over to the new chain of transactions (Kow & Lustig, 2017). Usually, consensus is reached among the core maintainers, and the miners will quickly rally around the new chain. In some cases, however this fails to happen, either resulting in parallel chains with different followings, or in an inability to reach consensus among maintainers with inertia and bottlenecks as a consequence. Importantly, the state of consensus between the core maintainers, and the community at large, e.g. miners having to implement new code updates, is very dependent on the composition of the community. As the initial libertarians and cypherpunks that make up the bulk of the community are engaged by groups of newcomers with different agendas, the trajectory of the project can get altered. In paper no. 1, I illustrated how the bitcoin community was increasingly sought out by actors with a finance and banking background, resulting in pressures to put more focus on commercial applications. In other words, the kernel of the Blockchain information infrastructure, hereunder its cache and associated addressing activities, is an evolving entity, that through the dynamic changes in community composition can easily get repurposed, elaborated and extended.

I would argue that the mechanisms described above, and the kernel adjustments that they have entailed, have in large part accounted for the rapid proliferation of cryptocurrencies into the thousands today, as well as for the ongoing extension of the Blockchain information infrastructure into other areas of application. In particular, the ability of anyone with good coding skills to participate in Blockchain projects, appropriate and tinker with existing code, and deploy new blockchains, makes entrepreneurship in the context on this emerging infrastructure very closely linked to the trajectory that the information infrastructure takes. Indeed, the trajectory is still in the making, as these globally distributed entrepreneurial actors go about their mundane activities, and in so doing actively shape the way in which the kernel of the infrastructure develops over time, and retains its ability to regenerate its cache

3.4. The heterogeneous domains of Blockchain application

We have seen that in roughly one decade, Blockchain technology has evolved from being a simple digital protocol – Bitcoin – anonymously shared online (Nakamoto, 2008), to the global and composite phenomenon it is today. In order to unpack this trajectory of emergence, I will now inspect it through the lens of domains. Blockchain is indeed many things to many people, and as such the phenomenon has shady boundaries, is embodied in multiple figurations, and follows complex and entangled trajectories. Today, Blockchain has become an umbrella term covering (i) the thousands of cryptocurrencies that are tradeable on scores of online exchanges, (ii) the widespread gateways and service providers giving materiality to these cryptocurrencies, such as brokers, software wallet manufacturers, and developers of specialized hardware (e.g. mining equipment, point of sales systems, cold storage devices and Bitcoin ATMs) (iii) the Blockchain-based technology platforms allowing for the development of so called distributed applications (Dapps), through the use of smart contracts (e.g. Ethereum, Neo, and Stellar), (iv) the ongoing fundraising campaigns, initial coin offerings (ICOs) or token generation events (TGEs) leveraging the features of Blockchain in order to tokenize a business idea, as well as (v) the alternative distributed technologies sharing Blockchain-like features, also known as Distributed Ledger Systems (DLTs), which are mainly intended for industry applications (e.g. Hyperledger Fabric, and R3 Corda).

This broad conceptualization of Blockchain, has taken shape over time as the affordances of the technology and its embodied figurations have allowed for a wider area of application. This has not happened as a formal exercise of categorisation, but rather organically, as new technological affordances have resulted in new solutions and practices, which in turn have become added and vernacularized into the kaleidoscopic hodgepodge of Blockchain (writ large). This leaves me needing to address relevant questions going forward, which will help me to better situate my analysis: What is within the realm of Blockchain, and what is not? How is “Blockchain - the technology”, different from “Blockchain – the domain”? Is there one or multiple domains at play? How are these connected? And is there such a thing as Blockchain deprived of domain – a certain “domain agnostic” Blockchain space?

Just as Blockchain has become a composite term employed by multiple actors, covering many specific systems, applications, and areas of deployment, the concept of domains has itself been subjected to such a vernacularization. This is explained in the paper by Ribes, Hoffman, Slota, and Bowker (2019), where various figurations of domains are examined. Interestingly, all three figurations presented in the paper conceive of domains as something that co-exists with an undefined non-domain that has general or even universal characteristics: a “domain independent”, “domain general”, or “domain agnostic” tertium quid (a third position). This is very much also the case of the domains associated with Blockchain technology.

As we have seen, Blockchain started as a simple protocol, and is currently in the process of emerging as an information infrastructure that is expanding beyond its original scope. In that sense one could argue that the initial domain of Blockchain application was an area, which was in itself in a state of emergence. Indeed, prior to Bitcoin, the domain that I call “the cryptocurrency domain” did not exist. Although the issues addressed by Bitcoin, and later other cryptocurrencies, relates to payments and currency, the underlying framing of the technology deployment into the world was one of antithesis to the established banking sector. Therefore, as the technology got deployed in vivo, it did not automatically do so within the banking sector, but rather alongside it. A whole new domain came into existence, with all its practices, jargon, and associated build-up of domain knowledge. In other words, one can say, that the initial Bitcoin protocol emerged into an information infrastructure with the characteristics covered earlier, which in turn supported the practices of an equally emerging cryptocurrency domain.

It is from this nascent cryptocurrency domain that further deployment of Blockchain technology into other established domains began taking place. As this happened, the non-domain implied in the paper by Ribes and colleagues, became more explicit. Indeed, the domain-specific attributes of Blockchain as applied to cryptocurrency, started taking on universalistic aspirations, as

Blockchain evangelists, and numerous entrepreneurial actors started to prophesize the attributes and virtually limitless potential for application of this ground breaking technology. From being tightly linked to peer-to-peer transactions, Blockchain was now perceived as a universal technology – a tertium quid - that could be deployed across domains. All that was needed was a domain analysis (Neighbors, 1984) that would investigate the targeted domain, and represent the activities and objects of this domain into models that could be codified around a Blockchain system. This approach is apparent in several of the cases covered in the papers that constitute this thesis, for instance within the shipping and energy sectors.

The considerations above mean that, in this thesis and papers, I tend to use the notion of domain in vernacularized sense. While I am aware of the epistemic logic of domains (Ribes, et.al., 2019), and the inherent crossing that takes place between non-domain (independence or agnosticism) and domain, as Blockchain technology gets "applied", "tailored" or "customized", I also use the term as an acquired matter of fact. This can for instance be seen in two of the papers, where I refer to the "Blockchain domain" in juxtaposition to the "shipping domain", while realizing that what I call the Blockchain domain is in fact a universalized representation of the technology as an entity that holds domain agnostic qualities. If we now assume that the Blockchain domain is indeed a non-domain with universal aspirations, then the overall domain landscape that I cover in this thesis is easier to map out. The landscape looks like this: The domains that the Blockchain information infrastructure is entangled with are all based on specific areas of application, in this case cryptocurrency, shipping, energy. What I sometimes call the Blockchain domain is in fact the underlying non-domain that intermediates the other domains through technology representations, and efforts aiming at applying, tailoring and customizing the technology to the specific domain practices. In this sense, the Blockchain information infrastructure cuts across multiple domains, supporting (or attempting to support) the practices and embedded knowledge that is specific to these domains. Finally, it is also important to emphasize that the domains addressed in this thesis are parsing categories, which can be broken down into sub-domains and further sub-domains, much in the same sense as the concept of sector can be broken down into constituting sub-sectors. An instance of this could be the cryptocurrency domain, under which other sub-domains, such as cryptocurrency trading, or cryptocurrency mining have their specific knowledge, practices and jargon.

Now that I have introduced the basic functioning of Blockchain as a technology, and framed this technology as an emerging information infrastructure, with an evolving kernel, and expanding domains of application, I will zoom in on the activities performed by the entrepreneurs that shape this infrastructural emergence.

Chapter 4: Entrepreneurial activities in the context of Blockchain.

When I started examining the ongoing socio-technical activities performed by entrepreneurial agents in the Blockchain information infrastructure, it became apparent to me that the entrepreneurship literature has traditionally only had a limited focus on practice-based, and relational aspects of entrepreneurial action. In other words, only a very limited part of the literature addresses entrepreneurship as socio-technical activities that through their enactment shape the emergence of innovative business ventures. Instead the vast majority of the entrepreneurship literature tends to have a focus on predefined entrepreneurial stages, that are linearly connected, and that entrepreneurs go through as they transform their business idea into a scalable start-up. Common for these approaches is that they are entitative, meaning that they take the constituting elements of the phenomenon, i.e. entrepreneurs, opportunities, organizations, technologies, etc. as stable entities divorced from any possible recursivity (Hjort, 2015). They are ontologically stable pre-existing entities, decoupled from emergence, that can be connected to each other by rational processual trajectories, e.g. opportunity discovery (Shane & Venkataraman, 2000), followed by firm creation (Gartner, 1985; Katz, 1993), and growth and scaling (Freeman & Engel, 2007).

Through such lenses, opportunities are assumed to exist independently from the ongoing practices of the entrepreneurial actors who "discover" them (Steyaert, 2007). Opportunities are out there in the wild, and what makes the entrepreneurs discover them relates to their cognitive dispositions, risk-taking profiles, and self-efficacy. Furthermore, the entrepreneurial process seen in this light is expressed as a linear, causal, sequential and predictive chain of events that according to critics (Chiles, et.al., 2007) fails to capture the essence of what is happening "as it happens" between the stages of the process (Downing, 2005). Process in this context is seen more as the unlabelled arrows between highlighted boxes in a flow chart, where stable states are momentarily interrupted by processes leading to new stable states. The process between states is not something that gets unpacked, as the relevant focus of analysis is the outcome of the rationally derived stable entities (Casson, 1982). According to Anderson (2017), the areas investigated by the entrepreneurship literature generally seems to work best in disciplinary silos. He summarizes it as follows: *"From a functionalist perspective, we know that innovation is a critical component of entrepreneurship; from a social perspective that entrepreneurs are socially situated and psychologists suggest that entrepreneurs have some qualities and traits that create* *a favourable disposition towards entrepreneurship. These theories are useful, but offer a fragmented contribution to understanding entrepreneurship."* (Anderson, 2017, p 110).

In the context of the emergence and evolution of Blockchain technology, driven by situated entrepreneurial activities performed by heterogeneous actors, I would argue that it is precisely the flow between states that is worth investigating, because it is in this complex process of "becoming" (Tsoukas and Chia, 2002) that the essence of Blockchain entrepreneurship is to be found. In other words, I am less interested in the quantitative outcomes of specific entrepreneurial activities, than I am in understanding how these activities unfold in-the making, and how this relates to the infrastructural characteristics of the technology, as I introduced it in the previous chapter.

These observations have led me to develop a view of entrepreneurship that is processual and in-the-making, inspired by what Johannisson (2011) calls *entrepreneuring*, deliberately employing the gerund form of the word to signal the processual nature of what is to be investigated. Viewing entrepreneurship though such a lens has the potential of situating the phenomenon in a "new form of connectivity and assemblage where both human and non-human elements are included to give form to the trajectories of a world in its becoming" (Steyaert, 2007, p 471). Since the domains of application of Blockchain technology are multi-sited, as covered above, and since Blockchain is emerging as an information infrastructure (Jabbar & Bjørn, 2017), it is important to situate the investigation of entrepreneurship in the context of Blockchain technology at the intersection of activity-based entrepreneurship (entrepreneuring), and of information infrastructures in the making.

4.1. Information infrastructures as a prerequisite for entrepreneurial activities

The entrepreneurial activities that connect distributed and heterogeneous actors within the Blockchain information infrastructure, simultaneously make use of pre-existing infrastructures as the underlying ubiquitous system that allows for their delivery of services to customers (Bjørn and Boulus-Rødje, 2018), and at the same time they contribute to creating, maintaining and growing these same infrastructures (Zimmerman & Finholt, 2007). Infrastructures can thus be seen as the invisible (Star, 1999) socio-technical prerequisite for effective entrepreneurial actions, as well as the result thereof. This is particularly relevant in the context of the emerging Blockchain infrastructure and its entanglement with other infrastructures and socio-technical arrangements. Entrepreneurial actors in the Blockchain domain thus rely on pre-existing digital and analogue infrastructures (e.g. the internet, legal infrastructures, etc.), with all their affordances in terms of opportunities and constraints. They also simultaneously contribute to the emergence of standards (Hanseth, et.al., 1996), conventions of practice (Bowker & Star, 1999), and an ongoing repositioning of the infrastructural kernel (Ribes, 2014) of the developing Blockchain infrastructure.

Because entrepreneurial actors rely on pre-existing infrastructures in their work coordination, and service delivery to customers, access to these infrastructures has been articulated by Bjørn and Boulus-Rødje (2018) as an essential part of being able to succeed as a tech entrepreneur. More specifically, the authors examine the context of Palestine, where they argue that locally situated tech entrepreneurship is dependent on four taken-for-granted types of infrastructure to remain afloat. These are infrastructures related to mobility, legal framework, payment gateways, and mobile internet. These types of classifications as it pertains to entrepreneurship in its reliance on infrastructures, address tech entrepreneurship in general terms (Bjørn & Boulus-Rødje, 2018). The cases that were covered in this study primarily involve technology applications solving situated problems, and relying on established technology components. None of the cases involve actual development of new digital infrastructure based on emerging distributed technology such as Blockchain, and therefore it would be justified to claim that the entrepreneurial activities in question rely more on infrastructure, than they contribute to creating it. This is not so in the cases of entrepreneurial activities covered in this thesis. Here the activities in question are as much infrastructural as they are entrepreneurial.

This being said, the pre-existing infrastructure types covered above also inform the nature, opportunities and constraints of entrepreneurial activities taking place in the emergence of the Blockchain information infrastructure. As I show in the papers that comprise this thesis, growing and keeping the Blockchain information infrastructure afloat requires that the entrepreneurial actors involved address the pre-existing infrastructures that enable their activities. As an example, running a start-up dealing with installing and managing Bitcoin ATMs requires reliance on the electric and WiFi infrastructure of the hosting venue. It also requires reliance on the established global transport and logistics infrastructure when hardware is bought and shipped around the world, as well as on the global legal and financial infrastructures in the sense that compliance with banking regulations in terms of KYC/AML (Know Your Customer / Anti-Money Laundering) needs to be addressed and proven. In other words, no infrastructure will emerge in a complete vacuum, and in the case of entrepreneurial actors in Blockchain, they will always have to address opportunities and constraints (Ribes, 2014) imposed by the established infrastructures that they are obliged to deal with, and whose affordances (Bietz et al. 2010) they can leverage.

An important point, however, is that in engaging with the affordances of pre-existing infrastructures, entrepreneurial activities in the context of Blockchain, also firmly position themselves as being infrastructural in nature. Indeed, the actors performing these activities, are as much infrastructuring (Pipek & Wulf, 2009) agents as they are entrepreneuring (Johannisson, 2010) agents.

4.2. Entrepreneurial activity as a form of infrastructuring

While infrastructure is something that entrepreneurial actors rely on when deploying their business ventures, these infrastructures are also simultaneously created, grown, and maintained by the amalgamation of specific entrepreneurial activities enacted by heterogeneous and distributed actors. Viewing infrastructures specifically through the gerund form of a verb, i.e. *infrastructuring* (Pipek and Wulf, 2009), allows for the affirmation of infrastructures as a relational concept underpinned by a process term. By doing so, the traditional design considerations related to infrastructures get defined in broader terms than design-before-use or design-after-design (Ehn, 2008) and now encompass all socio-technical activities taking place in shaping, growing and sustaining a given infrastructure (Karasti et al. 2010). Through the lens of infrastructuring, the emergence of infrastructures is thus the purview of heterogeneous groups of users, designers, and innovators, hereunder entrepreneurial actors.

The introduction of the notion of infrastructuring by Karasti and Baker (2004), and later by Pipek and Wulf (2009) gave us a high-level term for simultaneously addressing social, technical and organizational processes that contribute to the integration of complex socio-technical artefacts into practices in such a way that these become seamless and taken for granted over time (Star, 1999). Under the umbrella of this term, other more specific activities were conceptualized as specific manifestations of infrastructuring activities addressing particularities of individual infrastructural development, or reconciliations across infrastructures. These could for instance be *addressing* activities, sustaining the availability of the infrastructural kernel for others to use (Ribes 2009), or *synergizing* activities, composed of *leveraging* and *aligning* (Bietz, et.al. 2010), allowing for the building and maintenance of productive relationships among people, organizations, and technologies. These activities can be enacted by a multitude of actors, some professional designers, others technology users, and yet others again business developers operating in the domain in which the particular infrastructures are developed or deployed into.

Although the multiplicity of potential actors is implicit in the notion of infrastructuring, the specific accounts that have been developed in HCI/CSCW have primarily looked at infrastructures that are the result of specifically mandated projects such as cyberinfrastructure projects (Ribes, 2014) or healthcare projects (Constantinides & Barret, 2011). One characteristic of such mandated projects is an aligned focus by the actors involved on achieving infrastructural goals, albeit in a distributed or loosely coupled fashion. This means that these actors, generally speaking, are not explicitly driven by interests that fall outside the infrastructural mandate of the project, and are therefore not being entrepreneurial in the traditional sense of the word. If we however look at other domains, such as large-scale open digital infrastructures (Henfridsson & Bygstad, 2013), there is often no central governing authority, or a mandate to achieve particular infrastructural objectives. Such emerging infrastructures, e.g. the internet, are typically driven by similar infrastructuring activities as in the case of cyberinfrastructures, however these activities are enacted in a much more uncoordinated and heterogeneous manner. This is also the case for the emerging Blockchain infrastructure, that is grown through infrastructuring activities that are clearly entrepreneurial in nature. This means that the main driver and objectives of many of these actors is not articulated in relation to a specific infrastructuring mandate, but as a self-serving entrepreneurial agenda aimed at building a business around a new technology.

In the HCI/CSCW literature, other accounts of infrastructuring activities have investigated domains that are much more driven by self-serving and entrepreneurial agendas than what is the case with cyberinfrastructures. One example of this is the paper by Jack, Chen and Jackson (2017), in which they examine the appropriation of internet tools in Phnom Penh not as an import of technological substrate, but as an ongoing infrastructuring (Pipek & Wulf, 2009) process. In this process, the *creative infrastructural actions* of heterogeneous actors (consumers, business owners, delivery drivers, and call center staff) contribute to the development of a socio-technical infrastructure for managing complex global sales and logistics that is adapted to the specific socio-cultural context in Cambodia. The nature of these creative actions is clearly entrepreneurial, and business oriented, rather than being deliberately infrastructural. Infrastructure in this case emerges as a side-effect of the multiplicities of entangled business practices and workarounds enacted by the involved actors. Similarly, and closer related to

Blockchain, Kow and Lustig (2017) have investigated the role of imaginaries (Murphy, 2004) and crystallization (Neumann & Star, 1996) within the infrastructuring of Bitcoin. In so doing, they find that imaginaries are used by stakeholders in their negotiations around future infrastructural visions, specific socio-technical artefacts, and potential integration with pre-existing infrastructures. These negotiations lead to crystallization, i.e. points of understanding that align expectations and allow for infrastructural integration. Here the act of negotiating implies a diversity of positions, and as an extension of this, a primarily self-serving set of agendas developed by entrepreneurial agents aiming at manifesting a particular infrastructural vision.

In paper no. 2 of this thesis I develop the notion of *Blockchain Assemblages* (Jabbar & Bjørn, 2019), that adds granularity to processes somewhat similar to what Kow and Lustig present in their paper. Blockchain assemblages, in this context, refers to fabricated fluid and dynamic socio-technical constructs that embody technology, business practices and imaginaries about present or future states of the Blockchain information infrastructure. While these assemblages have directed agency, and are the result of collaboration between stakeholders involved in manifesting certain imaginaries, they are also physical, as they include artefacts that embody the imaginaries in question. In other words, the infrastructuring activities of entrepreneurial agents in Blockchain, seem to make use of an intricate portfolio of Blockchain assemblages that are created to manifest a vision, and to serve as a "prop" of sorts in their ongoing negotiations with other stakeholders in the information infrastructure. Interestingly, I found that these Blockchain assemblages evolve in an ongoing iterative manner, though which the act of assembling this Blockchain assemblage, can be abruptly challenged by disconfirming events that question the very premises of the assemblage. This leads to a process of *whiteboxing* through which the assemblage is broken open, revealing its inner workings and misalignments. In this process, the underlying socio-technical assumptions, technical complexities and associated imaginaries that made up the assemblage, and that were made opaque by ongoing engagements with stakeholders, all of a sudden need to be reassessed. Whiteboxing iteratively leads to new assembling, that in turn leads to more whiteboxing as the entrepreneurial actors in Blockchain go about their infrastructuring work.

A characteristic of the iterative assembling and whiteboxing taking place in Blockchain assemblages is that they relate to issues pertaining to opacity in infrastructures, invisibility in use, and appearance at times of infrastructural breakdown (Star, 1999). This draws parallels to social construction of technology (Bijker, 1992) whereby infrastructural black boxes can be opened up, and the details of the historical socio-technical complexities that have led to a current blackboxed state can be unpacked. While this approach has strong merits for examining infrastructures ex-post, one cannot employ it in the case of infrastructures that are at the very early stages of infrastructural development, before the emerging infrastructure is properly consolidated and has become embedded into other relational structures. Rather than looking at a socio-technical black box and attempting to open it up, the Blockchain assemblage approach examines the process whereby the infrastructure slowly gains black box-properties. Here, entrepreneurial activities iteratively assemble and whitebox artefacts, practices and imaginaries, which in turn are used to align future trajectories with relevant stakeholders. This is an inherently forward-looking approach addressing infrastructural opacity in the making, prior to the creation of a technological black box. It is what David Ribes (2018) calls "front-loaded work and epistemically charged negotiation that thereafter becomes infrastructural".

The main contribution of Blockchain assemblages and whiteboxing is their strong focus on early-stage information infrastructures that are still in the making, where the overall trajectory of the infrastructure is still completely open-ended, and where most of the applications at the forefront of the technology are still conceptual and highly comprised of visions, narratives and imaginaries. At this stage, infrastructural consolidation is only beginning and this emerging consolidation is driven by complex socio-technical activities that can be seen as manifestations of infrastructural entrepreneurship. In this connection, the notion of Blockchain assemblage adds specificity to the socio-technical elements that make up the object of focus of the entrepreneurial actors in Blockchain. It simultaneously recast this object from being an artefact to being a complex composite construct, that is highly dependent on imaginaries, and that is constantly being repositioned as it gets socio-technically enacted through interaction with relevant others.

The Blockchain assemblage concept, introduced above, will be further exemplified in Chapter 5, where it will be framed as a main component of *Infrastructural entrepreneurship*. Now, let's move on to entrepreneurial activities, as they take place across infrastructural seams.

4.3. Entrepreneurial activities across infrastructures

Entrepreneurial activities do not only take place within a given infrastructure, but also across infrastructures, as the natural evolution of infrastructures, particularly large-scale open infrastructures, involves expanding (what Grisot, et al (2014) call innovation *of* infrastructure), and disseminating (what they call innovation *in* infrastructures) into other established domains and practices, ultimately resulting in embeddedness (Star & Ruhleder, 1996). This particular intersection between infrastructures, has however been underrepresented in traditional HCI/CSCW literature, which has more of a bias towards accounts of single-infrastructures and single sites of practice (Ribes, 2018). This being said, a number of papers and books have attempted to more specifically address studies in which emerging infrastructural technology meets established domains.

One of the examples of this is Pollock and Williams' book "Software and Organization" (2008), in which they address the challenges of implementing ERP technology packets into existing work infrastructures. More specifically they focus on the tensions between standardization of technology packets and the specificities of work processes in established settings. *Generification* is proposed as a concept that describes the process of making technology generic so that it can be implemented in receiving organizations in an easier manner. Another example is the work by David Ribes on the socio-technical qualities of data interoperability in an ecology of complex, evolving, and intersecting infrastructures (HIV testing data) (Ribes, 2017). Here the focus of the analysis is on the *"front-loaded practical work, negotiation and technical innovation that is thereafter black-boxed, largely forgotten, eventually taken for granted and naturalized as the inevitable technological trajectory for data."* (Ribes, 2017, p1514). The paper shows that interoperability brings about questions of reversibility/irreversibility, whereby data aggregation on its own is likely to cause relative irreversibility, thus locking-in previous data input into new integrated data records with no traces back to the original data. Reversing the interoperability would require far greater additional effort than relying on extant assembled data. Similarly, the paper highlights the interdependent and entangled relationship between seamfullness and seamlessness in technology interoperability, drawing on the work of Janet Vertesi (2014). More specifically, it shows how interoperability is the enacted result of users working across tangible socio-technical seams in an attempt to bring together diverse infrastructures (in this case co-located 110V and 220V electrical circuits).

The enactment work described in the examples above, which is front-loaded, and over time becomes more seamless and blackboxed (Bijker, 1992), can be seen as a type of infrastructuring work aiming not just at growing and consolidating a single infrastructure, but at creating infrastructural seamlessness (Vertesi, 2014), technology implementation (Pollock & Williams, 2008), and interoperability (Ribes, 2017) across infrastructures. This is particularly relevant for the subject of this thesis, Blockchain, in the sense that this emerging infrastructure is evolving into a patchwork of co-existing socio-technical networks with varying degrees of interoperability, and various degrees of permeation into a multiplicity of established industry domains.

In papers no. 3 and no. 4 of this thesis, I develop the notion of *Infrastructural Grind*, which can be situated in extension of the above literature emphasizing entrepreneurial activities across infrastructures. While Vertesi's focus on overlaps among infrastructures, and on the creative situated work of users across infrastructural seams, gives a good insight into how these users align infrastructural commitments, it does so at a single point of overlap between infrastructures. It is a single-sited approach to unpacking the activities of users having to deal with the co-existence of disparate and siloed infrastructures as they happen to be simultaneously present in the same site. In her study, the interoperability between the infrastructures is not secured through computational means, but rather through artful human activities that work around and across the seams of the overlapping infrastructures. A similar single-sited approach can be seen in Pollock and Williams' book referred to above, where the focus is on implementing generified software packets into specific business domains. Infrastructural Grind on the other hand, takes a point of focus that is an aggregation of simultaneously occurring activities at the seams of overlapping infrastructures. As such, the usefulness of the concept is not as much to give granularity to the specifics of the activities taking place at individual and situated seams, but rather to express higher-level patterns of distributed and uncoordinated activities that take place at various intersections between two converging infrastructures. In other words, Infrastructural Grind is an overarching concept that aims at addressing multiple sites of infrastructural intersection, and at verbalizing the permeation patterns that emerge from this kind of multi-sited analysis. Now, when I say grind, what do I actually mean? What elements exactly are grinding against each other when Blockchain and shipping, for instance, are in a process of infrastructural grind?

To answer this, it is essential to highlight that *Grind* is a metaphor at its core, drawing attention to geology and grinding tectonic plates, which apply pressure against each other, and thereafter get momentarily realigned. Grind is a physical phenomenon with implicit "thingness". It is a thing in the same way as a Kernel is a thing. However, this thingness is only an analytical lens aimed at extracting high-level patterns of activities that take place simultaneously in various sites. The underlying activities that manifest Infrastructural Grind, are relational in much the same way as the entangled cache and addressing activities proposed by Ribes (2014). This means that through the lens of Infrastructural Grind, infrastructures are seen as metaphorical physical entities that converge towards each other as heterogeneous entrepreneurial actors attempt to “implement” an infrastructural technology – i.e. a technology that in itself has infrastructural properties, into a domain-specific information infrastructure. The grind metaphor is intended to emphasize that the technology in question is not going to be “implemented” or “diffused” into the targeted domain in a linear and straight-forward manner. On the contrary, what I have seen happening through my research, is that the process of introducing Blockchain technology into the shipping domain is in fact an amalgamation of specific asynchronous initiatives at different intersection points between infrastructures.

Sticking with the metaphor, one can say these overlaps between infrastructures are spread out across multiple sites within the targeted domain, in this case from upstream to downstream sites of the shipping supply chain. At each one of these intersections, the process of implementing, customizing or appropriating the incoming technology will take on different situated characteristics. Common for all intersections however, is that it is a reflexive and dynamic process, where the affordances of the future version of Blockchain that will eventually become embedded in the technological and relational arrangements of the shipping information infrastructure, is under constant (re)negotiation.

This process, taking place at the points of intersection between infrastructures, can be seen as a manifestation of an ongoing repurposing of the kernel of the Blockchain information infrastructure, which aims at adjusting the cache of the Blockchain kernel, i.e. the resources that it makes available to users, to fit the future needs of the shipping domain. Looking at this in more details, one could say that the Blockchain kernel, being an overarching term for a patchwork of diverse co-existing systems, is a multi-core kernel – a shabby dog kernel, to use Ribes’ analogy (2014). Indeed, the specific Blockchain, and Distributed Ledger systems that are being introduced to the shipping domain are multiple, and uncoordinated, with different affordances, and built in socio-technical trade-offs. My cases indeed illustrated one project relying on IBM Hyperledger, another on a customized Blockchain designed by a university, and a third project relying on a distributed ledger built by a small British start-up. This means that as entrepreneurial actors aim at introducing Blockchain to the shipping domain, they will need to rely on a specific embodiment of Blockchain technology, at the expense of other options. The chosen technology option will, in the terminology of Infrastructural Grind, have specific *interoperability* properties, e.g. permissioned vs permissionless access, anonymous vs KYC compliant, or yet again system replacement vs system adaption. This will influence how the infrastructural grind will unfold at that particular point of intersection between infrastructures, since the chosen system will influence the speed (I call it *Velocity* in my paper no. 3 and no. 4) at which implementation into the shipping domain will take place (if at all).

It is not only the properties of the specific Blockchain embodiments chosen to be introduced into the shipping domain that influence the nature of the infrastructural grind taking place at that particular point of infrastructural intersection. Remaining in the terminology of Infrastructural Grind, certain points of intersection between infrastructures will display a high level of *permeability*, while others will not. This simply means that specific sites within the shipping domain, will be more receptive to the activities of the entrepreneurial actors aiming at introducing Blockchain technology, and others will not. The reason for this is a combination of several factors. The state of the current shipping information infrastructure at the particular site, can for instance be fragmented and less consolidated than in other parts of the domain. This can be enhanced by situated business practices and competitive considerations at the particular stage of the supply chain, which could be more open to collaborative initiatives and new technology. Finally, this can also be enhanced by the specific technology solutions and their *interoperability* properties.

Finally, and importantly, infrastructural grind should be seen as a reflexive process, in which these simultaneously occurring touch points between converging infrastructures enable kernel alterations in both infrastructures. In the shipping domain, the information infrastructure that has been supporting domain-specific practices for decades, gets challenged by potential new ways of structuring and sharing data. Some of the ideas that Blockchain bases itself on can stimulate change in parts of the industry, and contribute to an opening up and redesign of the kernel of the infrastructure. Similarly, the infrastructural grind process also enables the Blockchain information infrastructure to add features to its kernel, which can not only be used in the context of solutions for the shipping domain, but also become yet another attribute in the growing and expanding Blockchain information infrastructure. This reflexive exchange is what I refer to as the two infrastructures “rubbing off” one another, to stay in the explicitly descriptive metaphorical jargon of Infrastructural Grind.

This chapter has shown how entrepreneurial activities have been examined in the HCI/CSCW literature seen in relation to information infrastructures, and in particular how entrepreneurial activities in the context of Blockchain can be theoretically understood.

While each examined string of literature has elements that are applicable to a better understanding of the objective at hand, i.e. unpacking what defines entrepreneurship in the context of Blockchain, they need to be brought together in an understandable format. This is what I propose in the next chapter, where I examine what I call Infrastructural Entrepreneurship.

Chapter 5: Introducing Infrastructural Entrepreneurship

5.1. What is infrastructural entrepreneurship?

Infrastructural entrepreneurship is simultaneously "entrepreneuring" and "infrastructuring"

The research question of this thesis essay aims at defining entrepreneurship in the context of the emerging Blockchain information infrastructure. In order to answer this question, I have developed "Infrastructural Entrepreneurship" as a conceptual framework which unpacks how the basic nature of entrepreneurial activities taking place in the context of Blockchain are simultaneously *entrepreneuring* and *infrastructuring*. These activities cannot be conceptualized as being either entrepreneurial or infrastructural in nature. They are the both at once. Infrastructural Entrepreneurship can thus be seen as a conceptual approach which allows practitioners to guide their entrepreneurial activities by foregrounding the entangled nature of these activities with the ongoing growth and sustaining of the Blockchain information infrastructures within which they operate.

In my research, this simultaneity inherent to infrastructural entrepreneurship is exemplified by multiple empirical accounts, such as a case examined in paper no. 1, which looks deeper into the practices of an entrepreneur whose business focus is on importing, installing, and operating Bitcoin ATMs (BTM) in Copenhagen. In this case, the paper shows that the informant's everyday practices are generally narrowly defined and aiming at solving mundane problems of customer relations, cash flow management, and strategic planning aiming at yielding profit - Typical entrepreneurial considerations. The paper, however, also demonstrates that in this particular case, all the entrepreneurial activities performed by our informant are simultaneously infrastructural in nature. Through his activities he is performing infrastructuring (Pipek & Wulf, 2009), and thus contributing to making the resources of the Kernel (Ribes, 2014) of the Blockchain information infrastructure - the cache - available for others to interact with. It is through his socio-technical decisions that our informant is setting himself up as a gateway service between the core bitcoin protocol and the multiple users that now have access to buy and sell the cryptocurrency via the BTMs. This means that although the specific activities are practical and mundane, and aim at (i) embedding the BTM machines into the fabric of existing infrastructures, such as electricity, internet, and payment infrastructures, (ii) deciding on locations and screening potential partners, and (iii) making strategic choices about expansion into other bitcoin-related domains such as mining, these activities also have clear infrastructural consequences. Through his socio-technical decisions our informant is indeed addressing the opportunities and constraints of the current state of the Blockchain information infrastructure, and through his activities he is simultaneously contributing to the growth and consolidation of the kernel of the infrastructure (Ribes, 2014). The paper shows that in this particular case, the primary driver of the entrepreneurial activities performed by our informant is not directly to develop the emerging information infrastructure, but instead, it is based upon self-serving economic interests. In the paper I explain it as follows:

> *"These economic interests are manifestations of the built-in economic rationale, which is encapsulated within the Bitcoin protocol. It is this economic rationale that incentivizes the entrepreneurial actions, which keep the blockchain infrastructure afloat. The protocol features an encoded model for how to earn money based upon mining activities, as well as derived incentives to capitalize on the extension of the protocol into the physical world. The explicitly encoded and transparent rules embedded in the design of the protocol is what creates the cohesiveness of the infrastructure. Development and consolidation of the blockchain infrastructure is a side-effect of the economic rationale inherent to the protocol, which incentivizes growing one's own business."* (Jabbar & Bjørn, 2017)

The above quote hints at the observation that there is something particular about the Bitcoin protocol, which in many respects can be extrapolated to other Blockchain implementations and tokenization models, that incentivizes independent economic action in pursuit of algorithmically-codified rewards and derived business opportunities. This incentivized entrepreneurial practice then in turn ties into infrastructural properties that at an aggregate level contribute to growing, sustaining, and propagating the Blockchain information infrastructure.

Entrepreneuring, as I employ it in this thesis essay is an extension of the concept of "entrepreneurial actions" that I introduced in paper no. 1. It is a broader concept than the more traditional view of entrepreneurship as the "pursuit of opportunities for profit" (Casson, 1982). Entrepreneuring (Steyaert, 2007) is an activity-centered view of entrepreneurship rather than a view based on cognition, or entrepreneurial outcomes and antecedents. In the context of Blockchain, entrepreneuring (Steyaert, 2007)) can be pursued by conventional start-ups, being legally incorporated in a firm, or similarly it can be pursued by established companies as well as by individuals not acting within the legalities of a firm setting. Whether the infrastructuring agents in Blockchain are start-ups (such as my Bitcoin ATM informant), or individual amateur cryptocurrency traders, or even yet large corporations like Maersk or IBM, they all through their individual activities can be seen as performing *entrepreneuring*.

Infrastructural entrepreneurship thus captures this broader concept of entrepreneuring and shows that although the activities in question are primarily perceived by the entrepreneurial actors as being self-serving and focused on the execution of a particular narrow-focused entrepreneurial vision, they are simultaneously also strongly connected to the development of the emerging Blockchain infrastructure. Socio-technical decisions about physical and digital alignment of opportunities (choice of protocol, partnerships, workarounds, etc.) all open up, or lock in opportunities for developments that can be leveraged in future endeavors. While this is common in many technological fields that have an infrastructural dimension, it is particularly important in the context of emerging and distributed technologies, such as Blockchain, that are still at an early stage of infrastructural development.

Infrastructural entrepreneurship thus implies an entanglement of purpose. Entrepreneuring is infrastructuring and vice-versa. The distinction between the two concepts is the scope of the outcome of the given activity. Entrepreneuring implies outcomes that directly impact the agent in terms of project feasibility, viability, sustainability, and profitability. Infrastructuring, on the other hand, implies outcomes measurable on the infrastructural scale i.e. contribution to lock-in, emergence of standards and conventions of practice, contribution to interoperability or balkanization, etc. All entrepreneurial activities in the area of Blockchain embody this simultaneity and manifest outcomes that are both infrastructural and entrepreneurial. Depending on the activities in question, and the inclination of the entrepreneurial agent performing the activity, the purposefulness of the activity, i.e. the perception of the actor, is either going to be primarily focused on entrepreneurial or infrastructural outcomes. Regardless of this purposefulness, however, any given entrepreneurial activity in Blockchain is going to be an entangled simultaneity yielding entrepreneurial and infrastructural outcomes.

5.2. How is infrastructural entrepreneurship performed?

Infrastructural entrepreneurship involves an ongoing and iterative creation of Blockchain assemblages

Infrastructural entrepreneurship is performed through a variety of socio-technical activities that aim at expanding the business ventures of heterogeneous entrepreneurial actors engaged in domains where Blockchain technology is being deployed. My empirical cases have shown that these activities often involve an ongoing and iterative creation of *Blockchain assemblages,* that are used by the entrepreneurial actors in their engagement with their stakeholders.

As introduced in Chapter 4, Blockchain assemblages, is the result of activities related to manifesting, sustaining, and repositioning an entrepreneurial concept into the shape of a *Blockchain Assemblage*, which is used by an entrepreneurial actor in ongoing relational alignments with other stakeholders. This is done through elaborate and iterative mixing of artefacts (hardware, software and analogue), imaginaries about the future of the solution and the associated infrastructure, as well as specific situated practices helping enact this manifestation. Blockchain Assemblages that are thus manifested, are temporal constructs that through practice, are dynamically created, sustained and repositioned through assembling and whiteboxing activities.

The dynamic nature of this ongoing iterative process is triggered by disconfirming events, which expose the limitations of a proposed Blockchain assemblage. When entrepreneurial actors, engaging with stakeholders using a Blockchain assemblage, realize that the assumed fundamentals inherent to the assemblage no longer hold true, they are incited to reassess the nature and constituting parts of the particular assemblage. This is done by opening up the assemblage, so to speak, and exposing its inner socio-technical cogwheels, visions and relational connections allowing for a repositioning of its constituting parts into a new and enhanced Blockchain assemblage, which in turn can once more gain opacity as it becomes consolidated and increasingly taken for granted. Assembling and whiteboxing are thus entangled concepts that reflexively inform each other as entrepreneurial actors carry out activities that, on the one hand, assemble and obscure socio-technical components, and on the other open up and expose these same components.

In my research I have looked at several empirical accounts that illustrate the iterative assembling and whiteboxing activities that take place as entrepreneurial actions are performed in the context of the Blockchain information infrastructure. In paper no. 2, I explicitly introduce the notion of Blockchain assemblages referred to above, and unpack two empirical cases from different Blockchain sub-domains in order to illustrate that it is currently difficult to distinguish the perceived imaginaries related to the Blockchain infrastructure from the infrastructure itself. I argue that this is a specific characteristic of information infrastructures that are at a very early stage of consolidation, and that in this case, the role of imaginaries about the future of Blockchain, decentralization, and potential use cases should not be underestimated. It is indeed as much these imaginaries that inform the directions in which the infrastructure develops. Because imaginaries, their creation and their propagation, are an integral and widespread part of the entrepreneurial activities in Blockchain, I propose to view the object of entrepreneurial focus within Blockchain not just as software code or technical artefacts, but as elaborate and entangled assemblages: Blockchain Assemblages.

In one of the empirical accounts in paper no. 2 I focus on a start-up involved in a project aimed at designing and implementing a Blockchain-based solution for transacting renewable solar energy between distributed peers. Here I show how the start-up began by developing a Blockchain assemblage largely composed of an imaginary pertaining to the future of energy trading. This imaginary envisioned a replacement of existing centralized modes of energy production with a more “democratic” and open network of prosumers (producer/consumers), who would optimize the distribution grid and empower individuals to take control over their energy production and consumption. Entangled with this imaginary, there were general assumptions and technical ideas about a specific distributed ledger system that could potentially be used for the project, as well as practical engagement activities with the developer team behind this technology. In this case, the technology, the practices involved with stakeholders, as well as the elaborate imaginary about the future of distributed energy could be seen as an elaborate Blockchain assemblage that got reinforced the more the start-up engaged with its general stakeholders. Interestingly, I witnessed how this assemblage got cracked open as the underlying assumptions about project and technology got confronted with the realities of the project and contextual constraints at large. More specifically, it became clear that the legal context was a major constraint to the execution of the project, as peer-to-peer energy trading turned out to be illegal, and it also became clear that the basic assumptions about the existing infrastructure in the buildings targeted for the project were incorrect. In the paper I express it as follows:

> *"…it became clear that some of the assumptions that BLOC had about the current state of the electric infrastructure of the buildings were inconsistent with reality. While smart meters were assumed, it turned out that the selected building was of older date, and that the current electricity meters were revolving disc meters rather than smart meters. These types of meters are based on a mechanical metal disk that rotates and incrementally updates an analogue display. Connecting such a meter to a Blockchain would not be possible unless it is done as a work-around solution whereby one could add a small adhesive optic sensor on the casing of the meter."* (Jabbar & Bjørn, 2019)

What we see here, is that the initial Blockchain assemblage that the start-up brought into the project got met with a number of disconfirming events that shattered the coherence of the assemblage. The imaginary was no longer valid, and as an extension of this, the required technology and practices also needed rethinking. This forced the start-up to go back to the drawing table, and collaboratively try to reposition the constituting parts of the assemblage into something that would still be applicable in the given situation. What I then witnessed was a search for a new imaginary supported by alternative artefacts other than previously assumed. The outcome was an updated Blockchain assemblage fabricated to address the fact that the new objective of the project had become technology demonstration rather than scaling. In this connection, digital fabrication artefacts (such as the OpenBlock artefact, which I introduced earlier) became an integral part of a new imaginary, which now was more about testing prototypes, and proving technical feasibility, than about scaling and disrupting established players. In fact, during my research I also witnessed this second iteration of a Blockchain assemblage get whiteboxed once more, and repositioned in a manner that shifts the focus away from the original energy project, but instead recasts the start-up within a different sub-domain of the energy sector, namely financing of renewable energy assets, and carbon markets. Overall this example illustrates how the specific content of the activities performed by entrepreneurial agents in Blockchain is made up of iterative assembling and whiteboxing elements that continuously reconfigure the Blockchain assemblages that the entrepreneurial actors use in their relational engagements with stakeholders.

To summarize we can say that infrastructural entrepreneurship is performed through assembling activities and whiteboxing activities. Assembling is the process of creating a Blockchain Assemblage, which comprises configurations of digital and analogue artefacts that are entangled with imaginaries about the current and future state of the Blockchain information infrastructure. These configurations are case- and domain-specific and rely on a multiplicity of digital and analogue artefacts and practices. Whiteboxing on the other hand is the activity whereby blockchain assemblages are unpacked and unconcealed. It is the activity where the black box of infrastructures is opened for examination and re-organization. Whiteboxing is when the cogwheels, wires, and narratives which make up the blockchain assemblages are revealed and examined. Assembling and whiteboxing are entangled concepts that get enacted and re-enacted by entrepreneurial actors as they iteratively assemble and whitebox multiplicities of artefacts, practices and imaginaries aimed at constructing their object of entrepreneurial pursuit.

5.3. Where does infrastructural entrepreneurship take place?

Infrastructural entrepreneurship takes place through growing new infrastructures and grinding against existing infrastructures.

Infrastructural entrepreneurship takes place within and across the seams of domains. The entrepreneurial activities in question, which we have established to be simultaneously infrastructural, as well composed of assembling and whiteboxing activities, unfold in situated locales that are distributed across domains where there is a perceived opportunity in introducing Blockchain.

My empirical data reveals that infrastructural entrepreneurship contributes to growing new infrastructures as well as to grinding against established industrial domains containing their own legacy of infrastructures and connected practices. Infrastructural entrepreneurship is therefore as much about "growing" previously inexistent infrastructures (e.g. cryptocurrency trading), as it is about "grinding" the emerging infrastructure against established industry domains in search for new addressable use cases (e.g. Blockchain projects in the energy or shipping industries). The activities performed in Blockchain will thus always be entangled with the simultaneously occurring processes of growing and grinding. The specific activities in question can obviously be more or less related to growing a new infrastructure, or grinding against an established infrastructure.

The activities of my informant from paper no. 2, for instance, who is a cryptocurrency trader, and who makes use of online gateway services, and hardware storage for the keys to his coins, are contributing to growing the cryptocurrency infrastructure. He is doing so by engaging with these gateways and hardware producers, buying their storage devices, and in so doing he is contributing to enacting emerging standards, and to consolidating the crypto-trading infrastructure. This growth, however, also has derived grinds. The cryptocurrency infrastructure, although new and emerging, will still be involved in grinds, for instance with the traditional banking system that the gateway services rely on to run a legitimate business.

On the other hand, several examples of infrastructural entrepreneurship across domain seams can be illustrated by the Blockchain projects in the shipping domain covered in papers no. 3 and no. 4. In these papers, I introduce the notion of Infrastructural Grind as a concept to better understand the infrastructural activities taking place at the intersection between converging information infrastructures. More specifically, the empirical data shows that as Blockchain technology gets introduced in the shipping industry, the two infrastructures socio-technically rub off each other at various points of infrastructural intersection, leading to a permeation of Blockchain technology into the fabric of the shipping information infrastructure in varying manners and at differential velocity. An explanation as what I specifically mean by the term "rub off each other" has been given in the last page of Chapter 4.

Addressing where infrastructural entrepreneurship is performed, shifts the focus away from single infrastructures to the intersection between infrastructures as well as the socio-technical entanglement between infrastructures. The literature on Information Infrastructures in HCI / CSCW that addresses relational activities across infrastructures is somewhat limited as pointed out and called for by Ribes and Lee in their 2010 CSCW journal paper. One such contribution, that I have also referred to earlier, is Pollock and Williams' book entitled Software and Organizations (2008), in which the authors look at the challenges of implementing technology packets into new (industry) domains. Importantly they introduce the notion of *generification* as the process whereby tech vendors attempt to implement a product designed for one particular setting into another setting. As they do so they will enact generification activities that aim at rendering the technology package "generic" so that it can be easily appropriated by the existing infrastructures. While Pollock and Williams' generification approach is vendor-centric and aiming towards implementation, seamfull and seamless infrastructures should be seen through creative activities performed by technology users across infrastructural seams. This user-focused approach focuses on the infrastructural heterogeneity experienced by technology users as they navigate domains that are composed of multiple infrastructures with clear delimitations and "seams". Navigating across such an ad hoc patchwork of technologies that have not yet achieved seamlessness (Vertesi, 2014) is and exercise in micro-level infrastructural alignment (Bietz et al. 2010), and a way of sustaining coherence across infrastructures.

The notion that the implementation of a technology into another domain is a complex socio-technical process aligns well with the concept of infrastructural grind that I propose, as a manifestation of infrastructural entrepreneurship. There are differences, however, in the sense that generification, as well as seamfull/seamless infrastructures are typically looked at from the perspective of a singular and coherent set of activities undertaken by a vendor or a user. In the one case the vendor is trying to find a new outlet for a specific proprietary technology packet, and in the other the user is attempting to navigate across the seams of an infrastructural patchwork made up of multiple overlays of systems, standards, and practices. In contrast to this, infrastructural grind refers to amalgamations of heterogeneous activities resulting in complex, distributed and asynchronous patterns of permeation into pre-existing infrastructural fabrics, and interoperability with existing systems. Infrastructural grind is in principle of a higher order than generification, and seamfull/seamless infrastructures, and more of a contextual lens (the *where*) through which the drivers and outcomes of infrastructural entrepreneurship can be further unpacked.

To summarize, we can say that infrastructural entrepreneurship takes place in various distributed domains, some of which are new and emerging, while others are well established. Within new domains, such as cryptocurrency trading, infrastructural entrepreneurship takes place as socio-technical activities that contribute to growing the infrastructure of the emerging domain. In established domains such as the shipping and energy sectors, on the other hand, infrastructural entrepreneurship takes the shape of an infrastructural grind, in which various engagements with actors within the domain are performed in different intersections between infrastructures, and with various degrees of permeation. This process of introduction of Blockchain into existing domains is not linear and sequential, rather it is dynamic, and reflexive. In the case of blockchain in shipping, for example, it results in continuous repositioning of the kernels of the blockchain and the shipping information infrastructure, which over time get increasingly aligned.

5.4. Summarizing infrastructural entrepreneurship

I have now unpacked the concept of infrastructural entrepreneurship, illustrated it with examples from my empirical cases, and expanded on how it relates to previous theoretical contributions within the literature on information infrastructures. In this final section I will discuss the three characteristics of infrastructural entrepreneurship that can be extrapolated from the answers to the questions that have guided my inquiry about infrastructural entrepreneurship in this chapter, namely: what is it? how is it performed? and, where does it take place? In so doing, I will bring together the concept of infrastructural entrepreneurship as a framework for better understanding entrepreneurship as it takes place in the context of the Blockchain information infrastructure.

The three characteristics of infrastructural entrepreneurship that I have derived from my analysis of empirical data pertaining to entrepreneurial activities taking place in the context of the Blockchain information infrastructure can be summarized by the following 3 headlines:

1) Infrastructural entrepreneurship is simultaneously entrepreneuring and infrastructuring. (what is it?)
2) Infrastructural entrepreneurship involves an ongoing and iterative creation of *Blockchain assemblages* (How is it performed?)
3) Infrastructural entrepreneurship takes place through *growing* new infrastructures and *grinding* against existing infrastructures. (Where does it take place?)

As we have seen further above, infrastructural entrepreneurship is practice-based and different from the infrastructuring activities that for instance take place in the context of cyberinfrastructures. The difference lies in the fact that the main driver for infrastructural entrepreneurship is the self-serving entrepreneurial actions of distributed heterogeneous actors rather than the pursuit of directed infrastructural goals. This being said, the overall long-term objective of any of these entrepreneurial agents will be goals that simultaneously have infrastructural impact, and that ultimately lead to embeddedness of Blockchain into the fabric of other relational constructs. We can thus say that the goal of infrastructural entrepreneurship is to deploy an inherent entrepreneurial drive into the infrastructural fabric of society at large, be it through cryptocurrency gateway services, or blockchain applications designed for specific industry use. In the process of pursuing the goal of infrastructural entrepreneurship, its constituting characteristics highlighted above come into play in an entangled way, which I will now unpack.

The drive expressed by actors in the Blockchain information infrastructure to pursue entrepreneurial endeavors is at the core of the concept of infrastructural entrepreneurship. As we have seen in the case of bitcoin, this drive can in part be linked back to the protocol itself, which incentivizes the pursuit of entrepreneurial activities while simultaneously using this entrepreneurial drive to derive infrastructural effects, such as the validation of bitcoin transactions through a mining process that rewards individuals and entities for putting their computing power at the disposal of the network. This incentive structure can then be extended by the same entrepreneurial actors to include gateway services, or other solutions addressing user needs.

It is by looking at how infrastructural entrepreneurship is performed, in the nitty gritty situated specifics of everyday practice, that we can see how this drive to achieve entrepreneurial goals gets translated into specific socio-technical assemblages – Blockchain assemblages - that encompass artefacts, imaginaries and practices. The drive to be entrepreneurial is thus operationalized into an iterative exercise of creating and whiteboxing socio-technical assemblages of technology, practices and imaginaries. These situated Blockchain assemblages are in turn deployed by the entrepreneurial actors in their engagement with relevant stakeholders, with the purpose of transmitting their vision of current and future states of Blockchain into the fabric of society at large in a specific and targeted manner.

This engagement with stakeholders will take place within the societal fabric that the assemblage is aimed at. This means that the deployed Blockchain assemblage will be at the center of the growing of new infrastructures (e.g. cryptocurrency infrastructure), or the grinding against other domain-specific infrastructures that the assemblage is designed to permeate into (e.g. energy or shipping domains). Disconfirming events urging entrepreneurial actors to reconsider their Blockchain assemblage will often take place within the societal fabric that the assemblage is aimed at, therefore adding to the entanglement between the elements of infrastructural entrepreneurship.

This trajectory from fundamental entrepreneurial drive, to entrepreneurial construction (*iteratively creating Blockchain assemblages*), to entrepreneurial deployment (*growing and grinding*) is meant to illustrate the entanglements between the constituting characteristics of infrastructural entrepreneurship. This being said, however, the entanglements between the characteristics should not necessarily be seen as linear, rather they influence each other in a dynamic and ongoing socio-technical fashion. The same Blockchain assemblages can for example be repositioned to address other domains, i.e. shifting from growing new infrastructure, to grinding against existing infrastructure. In the process of so doing, the assemblage might run into disconfirming events that will force it to be cracked open and reconfigured to align itself with new imaginaries, technological upgrades, and altered understandings of business practices. While the entrepreneurial drive is inherent to infrastructural entrepreneurship, its translation into iterative assembling and whiteboxing, and its deployment in domain contexts of growing and grinding will be complex and multifaceted. This is indeed very different from the view that technology gets built in a vacuum, and diffused wholesale into industries with minor situated adaptions.

Other than providing a more nuanced and activity-based view on how an emerging infrastructural technology, such as Blockchain, actually gets introduced into various domains of application, Infrastructural entrepreneurship and its characteristics that I have unpacked in this chapter, also offers a useful framework for defining the entrepreneurial activities taking place in the context of the Blockchain information infrastructure.

Chapter 6: Conclusion

In this thesis essay I set out to answer the following research question: What defines entrepreneurship in the context of the Blockchain information infrastructure?

In order to answer this question, I have unpacked the entrepreneurial activities taking place in the context of the Blockchain information infrastructure, and introduced the concept of infrastructural entrepreneurship, as a loose framework for defining and better understanding these entrepreneurial activities as they happen in-the-making. The specific peer-reviewed papers that make up this article collection, all address various elements of this framework, and contribute with the specific pieces that have been combined and elaborated on in this thesis essay.

Methodologically, this thesis essay, and peer-reviewed papers, have drawn on ethnographic inquiry and interventionistic approaches, since this allowed for my empirical research to shape fluidly in accordance with the intervention opportunities that arose. In each of my empirical cases, I thus engaged with my informants in various immersive ways leveraging different elements from the research methods that inspired me. In so doing, I managed to get very close to my sources and got access to first hand empirical data that would have been hard to get hold of if I had not managed to become part of the group/community in question. Furthermore, as my investigations multiplied, and I got more experienced in enacting my dual role as active participant and researcher, I also increased my methodological awareness. In many respects, I would say that my ethnographic and interventionist strategies became more fine-tuned and targeted in parallel with the emergence of patterns in the data that I collected. In other words, the more I learned from partaking in various sites of practice, the more I was able to design better strategies for future interventions. This fluid and adaptive research approach fitted very well with the fragmented, dynamic, and everchanging Blockchain domain, the pervasiveness of which made it very difficult to approach through more canonical methods.

Engaging, in an active and participatory fashion, with various start-ups, communities, and individual entrepreneurs over longer periods of time resulted in a framework that addresses some of the shortcoming identified in the literature regarding the intersection between entrepreneurship and information infrastructures. Through my empirical cases that are further unpacked in the peer-reviewed papers, I identified various aspects of entrepreneurial activities in

Blockchain that shed light on the complexities and particularities of operating in a technology domain where infrastructure and business application are simultaneously in the making. Blockchain today is still a nascent technology, and as such it bundles multiple imaginaries and visions of future use. These visions and imaginaries are what today's Blockchain entrepreneurs work at materializing in the world and in so doing they necessarily need to address both the infrastructural and entrepreneurial dimensions of technology deployment. This means that the activities that I have investigated in the domain are simultaneously entrepreneurial and infrastructural. At some level they need to take into account not just the immediate commercial plans (product-market-fit), but also the complex and evolving landscape of underlying Blockchain technologies. In their actions, entrepreneurs in the Blockchain domain are thus simultaneously contributing to their own commercial targets, as well as to the evolution of the whole information infrastructure.

This simultaneity, causing the activities of entrepreneurial actors in the Blockchain information infrastructure to be both entrepreneurial and infrastructural is what I refer to as infrastructural entrepreneurship. Infrastructural entrepreneurship has another two main characteristics that add granularity to the understanding of the entrepreneurial activities taking place in the Blockchain information infrastructure. These other two characteristics respectively address specifics of technology deployment at an artefact assemblage level (Blockchain assemblages used in relational negotiations with stakeholders), and also give contextual understanding as deployment happens in-the-making within and across infrastructures (growing and grinding).

Going forward, the research presented in this thesis adds to the slowly burgeoning literature on Blockchain in CHI/CSCW, which until recently has primarily been focused on conceptual frameworks for Blockchain studies in HCI, or on select studies aiming at making this technology more user friendly. I would argue that approaching Blockchain from an infrastructural entrepreneurship perspective opens up many potential future avenues of research within CHI/CSCW. The principles addressed by Blockchain, e.g. transparency, trust, security, anonymity, all have complex socio-technical entanglements with broader societal structures, established practices, law and even ethics. Attempting to disintermediate given industries with Blockchain, for example, will inevitably put some of these principles in conflict with broader institutions, regulatory frameworks and ethical considerations. My empirical cases have shown examples of this, for instance when it pertains to anonymity of financial transactions in relation to formal Know Your Customer (KYC) regulations. Tracing these Blockchain principles as they are being materialized by entrepreneurial actors, and finding their intersection with broader societal structures and norms could in principle give rise to much interesting HCI/CSCW research into how the state of entanglement between technology and societal structures is dynamically (re)negotiated with implications for both users and populations at large. This will be particularly relevant since the proliferation of Blockchain systems into established industry domains has only begun.

References

Marc Ackerman. 2000. The Intellectual Challenge of CSCW: The Gap Between Social Requirements and Technical Feasibility. *Human-Computer Interaction*, 15, p179-203.

Madeleine Akrich, Michel Callon, and Bruno Latour. 2002. The key to sucess in innovation Part 1: The art of interessement. International journal of innovation management 6(2): 187-206.

Madeleine Akrich, Michel Callon, and Bruno Latour. 2002. The key to success in innovation Part 2: The art of choosing good spokespersons. International journal of innovation management 6(2): 207-225.

Alistair Anderson, Sébastien Ronteau, 2017. Towards an entrepreneurial theory of practice; emerging ideas for emerging economies, Journal of Entrepreneurship in Emerging Economies, Vol. 9 Issue: 2, pp.110-120

S. Avle, and S. Lindtner. 2016. Design(ing) 'here' and 'there': Tech entrepreneurs, global markets, and reflexivity in design processes. CHI. San Jose, CA, USA, ACM**:** 2233-2245.

James Basden, and Michael Cottrell. 2017. How Utilities Are Using Blockchain to Modernize the Grid, Harvard Business Review, March 2017

Matthew Bietz, Eric P. S. Baumer, and Charlotte P. Lee. 2010. Synergizing in cyberinfrastructure development. Computer Supported Cooperative Work (JCSCW)

Wiebe Bijker. 1992. The Social Construction of Fluorescent Lighting, or How an Artifact Was Invented in Its Diffusion Stage. In book: Shaping Technology - Building Society. Studies in Sociotechnical ChangePublisher: Cambridge, Ma.: MIT Press.Editors: W.E. Bijker, J.Law

Pernille Bjørn, and Nina Boulus-Rødje. 2015. The multiple intersecting sites of design in CSCW research. Computer Supported Cooperative Work (CSCW): An International Journal 24(3): 319-351.

Pernille Bjørn, A.-M. Søderberg and S. Krishna 2017. "Translocality in Global Software Development: The Dark Side of Global Agile." Human-Computer Interaction 34(2): 174-203.

Pernille Bjørn, M. Esbensen, R. E. Jensen and S. Matthiesen. 2014. "Does distance still matter? Revisiting the CSCW fundamentals on distributed collaboration." ACM Transaction Computer

Human Interaction (ToChi) 21(5): 1-27.Julian Bleeker. 2009. Design Fiction: A Short Essay on Design, Science, Fact and Fiction. Retrieved from http://nearfuturelaboratory.com

Jeanette Blomberg, and Helena Karasti. 2013. Reflections on 25 Years of Ethnography in CSCW. Computer Supported Cooperative Work (CSCW) August 2013, Volume 22, Issue 4, pp 373-423

Jeanette Blomberg, Mark Burrell & Greg Guest. 2002. An Ethnographic Approach to Design. In book: Human-Computer Interaction HandbookEditors: J. Jacko & A. Sears

Jeanette Blomberg, Giacomi, J.,Mosher, A. & Wall, Patricia. (1993). Ethnographic Field Methods and Their Relation to Design. Participatory Design: Principles and Practices.

Geoffrey C. Bowker, and Susan Leigh Star. 1999. Sorting things out – Classifications and its consequences. MIT Press

Geoffrey C. Bowker. 1994. Science on the run: Information management and industrial geophysics at Schlumberger, 1920–1940. Cambridge: The MIT

Burawoy, M. 1998. The Extended Case Method. *Sociological Theory.* 16:1, p4-33.

Marc C. Casson. 1982. The Entrepreneur: An Economic Theory, Oxford: Martin Robertson, [2nd. ed., Edward Elgar, 2003

Todd Chiles, Allen Bluedorn & Gupta Vishal. 2007. Beyond Creative Destruction and Entrepreneurial Discovery: A Radical Austrian Approach to Entrepreneurship. Organization Studies - ORGAN STUD. 28. 467-493.

Claudio U. Ciborra. 2000. Infrastructure As a Process: The Case of CRM in IBM. From Control to Drift: The Dynamics of Corporate Information Infrastructures 2000

Panos Constantinides and Michael Barrett. 2015. Information Infrastructure Development and Governance as Collective Action. *Info. Sys. Research* 26, 1 (March 2015), 40-56.

Paul Dourish, Genevieve Bell. 2014. ‘‘Resistance is futile’’: reading science fiction alongside ubiquitous computing. Personal and Ubiquitous Computing, Volume 18 Issue 4, April 2014 Pages 769-778

Paul Dourish. 2006. Implications for design. Proceedings of the SIGCHI Conference on Computer Human Factors in Computing Systems (CHI'06). Montreal, Quebec, Canada, ACM: 541-550.

S. Downing. 2005. The Social Construction of Entrepreneurship: Narrative and Dramatic Processes in the Coproduction of Organizations and Identities. Entrepreneurship Theory and Practice, 29(2), 185–204.

Paul N. Edwards, Geoffrey C. Bowker, Steven J. Jackson, and Robin Williams. 2009. Introduction: an agenda for infrastructure studies. Special Issue on e-Infrastructure of the Journal of the Association for Information Systems, 10(5), 364–374

Pelle Ehn. 2008. Participation in Design Things. PDC '08 Proceedings of the Tenth Anniversary Conference on Participatory Design 2008. Pages 92-101

Mark-Anthony Falzon. 2009. Multi–sited Ethnography: Theory, Praxis and Locality in Contemporary Research. Multi-sited Ethnography: Theory, Praxis and Locality in Contemporary Research.

Diana Forsythe.1999. "It's Just a Matter of Common Sense": Ethnography as Invisible Work. Computer Supported Cooperative Work. 8. 127-145.

Diana E. Forsythe. 2001. *Studying those who Study Us: An Anthropologist in the World of Artificial Intelligence*. David J. Hess (Ed.). Stanford University Press, Stanford, CA, USA.

J. Freeman & J. S. Engel. 2007. Models of Innovation: Startups and Mature Corporations. California Management Review, 50(1), 94–119.

Xianyi Gao, Gradeigh D. Clark, and Janne Lindqvist. 2016. Of Two Minds, Multiple Addresses, and One Ledger: Characterizing Opinions, Knowledge, and Perceptions of Bitcoin Across Users and Non-Users, Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems Pages 1656-1668

William B. Gartner. 1985. A Conceptual Framework for Describing the Phenomenon of New Venture Creation. Academy of Management Review, Vol. 10, Issue 4, p. 696-706 1985.

R. Stuart Geiger, and David Ribes. 2011. Trace Ethnography: Following Coordination through Documentary Practices. Proceedings of the 44th Hawaii International Conference on System Sciences.

Miria Grisot, Ole Hanseth, Anne Asmyr Thorseng. 2014. Innovation Of, In, On Infrastructures: Articulating the Role of Architecture in Information Infrastructure Evolution. *Journal of the Association for Information Systems*: Vol. 15 : Iss. 4 , Article 2.

Ole Hanseth, and Margunn Aanestad. 2003. Design as bootstrapping. On the evolution of ICT networks in health care. Methods of information in medicine 42 (4), 384-391

Ole Hanseth, Eric Monteiro, and Morten Hatling. 1996. Developing information infrastructure: the tension between standardisation and flexibility. Science, Technology and Human Values, 11(4), 407–426.

Ole Hanseth and Kalle Lyytinen.2010. "Design theory for dynamic complexity in information infrastructures: the case of building internet." JIT 25 (2010): 1-19.

R. R. Harper, J. A. Hughes, and D. Z. Shapiro. 1990. Harmonious working and CSCW: computer technology and air traffic control. In *Studies in computer supported cooperative work*, John M. Bowers and Steven D. Benford (Eds.). North-Holland Human Factors In Information Technology Series, Vol. 8. North-Holland Publishing Co., Amsterdam, The Netherlands, The Netherlands 225-234.

C. Heath & Luff, P. 1992. Collaboration and control Crisis management and multimedia technology in London Underground Line Control Rooms Computer Supported Cooperative Work 1: 69.

Hjorth, D., Holt, R., & Steyaert, C. 2015. Entrepreneurship and process studies. International Small Business Journal, 33(6), 599–611.

Lilly Irani. 2019. Chasing Innovation: Making Entrepreneurial citizens in Modern India, Princeton University Press.

Lilly Irani. 2015. "Hackathons and the making of entrepreneurial citizenship." Science, Technology, & Human Values 40(5): 799-824.

Karim Jabbar, and Pernille Bjørn. 2017. Growing the Blockchain Information Infrastructure, Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems

Karim Jabbar, and Pernille Bjørn. 2018. Infrastructural Grind: Introducing Blockchain Technology in the Shipping Domain. GROUP '18, January 7–10, 2018, Sanibel Island, FL, USA

Karim Jabbar & Pernille Bjørn. 2019. Blockchain Assemblages: Whiteboxing Technology and Transforming Infrastructural Imaginaries. In 2019 CHI Conference on Human Factors in Computing Systems Proceedings (CHI 2019), May 4–9, 2019, Glasgow, Scotland, UK. ACM, New York, NY, USA. 13 pages. https://doi.org/10.1145/3290605.3300496

Karim Jabbar & Pernille Bjørn. 2018. Permeability, Interoperability and Velocity: Entangled Dimensions of Infrastructural Grind at the Intersection of Blockchain and Shipping. In ACM Transactions on Social Computing - Special Issue on Group '18 and Regular Papers Volume 1 Issue 3, December 2018 Article No. 10 https://doi.org/10.1145/3288800

Margaret Jack, Jay Chen, and Steven J. Jackson. 2017.. Infrastructure as Creative Action: Online Buying, Selling, and Delivery in Phnom Penh, Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems

B. Johannisson. 2011. Towards a practice theory of entrepreneuring. Small Business Economics, 36(2): 135–150.

Helena Karasti, Karen S. Baker, and Florence Millerand. 2010. Infrastructure time: long-term matters in collaborative development. Computer Supported Cooperative Work (JCSCW)

Jerome Katz. 1993. The Dynamics of Organizational Emergence: A Contemporary Group Formation Perspective. Entrepreneurship Theory and Practice, Vol. 17, Issue 2, p. 97-101 1993.

Yong Ming Kow and Caitlin Lustig. 2017. Imaginaries and Crystallization Processes in Bitcoin Infrastructuring, Computer Supported Cooperative Work (CSCW). DOI 10.1007/s10606-017-9300-2

Tue Odd Langhoff, Mikkel Hvid Amstrup, Peter Mørck, and Pernille Bjørn. 2016. Infrastructures for healthcare: From synergy to reverse synergy. Health Informatics Journal.

Charlotte P. Lee, Paul Dourish, and Gloria Mark. 2009. The human infrastructure of cyberinfrastructure. Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work (pp. 483 – 492). New York: ACM Press

Charlotte Lee & Kjeld Schmidt. 2018. A bridge too far? Critical remarks on the concept of "infrastructure" in CSCW and IS. In book: Socio-Informatics: A Practice-based Perspective on the Design and Use of IT ArtifactsChapter: 5Publisher: Oxford University PressEditors: Volker Wulf, Volkmar Pipek, Dave Randall, Markus Rohde, Kjeld Schmidt, Gunnar Stevens

Silvia Lindtner, G. Hertz and P. Dourish. 2014. Emerging sites of HCI Innovation: Hackerspaces, Hardware startups & Incubators. CHI. Toronto, Canada, ACM.

Silvia Lindtner, A. Greenspan and D. Li. 2015. Designed in Shenzhen: Shanzhai manufacturing and maker entrpreneurs. Critical Alternatives: 5th decennial Aarhus Conference. Aarhus, Denmark, ACM**:** 85-96.

Bronislaw Malinowski. 1922. Argonauts of the western Pacific: An account of native enterprise and adventure in the archipelagoes of Melanesian New Guinea. London: G. Routledge & Sons.

George E. Marcus. 1995. Ethnography in/of the World System: The Emergence of Multi-Sited Ethnography. Annual Review of Athropology, Vol. 24, 95-117

George E. Marcus and Dick Cushman. 1982. Ethnographies as text. Annual Review of Anthropology Vol. 11 (1982), pp. 25-69

D. Martin, J. ONeil, N. Gupta and B. Hanrahan. 2016. "Turking in a global labour market." Computer Supported Cooperative Work (CSCW): An International Journal - published early online.

Bill Mauer, Taylor C. Nelms, and Lana Swartz. 2013. “When perhaps the real problem is money itself”!:the practical materiality of Bitcoin. Social Semiotics, 2013

Bill McKelvey. 2004. Toward a Complexity Science of Entrepreneurship. Journal of Business Venturing, Vol. 19, Issue 3, p. 313-341 2004.

Jessica Mesman. 2007. Disturbing Observations as a Basis for Collaborative Research. Science As Culture. 16. 281-295.

Eric Monteiro, Neil Pollock, Ole Hanseth, and Robin Williams. 2013. From Artefacts to Infrastructures. Computer Supported Cooperative Work: The Journal of Collaborative Computing (JCSCW), 22(4), 575–607

Keith M. Murphy. 2004. Imagination as Joint Activity: The Case of Architectural Interaction.Mind, Culture, and Activity, 11(4), 267-278

Satoshi Nakamoto. 2008. Bitcoin: A Peer-to-Peer Electronic Cash System. Retrieved form bitcoin.org (5 February 2016)

Neighbors, J. 1984. The Draco approach to constructing software from reusable components. *IEEE Transactions on Software Engineering*, 10:564–573.

Laura J. Neumann, and Susan Leigh Star. 1996. Making Infrastructure: The Dream of a Common Language. PDC’96 Proceedings of the Participatory Design Conference. J. Blomberg, F. Kensing, and E.A. Dykstra-Erickson (Eds.)

Pettersson, M., Randall, D. & Helgeson, B. 2004. Ambiguities, Awareness and Economy: A Study of Emergency Service Work. Computer Supported Cooperative Work (CSCW) (2004) 13: 125.

Volkmar Pipek, and Volker Wulf. 2009. Infrastructuring: towards and integrated prespective on the design and use of information technology. Journal of the association of information systems. Volume 10, issue 5, May 2009, 306 – 332.

Larissa Pschetz, Ella Tallyn, Rory Gianni, and Chris Speed. 2017. Bitbarista: Exploring Perceptions of Data Transactions in the Internet of Things, Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems

David P. Randall E. Ilana Diamant, Charlotte P. Lee. 2015, Creating Sustainable Cyberinfrastructures, Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems Pages 1759-1768

David Ribes. 2014. The Kernel of a Research Institution. Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing. Pages 574-587

David Ribes, and Thomas A. Finholt. 2009. The long now of infrastructure: Articulating tensions in development. In P. Edwards, G. C. Bowker, S. Jackson, & R. Williams (Eds.), Special Issue on eInfrastructure in the Journal of the Association for Information Systems, 10 (5), 375–398

David Ribes, and Thomas A. Finholt. 2007. Tensions across the scales: Planning infrastructure for the long- term. Proceedings of the 2007 international ACM conference on Supporting group work, Sanibel Island, Florida, USA (pp. 229 – 238). New York: ACM Press

David Ribes, and Charlotte P. Lee. 2010. Sociotechnical Studies of Cyberinfrastructure and e-Research: Current Themes and Future Trajectories. Computer Supported Cooperative Work (2010) 19:231–244

David Ribes. 2017. Notes on the Concept of Data Interoperability: Cases from an Ecology of AIDS Research Infrastructures. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (CSCW '17). ACM, New York, NY, USA, 1514-1526.

David Ribes, Hoffman, A. S., Slota, S. C., & Bowker, G. C. (2019). The logic of domains. *Social Studies of Science*, *49*(3), 281–309.

Jennifer A. Rode. 2011. Reflexivity in digital anthropology. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '11). ACM, New York, NY, USA, 123-132.

Everett M. Rogers. 2003. *Diffusion of innovations*. New York: Free Press.
K. Rolland. and E. Monteiro. 2002. "Balancing the local and the global in infrastructural information systems." The Information Society 18: 87-100.

S. D. Sarasvathy. 2001. Causation and Effectuatio : A Theoritical Shift From Inevitability to Economic Entrepreneurial Contingency. Academy of Management Review, 26(2): 243–

Kjeld Schmidt & Jørgen Bansler. 2016. Computational Artifacts: Interactive and Collaborative Computing as an Integral Feature of Work Practice. Conference: COOP 2014: 12th International Conference on the Design of Cooperative Systems, 23-27 May 2016, Trento, Italy.

S. Shane S and S. Venkataraman. 2000. The promise of entrepreneurship as a field of research. Academy of Management Review 25(1): 217–226.

I, Shklovski, J. Vertesi and S. Lindtner. 2014. "Introduction to this special issue on Transnational HCI." Human-Computer Interaction 29(1): 1-21.

Susan Leigh Star, and Karen Ruhleder. 1996. Steps toward an ecology of infrastructure: design and access for large information systems. Information Systems Research, 7 (1), 111–134

Susan Leigh Star. 1999. The ethnography of infrastructure. American Behavioral Scientist, 43, 377–3

Susan Leigh Star, and Geoffrey C. Bowker. 2002. How to infrastructure. In L. A. Lievrouw & S. Livingstone (Eds.), The Handbook of New Media (pp. 151–162). London: SAGE Publications.

Susan Leigh Star, and James R. Griesemer. 1989. Institutional ecology, translations and boundary objects: Amateurs and professionals in Berkeleys museum of Vertebrate Zoology, 1907-39. Social Studies of Science 19: 387-420.

C. Steyaert. 2007. “Entrepreneuring” as a conceptual attractor? A review of process theories in 20 years of entrepreneurship studies. Entrepreneurship & Regional Development 19 (November): 453–477.

Lucy A. Suchman. 1987. Plans and Situated Actions: the Problem of Human-Machine Communication. Cambridge University Press, New York, NY, USA.

Michael Bedford Taylor. 2013. Bitcoin and The Age of Bespoke Silicon CASES '13: Proceedings of the 2013 International Conference on Compilers, Architectures and Synthesis for Embedded Systems

David Tilson, Kalle Lyytinen, Carsten Sørensen. 2010. Digital Infrastructures: The Missing IS Research Agenda. Research Commentary. Information Systems Research, Vol. 21, No. 4, December 2010, pp. 748-759

H. Tsoukas and R. Chia. 2002. On organizational becoming: Rethinking organizational change. Organization Science 13: 568–582.

S. Venkataraman, S. 1997. The distinctive domain of entrepreneurship research. Advances in entrepreneurship, firm emergence and growth. 3(1): 119–138.

J. Vertesi. 2014. Seamful Spaces: Heterogeneous Infrastructures in Interaction. *Science, Technology, & Human Values*, *39*(2), 264–284.

Robin Williams and Neil Pollock. 2008. Software and Organisations: The Biography of the Enterprise-Wide System or How SAP Conquered the World (December 6, 2008)

Ann Zimmerman, and Thomas Finholt. 2007. Growing an Infrastructure: The Role of Gateway Organizations in Cultivating New Communities of Users. Proceedings of the 2007 international ACM conference on Supporting group work. Pages 239-248

Aviv Zohar. 2015. Bitcoin under the Hood. Communications of the ACM, September 2015, Vol 58, No 9, 104-113

J. L. Zittrain. 2006. The Generative Internet. Harvard Law Review , 119: 1974–2040.

Teun Zuiderent-Jerak, & Bruun Jensen, C. 2007. Editorial introduction: Unpacking ‘intervention’ in science and technology studies. *Science as Culture, 16*(3), 227-235.

Teun Zuiderent-Jerak. 2007. Preventing implementation: Exploring interventions with standardization in healthcare. *Science as Culture, 16*(3), 311-329.

Teun Zuiderent-Jerak. 2016. If Intervention Is Method, What Are We Learning?. Engaging Science, Technology, and Society. 2. 73.

Paper overview

Growing the Blockchain Information Infrastructure

This paper was presented at the 2017 CHI Conference on Human Factors in Computing Systems in Denver, Colorado. It is published in the conference proceedings and available in the ACM Digital Library. DOI: http://dx.doi.org/10.1145/3025453.3025959

Blockchain Assemblages: *Whiteboxing* Technology and Transforming Infrastructural Imaginaries

This paper was presented at the 2019 CHI Conference on Human Factors in Computing Systems in Glasgow, United Kingdom. It is published in the conference proceedings and available in the ACM Digital Library. DOI: http://dx.doi.org/10.1145/3290605.3300496

Infrastructural Grind: Introducing Blockchain Technology in the Shipping Domain

This paper was presented at GROUP '18 - the ACM Conference on Supporting Groupwork in Sanibel Island, Florida. It is published in the conference proceedings and available in the ACM Digital Library. DOI: https://doi.org/10.1145/3148330.3148345

Permeability, Interoperability and Velocity: Entangled Dimensions of Infrastructural Grind at the Intersection of Blockchain and Shipping

This paper was published in the ACM Transactions on Social Computing - Special Issue on Group ’18 and Regular Papers, Volume 1 Issue 3, December 2018 DOI: 10.1145/3288800

Growing the Blockchain Information Infrastructure

Karim Jabbar
University of Copenhagen
Copenhagen, Denmark
karim@di.ku.dk

Pernille Bjørn
University of Copenhagen
Copenhagen, Denmark
pernille.bjorn@di.ku.dk

This paper was presented at the 2017 CHI Conference on Human Factors in Computing Systems in Denver, Colorado. It is published in the conference proceedings and available in the ACM Digital Library. DOI: http://dx.doi.org/10.1145/3025453.3025959

Abstract

In this paper, we present ethnographic data that unpacks the everyday work of some of the many infrastructuring agents who contribute to creating, sustaining and growing the Blockchain information infrastructure. We argue that this infrastructuring work takes the form of *entrepreneurial actions*, which are self-initiated and primarily directed at sustaining or increasing the initiator's stake in the emerging information infrastructure. These entrepreneurial actions wrestle against the affordances of the installed base of the Blockchain infrastructure, and take the shape of *engaging* or *circumventing* activities. These activities purposefully aim at either influencing or working around the enablers and constraints afforded by the Blockchain information infrastructure, as its installed base is gaining inertia. This study contributes to our understanding of the purpose of infrastructuring, seen from the perspective of heterogeneous entrepreneurial agents. It supplements existing accounts of the "when" and "how" of infrastructure, with a lens for examining the "why" of infrastructure.

Introduction

In 2008 a mysterious and anonymous character under the name Satoshi Nakamoto introduced Bitcoin to the world: An encrypted and decentralized protocol for peer-to-peer transactions of digital cash, based on a secure distributed transaction ledger known as the Blockchain [23]. This new technical protocol revealed a whole new way of organizing financial transaction in the early aftermath of the global financial crisis. Anyone can download a Bitcoin Core client and set up payments using Bitcoin transactions [1]. Bitcoin transactions are validated by "Bitcoin mining", which is performed by computer nodes on the network, and which also generates new Bitcoins as a reward to miners for making their processing power available to the network [34]. At its inception, the Bitcoin phenomenon triggered the imaginations of many: Libertarians wanting to free people from a corrupt and inefficient banking system; hackers wanting to oppose surveillance and install true anonymity in all kinds of transactions; as well as criminals seeing Bitcoin as an ideal vehicle for anonymous illicit transactions.

Over the past years, the emerging Blockchain infrastructure is no longer just restricted to underground movements of tech-savvy people with ideological aspirations, but has moved into the mainstream. A multitude of alternative Bitcoin-like protocols have emerged (altcoins or altchains) [39] and Silicon Valley investors are backing start-ups working with Blockchain technology. Large industrial corporations and financial institutions are taking in Blockchain technology, and Blockchain technology is increasingly being described as an emerging Internet-based protocol layer serving as ground for entrepreneurs to build new innovative services, which potentially may disrupt a large number of industries. While the Bitcoin protocol is clearly an interesting technical phenomenon [39] [34] [1] [12] [16] [6], it is also an emergent information infrastructure [31] [7] [26], which represents a great opportunity for research in CSCW and HCI. Blockchain technology is more than a protocol allowing for peer-to-peer transfer of digital cash, it is an emerging Information Infrastructure made up of layered and complex social and technical practices that are distributed globally in multiple sites, and dynamically transformed over time. Supporting our interest in the socio-technical aspects of the Blockchain infrastructure, we explore: *What characterizes the infrastructuring activities that contribute to sustaining and growing the Blockchain infrastructure?*

In this paper, we draw upon empirical work conducted over the last 12 months, where we follow and explore the Blockchain information infrastructure as it is manifested in various socio-technical activities. We follow the physical activities done by entrepreneurs working out of incubators, the financial consultant advising banks, and the CEO of a small hardware company specializing in Bitcoin ATM machines (BTMs) – as they are all involved in making the Blockchain information infrastructure. We study the activities taking place online such as in the open-source Blockchain communities and on Reddit threads, as well as offline activities where we observe physical gathering such as Blockchain meetups.

Through our investigation, we find that the Blockchain information infrastructure is shaped by *entrepreneurial actions* which are self-initiated and primarily directed at sustaining or increasing the individual stakes in the emerging information infrastructure. These entrepreneurial actions wrestle with the enablers and constraints afforded by the installed base of the Blockchain infrastructure, and take the shape of *engaging* or *circumventing* activities. These activities purposefully aim at either influencing or working around the technological, economic, governance, and legal affordances which emerge as the Blockchain information infrastructure develops, and its installed base gains inertia.

This paper is structured as follows. Firstly, we introduce information infrastructures as part of CSCW and HCI research. Secondly, we present our method, data sources, and analytical approaches arriving from our multi-sited ethnography [19]. Thirdly, we introduce the basic functioning of bitcoin and Blockchain technology, and present our results. Fourthly, we discuss of our empirical findings related to the literature on information infrastructures. Finally, we conclude.

Information Infrastructure

Information infrastructures have been of interest to CSCW and HCI research for a long time. Thus, when we are exploring how the Blockchain information infrastructure is expanding through infrastructuring activities, we already have existing concepts to guide our endeavor. One of the important characteristics of information infrastructures is their *relational nature*, which challenges the view that an infrastructure is *"a substrate: something upon which something else "runs" or "operates", such as a system of railroad tracks on which rail cars run"* [30]. Instead, the information infrastructures approach recasts infrastructure as an expression of ongoing dynamic and constantly changing socio-technical relationships. The relational is put in the center in a process of "infrastructural inversion" [8]. Through this inversion substrate becomes substance [31]. Thus, information infrastructures do not exist in a vacuum, but are seen as embedded into other socio-technical structures and relational arrangements. They can simultaneously be embedded in technological networks, interpersonal networks, organizational networks, or community networks [3] [33]. This embeddedness both enables and constrains the development of the infrastructure. On the one hand, the inertia of the installed base enables the development of standards and conventions of use supporting the continuing existence of the infrastructure. On the other hand, these standards and conventions of use also limit the action space available for future development. Simultaneously, the embedded characteristic of an information infrastructure will allow for "network externalities" whereby the resources made available by an infrastructure can draw on the relational arrangements into which the infrastructure is embedded.

Large-scale information infrastructures are often characterized by ongoing development outside the initial scope of design, as a multitude of diverse actors continue to base their new activities on the existing infrastructure, and the affordances of its installed base. In example, gateway organizations [36] might develop new innovations that extend the functionality and range of the existing infrastructure [13]. This decentralized process means that such large-scale infrastructures can only to a certain extent be deliberately designed and built centrally. Instead they grow [10] organically within an everchanging environment.

Seeing "Infrastructur*ing"* as a transitive verb, brings about a conceptual shift in the focus of our analysis, which helps us better explain how ongoing infrastructural design activities as well as user appropriation activities contribute to bringing about and maintaining an information infrastructure [24]. Infrastructuring activities have also been explored as the *addressing* activities, which contribute to the ongoing trajectory of an information infrastructure [26], i.e. how these activities aim at sustaining the resources made available by the information infrastructure. Addressing activities are particularly related to the ways in which various tasks aid to *sustaining, renewing, adding,* or *shedding* features of the infrastructure Kernel.

So, what is it specifically that actors do, when they engage in infrastructuring at a practical operational level? *Synergizing* refers to the process of creating and maintaining productive socio-technical relationships [3]. Synergizing includes *aligning* stakeholders, and *leveraging* previous relationships, with the purpose of developing the information infrastructure. The processes of alignment and leveraging often draws on arrangements of relationships that originate in networks and webs into which the information infrastructure is embedded [3]. Simultaneously, these synergizing activities accumulate over time, and aggregate into further infrastructural embeddeness. Synergizing looks at the mundane everyday activities of heterogeneous, broadly-defined, *developers* who intentionally engage in aligning and leveraging activities with the goal of creating (cyber)infrastructure. In doing so, synergizing supplements the "when" of infrastructure [31], with an approach to understanding the "how" of infrastructure [33], as a dynamic relational process, and not an end goal. When we explore the infrastructuring activities taking place in the Blockchain infrastructure, we will investigate aspects related to embeddedness, synergizing, as well as intentionality.

Method

Due to the globally distributed and rapidly changing nature of Blockchain, uncovering the infrastructuring activities that contribute to creating, sustaining and growing this information infrastructure is a complex endeavor. This is particularly true because the Blockchain phenomenon is constituted by mobility, intersections, and flow, as well as connections, associations, and relationships across space and time. Thus, when we initiated our study in August 2015, we decided to engage in multi-sited ethnography [19], as a way to *trace the information infrastructure as an ethnographical phenomenon* [11].

Data collection: In our study, we followed, observed and interviewed companies and individuals involved with Blockchain technology in Denmark, and Ireland. Because of the relative novelty of Blockchain technology, these companies where mainly start-ups, which we identified through visits to incubators as well as by participating in events, such as Bitcoin meet-ups in Copenhagen. Examples of the types of start-ups that we engaged with are providers of Bitcoin ATM-machines, developers of digital Wallets, advisors to financial institutions on Blockchain technology, and Bitcoin security companies. More specifically we spent in excess of 80 hours observing the daily work of these companies, including regular operations, client meetings, business trips and social events. These observations, and ongoing meetings with our informants allowed for challenges, and tensions that we could not have foreseen to manifest themselves. Also, studying these sites allowed us to better understand the socio-technical aspects of the global Blockchain phenomenon through local activities.

Because of the distributed nature of the Blockchain information infrastructure, many connections between participating actors only takes place in digital fora. In these fora, be it Github, Reddit, BitcoinTalk, or Bitco.in, coordination between actors, as well as strategizing about the future of the technology takes place. We therefore saw it as important to supplement our various physical sites of investigation with ongoing examination of the digital traces left by the participants in relevant fora. Our informants were very helpful in directing us to the relevant corners of internet where activities influencing the operation, maintenance, and future plans for Blockchain technology are taking place.

Alternating between physical discussions with our informants and investigative work in digital fora created a synergy, whereby the data collected in either setting was enhanced and better understood as it was interpreted and corroborated by the other setting. Data was captured in field notes, documents, downloads of discussion fora, news articles, and audio-recorded interviews, which were later transcribed. Over the period, in excess of 180 hours were spent on collecting all the described forms of data.

Data analysis: Our data analysis began before data collection was finished. We iteratively worked through the data from observation notes, interview transcripts, article downloads, and so on, with the aim of finding categories and concepts that would help explain the characteristics of the socio-technical activities involved in the Blockchain information infrastructure. Initial proposed categories were organized by recurrent themes, and categorized in schemes, which were then transcribed into detailed write-ups of the data in an interpretative format. These write-ups were discussed with the informants, in order to assess the validity of the interpretation and selected categories and concepts. The write-ups were also the basis for preparing for ongoing field observations and interviews. As more data was collected, the initial categorizations several times needed re-sorting and re-analyzing, before finally solidifying into the interpretation presented in this paper.

Limitations: our local case was chosen because of the very tangible socio-material properties of Bitcoin ATMs, and our global bitcoin governance case on the other hand was picked with a focus on capturing moments of rupture in the infrastructure. At these moments of breakdown, infrastructures emerge and become available for scrutinizing, thus allowing us to explore the foundational entrepreneurial actions that contribute to sustaining the infrastructure. Obviously by making this choice we are omitting other socio-technical stories of entrepreneurial action in the Blockchain Information Infrastructure.

Results

Before presenting our empirical data, which looks at Blockchain from an information infrastructure perspective, we will briefly introduce the basic mechanics of how Bitcoin and its underlying Blockchain technology works. Bitcoin is fundamentally a technical protocol – the Bitcoin protocol - with hard-coded rules for monetary transactions between peers. Bitcoin is a distributed database that records all the transactions taking place on the network without the need for a trusted third party. Instead, Bitcoin relies on a network of communicating computer nodes running Bitcoin software. Bitcoin transactions use public-key cryptography to ensure security, thus each transaction must be signed with a private key giving access to spend the Bitcoin amount associated with a Bitcoin address. Each transaction is validated by the global Bitcoin network using the public key associated with that address. The Bitcoin protocol determines that every ten minutes, all the Bitcoin transactions of the last ten minutes are broadcast to the entire distributed network at the same time in one batch. Each batch is time stamped and locked into one block of transactions, which includes a cryptographic hash of the previous validated block, which in turn is connected to the previous one, and so on, all the way back to the first block, the so-called Genesis Block. The complete ledger of interchained transaction blocks, the 'Blockchain', is kept and updated every ten minutes on all computer nodes of the Bitcoin network. In order to ensure a fast propagation of the blocks to all the distributed nodes, the Bitcoin protocol sets a maximum size of one Megabyte (approx. 1700-1900 transactions) per block. A side effect of this maximum size is that it creates a limit to the scalability of the network as we will see in our empirical results. The process whereby the Bitcoin Blockchain is kept consistent, updated and immutable is called *Bitcoin mining.* Mining is the simultaneous process whereby transactions are validated and included in a block, and whereby new Bitcoins are created and given as a reward for putting processing power at the disposal of the network. Bitcoin mining, at its core, consists of computer hardware (nodes on the network) intensely utilizing their processor power in an attempt to solve an advanced cryptographic puzzle every ten minutes, in competition with all the other mining nodes on the global Bitcoin network. This is also referred to as "proof-of-work". Solving the puzzle gives the "winning" computer node the right to broadcast the finalized block to the rest of the network, and triggers a "block reward" consisting of freshly created Bitcoins. The puzzle is designed is such a way that it is impossible to solve by any other means than random trials. This means that the more processing power is thrown at the puzzle, the more hashes can be tried per second, and the greater the probability of solving the puzzle first. If there is an increase in the aggregate hashing power on the network, then the protocol will self-adjust making it more difficult to solve the puzzle. This prevents too many blocks, and Bitcoins as an extension of this, from being created too fast. The extreme amounts of processing power required to perform proof-of-work, and the chaining of blocks through cryptographic hashes, makes it virtually impossible to tamper with the Blockchain, as an attacker would have to change all subsequent blocks in order for changes made to one block to be accepted. Today, there are slightly over 16 million Bitcoins in circulation, with a market capitalization of 16.4 billion US Dollars. The protocol dictates that the block reward is halved every 4th year (currently 12.5 Bitcoins), until all 21 million Bitcoins have been created which will happen approximately in the year 2140. Today, the total hashing power of the Bitcoin network has become greater than the world's 50 largest supercomputers combined, meaning that the odds of solving a puzzle on a personal laptop, for example, have become infinitely small. Bitcoin mining has thus become a large-scale industrial endeavor taking place in enormous data farms, which are located in geographies that have access to large quantities of cheap electricity.

Synergizing work in Bitcoin: the "blocksize" debate

Bitcoin was originally developed as a reaction to the financial crisis. Bitcoin was seen as an alternative to the excessive power held by large banks in the global economy. It was about shifting the power to the individual, and allowing anyone to have the right to hold onto and spend their own money freely. A totally decentralized peer-to-peer system for digital cash. However, as Bitcoin developed, so did the composition of its constituting communities. As the Bitcoin phenomenon became more known to a wider public, its underlying technology, Blockchain, became the object of scrutiny of new actors such as financial institutions and later industrial corporations. As these new actors joined the Bitcoin community they brought with them pre-existing arrangements of relationships such as connections to corporate interests, as well as specific methods for driving innovation processes. This can for example be seen in the emergence of so called Fintech Accelerators, where start-ups working with Bitcoin and Blockchain technology are brought in, and guided through their business development process, in return for an equity share. Our informant Brian, who runs a Blockchain start-up out of Dublin explains the advantage of Fintech Accelerators in these words: *"in each of the banks in Dublin we had one dedicated person to talk to. So, that's invaluable. If we have a question we ask them, if they don't know they will find somebody in the bank working on it all day just to try to help us".* By leveraging their pre-existing relationships and aligning with corporate interests, these new members of the Bitcoin community create synergies that push the infrastructure in the direction that suits their interest. While the inclusion of new actors into the Bitcoin information infrastructure allows for it to expand, it also accentuates disagreements and creates friction in its governance structure, as witnessed by the so-called "blocksize debate". In the following we will see how the synergizing activities of corporate players are an entangled part of the current inability of the Bitcoin network to scale considerably beyond its current size.

The governance principles in Bitcoin were not initiated at the inception of the cryptocurrency. Rather, they are developed and transformed over time based upon the community's capabilities to settle controversies. After the creator of Bitcoin, Satoshi Nakamoto, disappeared from public view, he handed over the keys to the core protocol to one of his remote collaborators Gavin Andresen (the myth is that the two of them never met physically). Gavin maintained control of the Bitcoin Core GitHub repository and was considered Bitcoin's lead developer until he stepped back in 2014. Before stepping down, Gavin and other main contributors to the Bitcoin core protocol, set up a governance system whereby a small handful for Bitcoin Maintainers have commit access to the protocol and the responsibility of reaching a consensus before implementing major changes to the code. Most of the core developers up until about a year ago, did not work full-time on the Bitcoin project, but were also employed in companies dealing with Bitcoin/Blockchain. As Brian puts it: *"They were here from the very beginning most of them, so they are really talented people, really good engineers… it's not their full-time job to be working on the network so they have access to the core of the network, but they are also working with Bitcoin start-ups that have a lot of money"*. Today, to the best of our knowledge, this is still true for some core developers, while three of them, including Gavin Andresen, have been given independent employment at the Digital Currency Initiative at the MIT Media Lab. Here they are financed through an external fund raised by MIT.

Surrounding this core development team, there is an active community of contributors collaborating on websites such as GitHub and Reddit. In principle, any developer can influence the way in which Bitcoin technology evolves technically, since anyone can submit Bitcoin Implementation Proposals – so called BIPs. But when it comes to actually making changes to the protocol it is the Core Maintainers that have absolute power, assuming that they can agree amongst themselves. When the core developers decide to make changes to the protocol, a broader, community-wide consensus needs to follow. This is the process whereby the users of the network voluntarily upgrade to the newer version of the protocol. As the majority of users shift over, the rest will usually follow without any controversy. However, reaching consensus is not always easy, and the process can become entangled in vested interests as illustrated by the current "block-size" debate in Bitcoin. The Bitcoin blocksize debate is a dispute about the number of transactions that can be included in one block, meaning how many transactions per second the network is able to handle. Right now, the Bitcoin network can only handle around three transactions per second, which to put things in perspective is extremely little considering that VISA/Mastercard for instance handles over 2000 transactions per second on average. So, if Bitcoin is to properly scale into the mainstream public, blocksize is a bottleneck. Interestingly, the bottleneck can easily be resolved technically by making a few changes to the protocol. As Brian puts it: "*It's very, very easy to change. It's just one number in the code, it's not a technical limitation".*

According to Brian, what drives the blocksize debate is only partly a matter of technical dilemmas regarding blocksize versus network security, but mostly a matter of vested financial interests of certain groups within the community. In Brian's own words: *"There is way too much money in play, because some venture capitalists have invested a lot of money into some companies trying to fix this problem. And there is a lot of lobbying of people trying to block the problem of Bitcoin just to get some companies taking off (…) It's just competition between companies and they are lobbying against Bitcoin."* What we see here is that corporate players, through their investments, fintech accelerators, and hires, are trying to influence the pending decision by the core developers regarding blocksize. A decision that can have direct consequences for start-ups building on Bitcoin technology. If the blocksize is kept as it is, it will allow for certain start-ups to develop so-called “side chains”. Side chains are open tabs, where multiple transactions can be recorded outside the Bitcoin Blockchain, and then be re-consolidated with the Blockchain as one single transaction. Side chains allow for higher numbers of transactions without increasing the transaction cap that is built into the Bitcoin protocol. A prerequisite for the success of these start-ups strategically working on side chain technology, is that the Bitcoin blocksize remains unchanged, otherwise the core value proposition of the start-up will be greatly diminished. On the other hand, certain start-ups are in favor of increasing the blocksize because it would be an advantage for their specific business. At the time of writing this paper, the controversy over blocksize has come to a deadlock. No formal dispute settlement mechanisms have been put in place. The formal power to make changes to the protocol still lies with the Core Maintainers, who disagree on the future direction of Bitcoin. This technical dispute is bringing the growth of the Bitcoin infrastructure to a halt greatly impacting start-ups that have built their business model based on an expected scaling of Bitcoin.

Clearly, Bitcoin is not just a technical protocol, but instead a large information infrastructure shaped by the dynamically changing members of the Bitcoin community. The open nature of Bitcoin allows everyone to contribute code, and to participate in the development of start-ups building on the technology. What used to be a community grounded in cypherpunks, anarchists, and underground movements, has now become inflated by bankers, venture capitalist, and mainstream tech entrepreneurs, all trying to influence the development of the infrastructure. This is for instance done by aligning with the interests of mainstream industries and by pushing for the creation of more corporate-friendly business models. We have here shown that these synergizing activities, which aim at growing the Bitcoin infrastructure in a direction that is compatible with corporate interests, are entangled with the governance challenges in the Bitcoin community as witnessed by the blocksize debate.

Infrastructuring Bitcoin ATMs (BTMs): a labor-intensive endeavour

Shifting our focus to another site within the Bitcoin infrastructure, our empirical data shows us that the material properties of Bitcoin are embedded in the most basic and daily routines of Bitcoin entrepreneurs. We will look closer at a Danish start-up, Copencoin that specializes in setting up and operating Bitcoin ATMs (so-called BTMs) in different locations in Denmark. The company was founded by Daniel, who relocated to Denmark from his native New York. Daniel got involved with Bitcoin relatively early on, when mining was still an activity that could successfully be performed using a graphics card on a personal computer. His experience with the evolution of Bitcoin leads him to believe that the demand for Bitcoins will only grow in the future, which is why he sees himself as a bridge-builder between the abstract digital world of Bitcoin and the physical world into which the cryptocurrency is being manifested. Daniel sees his BTM machines as the embodiment of this bridge-building activity, which contributes to introducing Bitcoin to a mainstream public.

BTMs are "cash" machines, which allow users to exchange national currency for Bitcoin or vice-versa. BTMs are thus physical manifestations in the world of the material properties of the Bitcoin infrastructure. BTMs are often located in small kiosks or in bars and restaurants, precisely like regular ATMs. Establishments hosting a BTM do not necessarily know much about technology, as they mainly specialize in their own line of business such as purchasing beverages, serving drinks at a profit, and playing music. While BTM machines require a solid internet connection, setting up Internet is at best a peripheral endeavor to the hosts. Thus, prior to installing the BTM machine, Copencoin must upgrade the existing IT infrastructure of the host location. This work involves Daniel taking trips to the local electronics store in order to buy cables and routers, spending time with tools behind the counter and in the basement of the host establishment, setting up a Bitcoin payment solution, and giving adequate training to the staff about how to take Bitcoin payments. In so doing Daniel prepares the basic installed base of the BTM that connects the machine to the Bitcoin infrastructure. This work is highly practical and manual, and often missed in descriptions of work associated with Blockchain technology. Once the actual Bitcoin machine is installed, very tangible security issues arise. Here we are not talking about the security of the transactions taking place on the Bitcoin ledger, but about the physical safety of the BTM machine being left unattended in a given location. As Daniel explains it: "*The machine can be tampered with by the customers. It can be broken into by people who do not understand that the Bitcoins are actually not stored in the machine but on the Blockchain. Or sometimes the machine can be stolen…"*. Those are some very legitimate practical concerns that play an important role for Daniel's ability to sustain a viable business. Typically, the solution to this problem is to have security cameras installed that monitor the BTM machine at all times. In other words, yet another level of infrastructure needs to be added to the setup, which involves additional work.

After the basic IT infrastructure is in place, and the BTM machines are installed and monitored by security cameras, then the focus turns to attracting customers to the new location. In Daniel's own words: *"A machine is not worth much if people do not know where to find it"*. So now

Daniel's activities turn to social media and other means of making people aware of the new BTM location. In all locations where Daniel has placed a BTM, he has upgraded the location from either poor, or no wifi, or wifi demanding a password, to newer high-speed routers with social media logins, which have benefitted the online presence of the host location while simultaneously informing customers of the presence of a BTM. For the more seasoned Bitcoin traders, Daniel has listed his machines on a location website (CoinATMRadar.com) which also has an app allowing people to find BTM locations. Daniel is also a founding member and co-organizer of the Bitcoin meetups in Denmark since their inception in 2013. Daniel makes sure to host the meetups in locations that host a BTM, thus benefiting both the venue, as well as contributing to growing the base of Bitcoin users that could potentially use Copencoin's BTMs. Like with the physical activities that go into installing the BTMs, the activities promoting the locations are often overseen as important work for the Blockchain infrastructure, however they are critical for manifesting the cryptocurrency in material ways. Finally, operating BTMs also involves managing the available cash flow in the machines on an ongoing basis, as well as general repair and maintenance. At this stage, BTMs are not as sturdy as their industrial counterparts that dispense fiat currency, which results in more frequent breakdowns and a bigger need for frequent maintenance. Breakdowns can occur at any time, requiring Daniel to go to fix the problem so that the machine can be back online as quickly as possible to avoid losing transactions.

Unlike some of the start-ups referred to in the previous section, who aim at further appropriating the Bitcoin protocol for new uses, such as smart contracts or micropayments, Daniel's company is less affected by the blockchain debate, and less in need for an immediate increase in the size limit of the blocks. His business is not about further extending the use of Blockchain technology to other domains, but rather making the basic core functionalities of Bitcoin available to users. If his dream scenario of large scale market adoption of Bitcoin materializes however, then transaction confirmation on his BTMs will become jeopardized due to blocksize constraints. As it stands now, Daniel does not do anything to actively try to influence the blocksize debate, and is instead focused on operational activities that grow his BTM company.

These empirical observations demonstrate that the Bitcoin infrastructure extends beyond the digital protocol. For the Bitcoin infrastructure to exist in the real world, it needs to be embedded within the daily physical activities of people like Daniel, who work at making the affordances of the technology available to potential users. Doing so is a very practical and physical endeavor, including time spent on enabling the infrastructure at the host of the BTM through setting up

Internet, communicating to potential customer about the location, and in repairing the machines when they break down.

Socio-technical decisions about BTM location

The material properties of the Blockchain infrastructure extend beyond operation and maintenance to the choices made by Copencoin related to location, hosts, financial limits, compliance and so called KYC/AML (Know your customer, Anti-money laundering) requirements for BTMs. Daniel explains: *"Bitcoin and Blockchain technology is indeed a new and disruptive technology, but it does not exist in a vacuum. We are still as a company subject to the same laws, rules, regulations and expectations that all normal business operations must face."* At its core, the purpose of Copencoin's business is to create connections between the digital world of the Bitcoin infrastructure and the physical material world. It is about making the payment mechanism afforded by Bitcoin technology available to a mainstream public, who can buy or sell bitcoins for cash in an easy and convenient way. In order to achieve this, considerations about identifying the right hosts and supporting new and existing users of BTM machines matters. Since the Bitcoin infrastructure supports anonymous transactions, finding ways to avoid the "wrong" and potentially illegal use of the Bitcoin infrastructure is a critical consideration. Daniel is very much aware of this, and explains that when he began his BTM adventure, he sought legal counsel and approached financial regulatory bodies for approval in writing. *"I was very open about my intentions and activities from the beginning. I received guidance and confirmed permissions for operation and have followed the guidelines I received ever since".* Despite of this, banks are inherently suspicious of Bitcoin start-ups in part due to previous scandals that have connected Bitcoin to criminal networks, money laundering, and drug trafficking. It is in the very nature of the Bitcoin infrastructure that all the transactions are public, but that the identity of the users is unknown unless registered by operators (BTMs or online exchanges). This makes it very difficult for banks to do proper AML/KYC as mandated by law, and creates a general atmosphere of distrust towards start-ups working with Bitcoin. This is corroborated by our informant Søren, who is an advisor to the financial sector in Denmark on matters related to compliance in the domain of Bitcoin and Blockchain. He states: *"(if you work with Bitcoin) you cannot get a bank account if you do not have any compliance tools. Because the banks do not send money out into a big Bitcoin hole, or receive money from anonymous Bitcoin addresses. It is not going to happen. You might think this is good or bad, but that does not matter one bit."* This lack of trust affects the ways in which BTM companies need to navigate. In Daniel's case, the main concern is making sure that the company's compliance policies are up to date and aligned with current and changing requirements

In Copenhagen, one of the potential locations for a BTM machine is Christiania, a central part of the city. The Freetown Christiania, is a self-proclaimed autonomous neighborhood in Copenhagen founded in the 1970s on the grounds of old military barracks and parts of the city ramparts of Copenhagen. Christiania has a vibrant art scene, interesting architecture, but is also surrounded by controversy due to the fact that the neighborhood hosts a large part of Denmark's illegal cannabis trade. Attracting one million visitors a year, Christiania might be an excellent place to set up a BTM machine. There are many people with cash in hand, and a potential need for the services provided by a BTM. However, setting up a BTM in Christiania, although perfectly legal, might also amount to encouraging illicit actions, which will not reflect positively on Copencoin as a company. So far, Daniel has steered clear of Christiania as a potential site for his BTM machines, despite of the location being a potentially good business opportunity. The opportunity is in his mind not worth the risk that government, banks, and police might associate his company with illicit drug trading. In fact, Daniel sees this as a blatant double standard: banks can have their most lucrative ATMs located right next to Christiania, but if a Bitcoin company moves in, then it would be held to a higher standard than regular banks. Daniel expresses his choice to steer clear of Christiania in these words: *"Copencoin prefers to take the high road, doing our best not to tarnish our image"*

When installing a BTM machine, operators can choose to switch on a functionality on the machine that makes it mandatory to validate users' identity through an ID scan before each transaction. By so doing, Copencoin would ensure that only registered users can purchase or sell Bitcoins on the machines and that potential illicit actions are deterred. Turning on the identity functionality is mandatory in Sweden, but so far not so in Denmark unless a transaction exceeds the equivalent of 1000 Euro. However, adding the identity procedure adds several steps to the transaction, maybe to the point where users no longer consider it convenient. Particularly since the actual feeding and dispensing of bills on BTMs takes longer than on regular ATMs. Additionally, many Bitcoin users would strongly object to being registered on grounds of principles, regardless if what they are doing is completely legitimate. It would in their perspective run completely counter to the libertarian idea on which Bitcoin was founded. Therefore, from Daniel's perspective, it makes more sense to comply with the local legislation in Denmark, and keep the identity functionality on the ATM machines reserved for transactions exceeding the legal threshold. In his own words: *"We choose to be like Johnny Cash and walk the line by, on the one hand, being compliant with each jurisdiction, and also respecting* *customer privacy to a high degree. If we weren't, we would be promptly shut down by authorities".*

These empirical observations have shown us that the material properties of the Blockchain infrastructure are expressed in the strategic business choices made by Blockchain start-ups. Working with BTM machines, Daniel is obliged to deal with the constraints and affordances stipulated by this choice. Working with Bitcoin is far from a purely digital technological exercise. It is an exercise that has strong material properties and that enacts physical as well as ethnical constraints. Getting the right kind of customers that refrain from illicit activities, is not just an ethical consideration. It is also grounded in the AML/KYC requirement for companies operating BTM machines. Daniel must make balanced decisions without compromising his integrity about location, user base and impressions of his machines, while insuring absolute compliance with legal requirements.

Alignment work: the physicality of Bitcoin hardware

The two-way BTMs that Daniel operates require a constant balance between Danish currency and Bitcoins. This balance is prone to get skewed as buying Bitcoins is more in demand with users than selling Bitcoins. So, over time the machines need to get replenished with Bitcoins, and the cash needs to be removed and put in the bank. As the company grows, so does the size and volume of these transactions, making it important for Daniel to take risk factors into account, such as the fluctuating price of Bitcoins available for purchase on online exchanges. In order to mitigate this risk, Daniel has re-designed his company's business model to include Bitcoin mining. Implementing this plan involves physically buying large containers of bitcoin mining equipment in the Middle East, shipping the containers half way across the globe to Norway, where Daniel has set up a new start-up, connecting the equipment to a hydroelectric power plant, and transferring the created Bitcoins to his already existing BTM hardware infrastructure in Denmark. Specifically, this means that Daniel will invest the cash collected from the BTM machines into purchasing mining hardware, which will be running day and night solving the cryptographic puzzles that are required to propagate new Bitcoin blocks to the network, and that are a prerequisite for triggering block rewards. The block rewards collected will be freshly created Bitcoins that can then be transferred to the Bitcoin addresses of the specific BTM machines. This business model will give the company the economic benefit of not having to buy Bitcoins at a given daily spot price in order to replenish its BTMs, thus reducing the financial risk of sourcing the input for the BTMs. As Daniel puts it: *"At the end of the day we are going to need a guaranteed supply coming in faster so that we can meet the rush. (...) if you can own the* *whole process, you control it. There is less that can go wrong."* For a mining operation to be viable, scale is important. This means that Daniel had to invest in a substantial number of mining chips. Since the electricity in Norway is very cheap, Daniel and his new partner decided that it would make most sense to get slightly used equipment at a cheap price. This equipment would still be able to generate a profit when the energy cost is kept low. Through common acquaintances Daniel and his partner located second-hand mining equipment that was up for sale. The mining containers are shipping containers that have been retrofitted with powerful ASIC (Application Specific Integrated Circuits) mining rigs from floor to ceiling. The containers were located in the Middle East, and needed to be shipped to Norway. Daniel explains: *"The mining rigs are placed inside mining containers. We got some containers second hand. We bought them from the Middle East, where they were not of big use. The electricity is very cheap over there, but the chips would heat up like crazy in the hot desert weather. I guess you can't beat physics! So, we bought them cheap."*

The material properties of the Bitcoin infrastructure are far from digital only – they include physical containers and considerations about heat and electricity. The Bitcoin infrastructure extends the digital protocol through Bitcoin mining, which is vital to validating the transactions taking place on the Bitcoin network and which simultaneously creates new Bitcoins. This process is very much subject to the basic laws of physics. The mining chips might be the most performant on the market, but implemented in the wrong physical environment they become completely useless, as illustrated by the desert heat in the Arabian Peninsula. Also, the mining equipment is mobile, transportable, and subject to the same pathways as any other tradable physical good or commodity. Its physical embodiment in an actual shipping container emphasizes this materiality. The equipment is loaded, shipped, handled, subjected to custom procedures and duties as were it any other physical object. Handling this materiality requires real-world work, be it negotiation skills, trust between parties, time constraints, credit terms, and so on. Daniel's work in trying to solve his cash flow and sourcing issue is much more a material physical endeavor than an abstract digital one. Once the equipment arrives in Norway this physical work continues: *"We need to get a transformer so that we can turn them (the mining containers) all on and connect them to the Hydroelectric dam, and then we get a daily Bitcoin production. We will get our investment back by the third month. Three and a half months in theory if we get them all running. So now we are going to max out the power of that dam. We will literally be consuming everything that dam produces. And then after that we will have to buy it from the grid.".* When asked about what will happen if their plan to scale up production materializes, Daniel interrupts: "*then we have to buy a dam!"*

As during transportation, the Bitcoin mining equipment that Daniel bought cannot escape its material nature during installation and operation. It needs to be manually connected to the electrical infrastructure that will be powering the equipment, and it is subjected to the physical limitations of the electricity infrastructure. The equipment will only be able to produce as many Bitcoins as the electrical infrastructure allows. In so doing the electricity from the Norwegian dam will be channeled into running the mining equipment at the detriment of alternative uses. This will have a physical effect not just on Daniel's mining operation but also on the other activities taking place in that geographic location in Norway. Households for instance might have less access to electricity, and shortages might occur. Any subsequent decision to scale the Bitcoin mining operation will mean physically acquiring a whole dam, or having to rethink the business model so that it can support the added electricity cost incurred when connecting the equipment to the national electrical grid (e.g. replacing the chips with the newest on the market). In order to address his cash flow and sourcing problem, Daniel will have to make material decisions based on very tangible physical constraints

Discussion

In our empirical material, we have seen that infrastructuring activities in the Blockchain infrastructure include installing cables and Wi-Fi, buying and shipping mining containers, as well as pursuing strategic business opportunities through lobbying. All these diverse activities make the resources and services afforded by the Blockchain protocol available in various ways while continuously extending and transforming the information infrastructure both digitally and materially. What characterizes the particular subset of infrastructuring activities that we have studied, is that they are carried out in a purposeful self-initiated fashion with the primary objective of sustaining and potentially growing the initiator's stake in the emerging infrastructure, be it measured in terms of revenue, influence, or control. This can be seen in Daniel's actions when attempting to manage the economic challenges of running 2-way BTMs that require ongoing replenishment with both Bitcoins and fiat currency. Handling the cash flow in the machines comes with a financial risk, since planning for their replenishment requires buying Bitcoins on online exchanges at fluctuating daily prices, which might tear into the profits made by the machines. In order to address this challenge, Daniel engages with his economic constraint through entrepreneurial actions. By integrating his business model backwards into the supply chain, i.e. purchasing mining containers in the Middle East, shipping them to Norway, and connecting them to a dam, Daniel is leveraging the enabling properties of the technology, which allows for self-initiated material extensions of the infrastructure by anyone able to do so.

He is, in other words, circumventing his existing supply chain by expanding his business model to include Bitcoin mining. This entrepreneurial endeavor, involving setting up a new company with his Norwegian partner, as well as all the infrastructuring work described in the results section, is initiated for the purpose of solving an emergent challenge related to cash flow and financial risk mitigation. It is a company specific business concern that motivates the actions, rather than an overall concern for the development of the Blockchain information infrastructure. The primary driver of entrepreneurial activities in Blockchain is not directly to develop the emerging information infrastructure, but instead based upon economic interests. These economic interests are manifestations of the built-in economic rationale, which is encapsulated within the Bitcoin protocol. It is this economic rationale that incentivizes the entrepreneurial actions, which keep the blockchain infrastructure afloat. The protocol features an encoded model for how to earn money based upon mining activities, as well as derived incentives to capitalize on the extension of the protocol into the physical world. The explicitly encoded and transparent rules embedded in the design of the protocol is what creates the cohesiveness of the infrastructure. Development and consolidation of the blockchain infrastructure is a side-effect of the economic rationale inherent to the protocol, which incentivizes growing one's own business. The economic rationale is not directly pertinent in studies of e-science infrastructures [29], and less in focus in organizational studies of infrastructure [24], since the cohesiveness in these cases are based upon inter-organizational rationality [36], or the interest in finding ways to share data across diverse organizations [17]. As Bitcoin mining and Bitcoin dispensing through BTMs begins to take place through an integrated infrastructure, economic efficiencies will be created for the operators adopting this business model. Interestingly however, is that what is initiated as a purely economic strategy also creates enablers for further embedding [31] the Blockchain information infrastructure into mainstream financial infrastructures. One could indeed argue that by implementing an integrated business model, Daniel also opens up for the opportunity of leveraging the "fresh" nature of the Bitcoins in his BTMs, and the "green" source of energy used to mine them. This could be quite relevant when further developing the company's compliance and corporate responsibility policies, which would ensure a convergence with the institutions of the mainstream financial infrastructure, while simultaneously consolidating the blockchain infrastructure.

Research on cyberinfrastructures shows that agency is given to a *developer*, whose primary task is to technically design the emerging information infrastructure, while taking into account a range of considerations such as temporality [27], scale [28], and control [37]. Because of the difference between technically design-driven interests and business-driven interests, the actors shaping the blockchain infrastructures are not developers in the conventional sense, but rather entrepreneurs, who also do development activities that contribute to the emerging infrastructure. Thus, we argue that the infrastructuring activities shaping the Blockchain infrastructure are *entrepreneurial actions*. In other words, we view the process of infrastructuring in Blockchain as inherently entangled with the pursuit of entrepreneurial activities driven by heterogeneous individual concerns and goals. While these individual concerns and goals become manifested in specific start-ups, reflecting the demands of various user segments, our concept of entrepreneurial actions does not as such explicitly look at the specifics of user appropriation of various protocol extensions [24]. Rather it keeps a focus on the strategic motives behind specific infrastructuring activities. Because of this entanglement between infrastructuring and entrepreneurial actions, it is therefore impossible for us to, for instance, separate Daniel the entrepreneur from Daniel the infrastructuring agent. He is both at once.

Our empirical data has shown that the emerging Blockchain information infrastructure is embedded, or *sunk into*, other infrastructures, networks, processes and relationship practices [31]. This embeddedness is both the result of the *entrepreneurial actions* taking place when integrating the blockchain infrastructure with the material world, as well as a resource for the ongoing infrastructuring process [3]. Embeddedness into multiple infrastructures shapes how the installed base [7] of the emerging Blockchain information infrastructure grows, and ultimately takes on its own inertia [31]. As this happens, technological, economic, legal and governance considerations arise and present themselves as affordances of the emerging installed base. These affordances can be seen as either enablers or constraints for infrastructural development. The entrepreneurial activities contribute to sustaining and growing the Blockchain information infrastructure dynamically wrestling with the enablers and constraints afforded by the installed base.

We introduce *circumventing* and *engaging*, as core components of the entrepreneurial actions taking place in the Blockchain information infrastructure. These concepts offer new perspective on the process of infrastructure creation, namely a perspective rooted in purpose, seen from the perspective of the people who are creating the infrastructure. In other words, the “why” of infrastructure. This is an extension of the current literature on information infrastructures that has thoroughly examined the “when” of infrastructure [31], and the “how” of infrastructure [3] [33]. Circumventing and engaging are complementary to synergizing and its sub-components of leveraging and aligning [3]. Synergizing looks at the processes that *“entail the incremental alignment and realignment of people, processes and tools”*, while not looking into the characteristics of concrete synergies being made. Synergizing is all about process, not typologies or drivers. *Circumventing* and *engaging* are concepts that are dynamically connected with the enablers and constraints afforded by the installed base of the Blockchain information infrastructure. Circumventing and engaging provides a lens to examine the characteristics of the activities driving the Blockchain information infrastructure forward. We argue that circumventing and engaging are characteristics of the infrastructuring activities taking place in Blockchain, and important drivers for agency. So rather than the infrastructure being driven by tension typologies [28], the Blockchain infrastructure is driven by the activities of circumventing and engaging.

As Bitcoin evolved from an underground movement, multiple new communities joined the emerging Blockchain infrastructure, thus cypherpunks, anarchists, bankers, and venture capitalists all wrestle with the installed base of the blockchain information infrastructure through entrepreneurial actions. The malleability of the installed base has allowed for the growing communities to influence the governance process. This is done through *engaging* activities ranging from submitting implementation proposals (BIPs) to contributing code on GitHub, and hiring core developers to work on start-ups with vested interests. These engaging activities are largely made possible by the governance enablers of the installed base at this early stage of infrastructural development: an evolving governance process, and an open participation by all community members. While these enablers in principle incite participation and infrastructural growth, engaging with them can also create constraints for oneself and others, as illustrated by the deadlock on the issue of blocksize. It is the very open nature of Bitcoin governance that, through engaging activities, by heterogeneous groups has caused the current blocksize constraint. This constraint is in turn either engaged with through lobbying and investing as we saw in the results section, or worked around as witnessed by the emergence of alterative Blockchains (sidechains and altchains, such as Etherium, Rootstock or Counterparty). Through this optic, this emergence of alternative Blockchains is the result of *circumventing activities* by various groups and individuals. The deadlock on blocksize seems to drag on, and the interests of certain entrepreneurs and companies are not met in the current status-quo, so they set out to leverage the very open nature of the Bitcoin installed base with the purpose of working around the blocksize constraint. Open-endedness of infrastructures can be counter-productive, and can lead to reverse synergy [17]. In the Blockchain information infrastructure, the open-endedness is productively supporting propagation beyond the Bitcoin Blockchain, since it consequently opens the infrastructure up for larger audiences, and in so doing unlocks new enablers for others to engage with, e.g. smart contracts and other industry applications. Enablers, constraints, circumventing, and engaging are thus entangled in a dynamic and recursive way. *Circumventing* and *engaging* activities are directed entrepreneurial actions aiming at dealing with the technological, economic, legal or governance affordances expressed by the installed base of the Blockchain information infrastructure. While *circumventing* activities specifically leverage the resources of the installed base with the purpose of working around constraints, *engaging* activities leverage these same resources in order to push for the minimizing and/or removal of the imposed constraints Often circumventing and engaging activities are carried out simultaneously. The two concepts can be seen as a dualism, rather than a duality, in the sense that one does not exclude the other.

Conclusion

In our investigation of the infrastructuring activities that contribute to developing and expanding the Blockchain information infrastructure, we uncovered three main characteristics. Firstly, we found that the Blockchain infrastructure is shaped by *entrepreneurial actions,* which are purposeful and self-initiated, aiming at sustaining or increasing one's own stake in the emerging information infrastructure. Secondly, we saw how these entrepreneurial actions wrestle against the emerging enablers and constraints afforded by the installed base of the infrastructure as it develops and gains its own inertia. These enablers and constraints can be of a technological, economic, governance and legal nature. Finally, our investigation showed that the purposefulness of the entrepreneurial actions shaping and growing the Blockchain information infrastructure can be captured by the concepts of *engaging* and *circumventing* activities. Engaging and circumventing are two types of entrepreneurial actions that leverage the affordances of the installed base of the Blockchain information infrastructure, and either aim at minimizing or eliminating afforded constraints, or at working around these constraints in creative ways. Viewing the evolution of the Blockchain information infrastructure through the lens of engaging and circumventing activities supplements current approaches to infrastructuring. It does so by emphasizing a sense of purpose from the perspective of the heterogeneous groups of infrastructuring agents pushing the Blockchain infrastructure forward: the *why* of infrastructure. The growth of the Blockchain information infrastructure will be very interesting to keep updated on, particularly since its expansion into other domains is still only at a nascent state. While we have seen how the infrastructure has grown beyond monetary transactions, through the involvement of new member communities, and through entrepreneurial actions that circumvent perceived deadlocks or constraints, it will be interesting for future research to keep an eye on how the infrastructure further propagates into new domains.

References

1. Antonopoulos, A. M. (2014). Mastering Bitcoin. O’Reilly Media, Inc.
2. Bansler, J., and Havn, E. (2003) Technology-use mediation: Making sense of electronic communication in an organizational context. In Proceedings of the International ACM SIGGROUP Conference on Supporting Group Work (GROUP ’03) (Sanibel Island, Florida, November 9-12, 2003), ACM Press, New York, NY, 2003, 135-143.
3. Bietz, M. J., Baumer, E. P. S., & Lee, C. P. (2010). Synergizing in cyberinfrastructure development. *Computer Supported Cooperative Work* (JCSCW)
4. Bjørn, P. and Østerlund, C. (2014). Sociomaterial-Design: Bounding technologies in practice. Springer, 2014.
5. Blomberg J. & Karasti H. (2013). Reflections on 25 Years of Ethnography in CSCW. *Computer Supported Cooperative Work* (CSCW) August 2013, Volume 22, Issue 4, pp 373-423
6. Bonneau, J. et.al. (2015). SoK: Research Perspectives and Challenges for Bitcoin and Cryptocurrencies. 2015 IEEE Symposium on Security and Privacy
7. Bowker, J and Star, S. L. (1999). Sorting things out – Classifications and its consequences. MIT Press
8. Bowker, G. C. (1994). Science on the run: Information management and industrial geophysics at Schlumberger, 1920–1940. Cambridge: The MIT
9. Damsgaard, J., and Lyytinen, K. (2001). The role of intermediating institutions in the diffusion of electronic data interchange (EDI): How industry associations intervened in Denmark, Finland, and Hong Kong.

The Information Society 17, (2001), 195-201.

10. Edwards, P. N., Bowker, G. C., Jackson, S. J., & Williams, R. (2009). Introduction: an agenda for infrastructure studies. Special Issue on e-Infrastructure of the *Journal of the Association for Information Systems*, 10(5), 364–374
11. Geiger, R. S. and Ribes, David. (2011). Trace Ethnography: Following Coordination through Documentary Practices. Proceedings of the 44th Hawaii International Conference on System Sciences.
12. Gervais, A. (2014). Is Bitcoin a Decentralized Currency? *IEEE Security and Privacy Magazine* 12(3):54-60 · May 2014
13. Hanseth, Ole and Aanestad, Margunn. (2003). Design as bootstrapping. On the evolution of ICT networks in health care. Methods of information in medicine 42 (4), 384-391

14. Hearn, M. (2015). The resolution of the Bitcoin experiment. Post on Medium.com on January 14th 2015.
15. Karasti, H., Baker, K. S., & Millerand, F. (2010). Infrastructure time: long-term matters in collaborative development. *Computer Supported Cooperative Work* (JCSCW)
16. Kazan, E. et.al. (2015). Value Creation in Cryptocurrency Networks: Towards a Taxonomy of Digital Business Models for Bitcoin Companies. PACIS 2015 Proceedings. Pacific Asia Conference on Information Systems.
17. Langhoff, Tue. O., Amstrup, Mikkel. H., Mørck, Peter. and Bjørn, Pernille. (2016). Infrastructures for healthcare: From synergy to reverse synergy. *Health Informatics Journal*.
18. Lee, C. P., Dourish, P., & Mark, G. (2009). The human infrastructure of cyberinfrastructure. Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work (pp. 483 – 492). New York: ACM Press
19. Marcus, George E. (1995). Ethnography in/of the World System: The Emergence of Multi-Sited Ethnography. *Annual Review of Athropology, Vol. 24, 95-117*
20. Mauer, B. et.al. (2013). "When perhaps the real problem is money itself"!: the practical materiality of Bitcoin. *Social Semiotics,* 2013
21. Matthiesen, S & Bjørn, P. (2015). Why Replacing Legacy Systems is So Hard in Global Software Development: An Information Infrastructure Perspective. CSCW 2015, March 14-18, 2015, Vancouver, BC, Canada
22. Maxwell, G. (2015). Bringing New Elements to Bitcoin with Sidechains. SF Bitcoin Devs Meetup, June 8, 2015
23. Nakamoto, Satoshi. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. Retreived form bitcoin.org (5 February 2016)
24. Pipek, V & Wulf, V. (2009). Infrastructuring: towards and integrated prespective on the design and use of information technology. *Journal of the association of information systems*.Volume 10, issue 5, May 2009, 306 – 332.
25. Randall, D. P., Diamant, E. I., Lee, C. P. (2015), Creating Sustainable Cyberinfrastructures, CHI 2015, Crossings, Seoul, Korea
26. Ribes, David. (2014). The Kernel of a Research Institution. CSCW'14 February 15-19 2014, Baltimore, MD, USA
27. Ribes, D., & Finholt, T. A. (2009). The long now of infrastructure: Articulating tensions in development. In P. Edwards, G. C. Bowker, S. Jackson, & R. Williams (Eds.), Special Issue on eInfrastructure in the *Journal of the Association for Information Systems*, 10 (5), 375–398

28. Ribes, D., & Finholt, T. A. (2007). Tensions across the scales: Planning infrastructure for the long- term. Proceedings of the 2007 international ACM conference on Supporting group work, Sanibel Island, Florida, USA (pp. 229 – 238). New York: ACM Press
29. Ribes, D & Lee, C. (2010). Sociotechnical Studies of Cyberinfrastructure and e-Research: Current Themes and Future Trajectories. *Computer Supported Cooperative Work* (2010) 19:231–244
30. Ribes, D. (2014). Ethnography of scaling, or, how to fit a national research infrastructure in the room. CSCW '14 Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing. 158-170
31. Star, S. L., & Ruhleder, K. (1996). Steps toward an ecology of infrastructure: design and access for large information systems. *Information Systems Research*, 7 (1), 111–134
32. Star, S. L. (1999). The ethnography of infrastructure. *American Behavioral Scientist*, 43, 377–3
33. Star, S. L., & Bowker, G. C. (2002). How to infrastructure. In L. A. Lievrouw & S. Livingstone (Eds.), The Handbook of New Media (pp. 151–162). London: SAGE Publications.
34. Taylor, M. B. (2013). Bitcoin and The Age of Bespoke Silicon CASES '13: Proceedings of the 2013 International Conference on Compilers, Architectures and Synthesis for Embedded Systems
35. Tilson, D., Lyytinen, K., Sørensen, C. (2010). Digital Infrastructures: The Missing IS Research Agenda. Research Commentary. Information Systems Research, Vol. 21, No. 4, December 2010, pp. 748-759
36. Wilson, S; Berente, N; Howison, J; Butler, B (2014). Beyond the organizational 'container', *Information and Organization*, Volume 24 Issue 4, October 2014, Pages 250-269
37. Zimmerman A. & Finholt, T. (2007). Growing an Infrastructure: The Role of Gateway Organizations in Cultivating New Communities of Users. GROUP'07, November 4 – 7, 2007, Sanibel Island, Florida, USA

Zohar, A. (2015). Bitcoin under the Hood. *Communications of the ACM*, September 2015, Vol 58, No 9, 104-113

Blockchain Assemblages: *Whiteboxing* Technology and Transforming Imaginaries

Karim Jabbar
University of Copenhagen
Copenhagen, Denmark
karim@di.ku.dk

Pernille Bjørn
University of Copenhagen
Copenhagen, Denmark
pernille.bjorn@di.ku.dk

This paper was presented at the 2019 CHI Conference on Human Factors in Computing Systems in Glasgow, United Kingdom. It is published in the conference proceedings and available in the ACM Digital Library. DOI: http://dx.doi.org/10.1145/3290605.3300496

Abstract

In this paper we unpack empirical data from two domains within the Blockchain information infrastructure: The cryptocurrency trading domain, and the energy domain. Through these accounts we introduce the relational concepts of *Blockchain Assemblages* and *Whiteboxing*. Blockchain assemblages comprise configurations of digital and analogue artefacts that are entangled with imaginaries about the current and future state of the Blockchain information infrastructure. Rather than being a black box, Blockchain assemblages alternate between being dynamic and stable entities. We propose Whiteboxing as the sociomaterial process which drives blockchain assemblages in their dynamic state to be (re)configured, while related artefacts and imaginaries are simultaneously transformed, creating dynamic representations. Whiteboxing is triggered during disconfirming events when representations are discovered as problematic. Complementing existing historical accounts demonstrating technologies in the making, the contribution of this paper, proposes whiteboxing as an analytical concept which allows us to unpack how contemporary technologies are created through entrepreneurial activities.

Introduction

Blockchain is an emerging and rapidly growing information infrastructure [52] [21]. This infrastructure is evolving through the infrastructuring activities [38] of heterogeneous entrepreneurial actors who work at maintaining, extending and propagating the infrastructure. Infrastructuring in Blockchain is currently taking place as protocol extensions [21], which allow users to engage with the infrastructural kernel of cryptocurrencies such as Bitcoin. Point of Sales hardware (PoS), Bitcoin ATMs (BTMs), and online exchanges are examples of the gateway services that work at making the affordances of the Bitcoin kernel available to users [41]. Infrastructuring in Blockchain is also taking place as the technology permeates into already established information infrastructures through a process of infrastructural grind [22]. What started as a contained and purely digital protocol has now propagated to become a widespread technology that is carving out new markets (e.g. the cryptocurrency trading domain), or attempting to transform existing markets (e.g. the energy domain). Although Blockchain is often referred to as a monolithic entity, previous work in HCI has begun demonstrating the complexity of this multifaceted infrastructure [27] [45] [39] [21] [22.] While Blockchain can formally only be dated back less than a decade [36], it is clear that certain Blockchain sub-domains are more evolved and consolidated than others. Cryptocurrency trading was one of the first activities associated with the technology, and an infrastructure supporting this practice has been emerging for a number of years already. On the other hand, Blockchain in the Maritime [23] or Energy sectors [4], for instance, are much newer realms of application, and can therefore be considered at the very early stages of Blockchain infrastructuring.

Generally in the Blockchain information infrastructure, and particularly in the areas related to the permeation and appropriation of Blockchain into established domains, it is evident that there is a wholesale of imaginaries, claims, visons, and story-telling and yet very few real-life implementations that have gone beyond Proof-of-Concept. These stories, imaginaries, and associated artefacts are often evangelized by various entrepreneurial actors [21] who aim at further embedding [46] [48] the Blockchain information infrastructure into the fabric of pre-existing relational structures [47]. The facts, as well as the state of the projects that are being marketed through these entrepreneurial agents, are very often difficult to assess properly. How do we unpack a cacophony of narratives, stories, prototypes, whitepapers and blog posts making specific claims about ongoing Blockchain projects in new and pre-existing domains? This is particularly relevant because we have observed that these narratives and stories tend to transform as the entrepreneurial agents evangelizing them get further along in their infrastructuring process. Taking a point of departure in the well-established notion that information infrastructures tend to only become visible upon breakdown [47], we will in this paper examine points of tension in the early stages of development of the Blockchain information infrastructure. More specifically, we will try to use these tensions and breakdowns to further unpack how these are tackled by entrepreneurial actors engaging in infrastructuring activities, which involve diverse digital and analogue artefacts, as well as evolving stories and narratives about their contribution to the overall development of blockchain technology. Our research question is as follows:

How are breakdowns at the early stages of Blockchain infrastructuring resolved?

In this paper we unpack empirical data collected over the past 36 months in multiple venues. We will show that at the early stages of Blockchain infrastructuring, it is impossible to distinguish between imaginaries pertaining to the infrastructure, and the infrastructure itself. They are socio-materially entangled. Similarly, the various artefacts and imaginaries that entrepreneurial actors engage with in their infrastructuring activities can be seen as sociomaterially entangled assemblages, which we will label Blockchain assemblages. At the early stages of infrastructural development, it is these Blockchain assemblages that tend to break down when they are exposed to disconfirming events, which question the nature of their representation. We found that these breakdowns in Blockchain assemblages are resolved through particular activities. We call these activities whiteboxing activities, as they are enacted by the heterogeneous entrepreneurial actors that have configured the assemblage in its current state. We complement current research on infrastructures within HCI by unpacking the early stage of infrastructuring technology in-the-making, long before they have become stable entities – long before technology turns into a black box [29] [6].
Our paper is structured as follows: First, we present the related literature that will help us build our argument, Second, we go through the method employed. Third, we unpack our empirical findings in two accounts each representing a particular venue in Blockchain, namely the cryptocurrency trading domain, and the energy domain. Fourth, we propose the concepts of blockchain assemblages and whiteboxing activities and finally, we conclude.

Related literature

Blockchain has in the HCI literature been conceptualized as an emerging information infrastructure [21], which is yet in the making. Similarly to other large-scale infrastructures [52] [51], the Blockchain information infrastructure is sustained and expanded by the entrepreneurial

actions [21] of heterogeneous actors, for instance gateway services. Through their infrastructuring [38] and synergizing activities [5], these actors act as protocol extensions to the infrastructural kernel [41] and thus shape the evolution of the information infrastructure.
Viewing the evolution of Blockchain technology through this lens shifts focus away from infrastructure as a backdrop against which operations take place, to an approach emphasizing infrastructures as evolving socio-technical relationships [47] that are constantly in the process of being embedded, in pre-existing and overlapping structures and relational arrangements that can be technological, interpersonal, organizational, or communitarian [48] [46].

As the Blockchain information infrastructure evolves, its installed base will gain inertia over time as its kernel [41] consolidates, and its constituting socio-technical arrangements crystalize into standards and conventions of practice. Through this process, the complexities of the infrastructure will become opaque and the infrastructure itself will only become visible to the users upon breakdown [47], and otherwise remain black-boxed [29] [6] in everyday use.
Currently, the Blockchain information infrastructure is still in the process of achieving embeddedness [46], and slowly developing blackbox characteristics [29]. Latour frames Blackboxing as *"the way scientific and technical work is made invisible by its own success. When a machine runs efficiently, when a matter of fact is settled, one need focus only on its inputs and outputs and not on its internal complexity. Thus, paradoxically, the more science and technology succeed, the more opaque and obscure they become"* (Latour, 1999, p. 304).

In the case of the Blockchain information infrastructure, not all sub-domains are equally evolved. While Bitcoin mining for example is a basic functioning of the protocol, and a domain that has emerged into a proper, industrial-scale operation, other sub-domains are still at the very early stage of infrastructural development. This could for instance be the case of Blockchain applications in industry domains (e.g. in maritime or energy). At its current stage of evolution, *cryptocurrency mining* (e.g. Bitcoin) is slowly gathering Blackbox characteristics, whereby the socio-technical practice of implementing a proof-of-work algorithm is increasingly standardized into an input-output process supported by complex assemblages of artefacts [34]. These assemblages, which can be seen as ways of ordering socio-technical entities into a state of symbiotic co-functioning [34], comprise heterogeneous multiplicities of code, hardware, practices, strategies and motivations. In other words we can say that bitcoin mining is a sociomaterial [3] [8] working arrangement that includes Application-Specific Integrated Circuits, Mining “rigs”, collaborative mining practices (mining pools), geographical clustering decisions, and specific business strategies. At the core of this process are large industry-scale mining farms that input an ever-increasing amount of electricity, and output a stable supply of new bitcoins and contribute to maintaining a secure network. In retrospect, looking back at the evolution of bitcoin mining, this blackboxed amalgamation of sociomaterial assemblages [34] can be opened up [29] and viewed as a social construction of technology [6] through which the assemblages of artefacts facilitating bitcoin mining have been continuously reshaped and redesigned by the various social groups involved in the practice [6]. Such an analysis would highlight the trajectory of mining equipment from relying on standard components in a computer (CPU and GPU) to the development of highly specialized integrated circuits created by rapidly professionalizing hobbyists [50] who managed to creatively fund, design, develop, and bring to market hardware components that were vastly more performant than what was available on the market. Each new round of technological advancement got inscribed [29] on top of the previous ones, and got combined with iterative improvements of the mining "business model", resulting in increased standardization and blackboxing.

The analytical process of opening up the Blackbox as proposed by the social construction of technology approach [6] has been examined successfully as an ex-post exercise. It allows to unpack with great details the historical sociomaterial complexities that have led to the current blackboxed state of an artefact assemblage. However, the approach has shortcomings when trying to understand the future trajectory of technology domains that are still at the early stages of infrastructural development. In such a context, Blackboxing would indeed tell us little about how the various complex practices and evolving artefacts that make up the Blockchain information infrastructure will shape in the future, particularly as the technology gets diffused beyond its first domain of application (cryptocurrency) and permeates [22] into other domains such as shipping and energy. This permeation of Blockchain into established industries is currently on its way, and the possibilities hypothetically seem broad. While Bitcoin and other cryptocurrencies are focused on the transaction of units of currency, Blockchains can indeed have many other uses (in principle), in the sense that virtually any form of relevant transaction data can be recorded in a shared ledger, such as for instance chain of custody records, identity documents, digital certificates [19], etc. Because of this, existing industries have started to look into relevant uses of Blockchain technology, resulting in a process of infrastructural grind [22] whereby blockchain technology is permeating into established domains at differential velocity [22]. Through this process of infrastructural grind, which is enacted differently at various point of intersection between infrastructures, standardization takes place resulting in increased consensus about technology interpretation, and flexibility of use and openness to further changes [20]. While Infrastructural grind is taking place between blockchain and various established domains, it is often still confined to technical proofs-of-concept. Currently the challenge in

Blockchain domains that are at early stages of infrastructuring is how to move beyond these proofs-of-concept, which could be interpreted as imaginaries or design fictions [37] [7] [15]. In the context of blockchain domains that are at earlier stages of infrastructural development, an ex-ante approach to view the evolutionary trajectory of the technology is to unpack the imaginaries [37] [27] that shape the future visions of what the technology will become. Imaginaries about potential future use-cases for Blockchain technology, packaged as white papers, websites, public talks, slide deck, elevator pitches, and blog posts, make up a large part of the available data on Blockchain. These imaginaries can be seen as a medium for stakeholders to negotiate standards, practices and user bases of the infrastructure, which ultimately results in *crystallization* [37] – an agreement between negotiating parties. Kow and Lustig [27] develop this idea and unpack how the core stakeholders in bitcoin use imaginaries in their negotiations with each other aiming at achieving consensus and integrating with desired infrastructures. Imaginaries can furthermore be seen as co-created through communicative interaction between stakeholders who utilise material objects, gestures, and stories to iteratively imagine future scenarios [35]. This last approach to the creation of imaginaries will inspire our analysis of how sociomaterial Blockchain assemblages are dynamically created and used to open up the technology through *whiteboxing* activities.

Method

To explore breakdowns at the early stages of Blockchain infrastructuring, we report from two studies. Common for both studies is that they rely on approaches based on multi-sited ethnography [31], however this methodological approach is expressed differently in each of our empirical cases. When we study a phenomenon, which cannot be captured as existing only within one location and place, but instead take place and get produced across many sites and in multiple venues, we need to trace and follow the actors involved. Thus, part of our analyses becomes identifying the nature of the sites where the phenomenon takes place [9]. Studying breakdowns and complex configurations of artefacts, practices, and imaginaries as they take place in various domains within the blockchain information infrastructure is exactly such an elusive phenomenon, which cannot easily be captured by existing ethnographical methods, but requires us to critically identify where the sites of deployment are located. There are multiple roads by which we could start to explore breakdowns and assemblage creation and transformation within the Blockchain domain, but to be specific, we chose to explore it as it takes place in two different domains associated with the large-scale information infrastructures of Blockchain technology – namely within the cryptocurrency trading domain, and the energy domain. What makes these two domains interesting places to begin is that they represent two conceptually different ways in which the Blockchain information infrastructure is currently evolving. Firstly, we look into how multiple Blockchain artefacts and associated imaginaries contribute to creating and resolving breakdowns in a new infrastructure running in parallel to and inspired by an established domain (crypto-trading), and secondly, we look at how this takes place in connection with the proliferation and permeation of the technology underlying crypto-trading, Blockchain, into an already established domain (energy trading).

Data collection

Because of the different types of venues studied, our data collection strategies and sources also took different forms. Our data collection techniques comprised qualitative interviews, ethnographic observation, and involved interventionist participation over longer periods of time in relevant communities. Part of this work involved tech start-up communities, where the first-author was engaged and where he applied these various data collection approaches. More specifically, the first author has been involved with a Danish start-up called Blockchain Labs for Open Collaboration (BLOC) for the past 13 months. One of the projects that BLOC has been working on is a municipal initiative aiming at demonstrating the applicability of Blockchain technology for distributed solar energy production in an urban setting, specifically for creating a peer-to-peer marketplace for renewable energy produced by “prosumers” (Producer/consumers). The role of the first author in this case active participatory, and well as analytic.

Over the past 9 months, we interviewed a total of 16 people whose insights and experience were particularly relevant for addressing our overall research question. Of them, 7 people were engaged in cryptocurrency trading either directly on their own, or through the intermediation of a fund, and 9 were relevant stakeholders in the energy sector, particularly solar, as well as at the intersection between blockchain and the energy domain. The interviews were recorded and transcribed

We also observed the development, over a period of 4 months, of a “friends and family” fund of around 1 million US dollars aimed at cryptocurrency trading. We followed the people involved in the project from initial planning, to preparation of the investment package, fundraising and closing of the funding round. This was done through ongoing one-on-one talks, calls, and participation in various internal meetings as well as investor events. A total in excess of 100 hours were spent on these activities. Furthermore, the first author engaged in participant observation at BLOC on an ongoing basis. During the past 16 months the first author spent on average 10 hours a week being part of the start-up’s daily routines, hereunder joining in and participating in various business meetings, internal strategy meetings, speaking events at various conferences, and business trips in Denmark and abroad.

Besides the above concrete activities, the first author has been involved and explored the Blockchain innovation communities for 36 months, exploring the information infrastructure of Blockchain in both maritime sectors, and well as the entrepreneurial practices of start-ups involved in various gateway services, hereunder bitcoin ATMs (BTMs). This empirical work includes in excess of 300 hours of participant observation and over 25 interviews. While these cases are not directly included in the empirical work presented in this paper, the larger insight into Blockchain as an information infrastructure does impact our approaches to explore how breakdowns are resolved at the early stages of Blockchain infrastructuring.

Data analysis

Analyzing the empirical data from the two venues of cryptocurrency trading, and renewable energy trading, we decided to let ourselves be guided by considerations related to the various roles of the examined artefacts, as well as the specific situated expressions of these roles in the venues that we have chosen. Specifically, this meant that we went over the sum of our extensive data with a particular focus on finding concepts and categories that would help us understand the unique characteristics of Blockchain assemblages as they are created and transformed within our two Blockchain venues. Practically, we started our data analysis simultaneously with ongoing data collection, and as specific categories and concepts pertaining to the roles and expressions of Blockchain assemblages starting gaining salience, we adapted further data collection in a more narrow and focused manner. We iteratively went through this process until settling on the categories presented in this paper.

Results

Creating Blockchain assemblages in the cryptocurrency trading domain

The information infrastructure of cryptocurrency trading is still in its infancy. With the inception and growth of bitcoin and other derived altcoins, a whole range of gateway services acting as protocol extensions have started to emerge. Among others these comprise bitcoin ATMs (BTMs) providing easy access points to buy and sell bitcoins, Point of Sales systems (PoS) that seamlessly integrate cryptocurrency payments with existing payment infrastructures, and online exchanges where users can both access cryptocurrencies, and speculatively trade them against each other or against traditional fiat currencies. While exchanges primarily offer a digital service, BTMs and PoS systems involve hardware as well as software, which has been developed along a trajectory from hobbyist tinkering to more established industrial production.

The emergent nature of these gateway services and their hobbyist non-industrial origins make them less robust than the socio-technical kernel(s) that they are interfacing with. The kernel of the bitcoin infrastructure, i.e. the protocol and its derived mining and maintenance practices, has indeed withstood the test of time and proven to be very secure and robust to hacking, the same cannot be said about these gateway services. Numerous exchanges have indeed been hacked (e.g. MtGox), coins have gone missing, and the ethical practices of these companies have sometimes been quite doubtful (e.g. not investing in cybersecurity in order to keep profits high, or purposefully stalling the process whereby customers can get their money out of the exchange). This is not a criticism of gateway services, but rather an acknowledgement that they are still emerging and that in the process of professionalization of their business, the practices of their users have to adjust to the risk element inherent to engaging with the information infrastructure in its current state. This adjustment is done through tinkering activities that compensate for the lack of user-friendliness, and the real or perceived risks involved in engaging with cryptocurrencies.

Part of our empirical work includes following one amateur crypto-trader, going by the alias “SteelDuck” (SD). Below, we will show how he actively creates and tinkers with assemblages of digital and analogue artefacts, which allow him to counter the perceived trading risks associated with a sociotechnical infrastructure that is still unstructured and emerging.

According to SD, the biggest selling point of bitcoin is that it is a store of value. It has a limited supply that is hard coded into the protocol (only 21 million coins will ever be created), and it can therefore be equated with digital gold. He believes that bitcoin is the only true cryptocurrency, demonstrated by the size of the network and market cap, and that it is the only one so far that has the potential of truly transforming the economy. Regardless if it succeeds as a currency, he believes that it will remain the ultimate store of value in the long run. SD is generally pessimistic about the future of the global (non-crypto) economy, and he sees his activities as an exercise in hedging against future uncertainty, instability and financial crises. In his own words:

“In my opinion, almost everything else than bitcoin (other cryptocurrencies) will go to zero when the next financial crisis hits. But I believe in bitcoin. I still believe it has a value, right. It has the value proposition of being digital gold. So, I don’t think that that is going to go to zero. It will of course depreciate, but I would rather be in bitcoin when the financial crisis hits, and that’s why I have not just spread myself out on all the other altcoins.”

In accordance with his beliefs about the future outlook of the economy, SD's trading strategy has bitcoin at its core, and at any time he will allocate min 50% of his trading resources to bitcoin. He is as such not interested in exiting crypto and drawing his investment back into fiat currency, and he sees himself as a "long" investor when it comes to bitcoin. He believes that when the next financial crisis hits, bitcoin will be his safe haven, and value stored in bitcoin will depreciate less than other assets, whether fiat or crypto. SD is in other words a so-called "Bitcoin maximalist", a term coined by the bitcoin community to characterize people with his views. SD's interest in altcoins, on the other hand, is mainly as a short-term accelerator of bitcoin performance. That means that his benchmark is bitcoin value (not fiat), and that investing in altcoins should only be done when they momentarily outperform bitcoin, i.e. appreciate faster. Profits on his altcoin portfolio will be brought back into his base currency (bitcoin) in a fashion that the allocation remains steady (50% bitcoin, 25% top-altcoins, 25% small emerging coins). He explains it simplistically as follows:

"…when bitcoin goes like this (SD illustrates a linear downwards path by gesticulating his arm)… then altcoins go like this (he illustrates the same downwards pattern downwards, but with waves going up and down)… when bitcoin is going down, then altcoins tend to go down faster, and then it's good to be in bitcoin. When bitcoin goes up, then you would want to allocate more to altcoins, because they will tend to appreciate faster than bitcoin. And then you can have some goals about when to sell the altcoins and how many to keep… so it is simply about beating bitcoin."

SD is well aware of the weaknesses of online exchanges described earlier, and the fragility of the emerging cryptocurrency trading infrastructure. Therefore, in order to practically manage his portfolio, and go about his trading strategy described above, SD needs to spread his risk. We will cover this below.

As an active cryptocurrency trader, SD is directly contributing to the growing and consolidation of the blockchain information infrastructure. His entrepreneurial actions aimed at implementing the trading strategy described above, directly impact the gateway operators that he engages with, as well as the manufactures of hardware that he relies on for his trading. Through these actions, he is, as all other entrepreneurs and users engaged in the Blockchain ecosystem an active infrastructuring agent. In his particular case, he enacts his role as infrastructuring agent through the active use and remix of various blockchain artefacts, which allow him to implement his trading strategy in the absence of strong regulation setting standards for crypto-exchanges. Crypto trading is indeed still largely unregulated, and many of the protections that investors find on for instance Forex exchanges, such as segregated bank accounts, and deposit insurance are largely missing in current cryptocurrency exchanges. To compensate for this, SD leans on various digital and analogue artefacts and combines them in a way that enacts a sort of analogue "end-to-end trading system" which affords him acceptable levels of risk-taking.

Practically, this means implementing an intricate system of digital and analogue practices based on software, hardware, and analogue props such as laminated paper sheets containing the "seed codes" needed to regenerate a coin portfolio. As we will see this is a paradoxically clear illustration that while blockchain, as a protocol, is secure, self-executing, and tamper-proof, it is very much not the case for activities taking place at the gateway level of the information infrastructure. Here security vastly depends on human factors, and analogue practices diligently executed by the infrastructuring agents in question. In the case of SD, this means that he makes sure to keep most of his coins (bitcoin as well as altcoins) in so-called "cold storage" on secure hardware wallets. These wallets, which roughly resemble USB flash drives, can be plugged into SD's computer, and from the display on the device he can enter his codes and accept transactions. None of this is done on a browser screen on the laptop. As SD explains:

"No one has been able to hack these wallets yet. Hacks usually occur at the user interface level in the browser. Small scripts get downloaded onto the browser leading you to think that you are sending money to one address, but actually the transaction goes to another address. But if you avoid the browser and verify everything on the actual device, then it should be as secure as possible."

When asked about the manufacturing of these devices, SD shared with us that the hardware wallets generally are the result of hobbyist tinkering, which has developed into a specific product, that in turn has resulted in the creation of a start-up company addressing this specific need. These products are typically sold on the company's website, and SD clearly advises us not to attempt to buy them anywhere else:

"You don't want to buy it on Amazon… (laughs out loud) … then you will get one that has been tampered with in order to extract your seed codes!"

Interestingly, SD uses hardware devices initially created by hobbyists in order to implement his trading strategy in a secure manner. What is particularly interesting here, is that these hardware artefacts, once introduced "into the wild" and used actively by traders like SD, can become part of a higher-level tinkering and remixing activity. In this case the artefacts central to the practice are supplemented by other artefacts and associated imaginaries to create a more intricate Blockchain assemblage for achieving infrastructural goals. Indeed, using the hardware wallet correctly, and thus avoiding the risk of malware in the web browser, is only part of the

assemblage put in place by SD. Even more importantly, he has implemented an analogue security protocol around the physical storage of the hardware wallets and associated seed codes.
"The key that generates your account on the hardware wallet is a string of 24 words called a seed. This seed you of course need to keep in a different location than the actual device. And if you are smart you will inverse two of the words in a way that only you can remember. That way even the seed will be useless to a robber."

SD continues:

"AND you must store a copy of this seed with another person that you trust. So, if it burns here, you will have the seed there, and if the seed gets stolen over there, then you have it here… Moreover, you should preferably laminate your seeds and store them in fire-proof bags, and so on."

A final component of SD's implementation of his trading strategy pertains to the part of his capital, which is not kept in cold storage but stored on online exchanges for fast deployment. Here he explains:

"I would never have, let's say…(silence)… more than around 20% of my coins on online exchanges. And I would never have those 20% on the same exchange. It's about spreading your risk. So, you have for example 5% on Bittrex, 10% on Binance, 3% on Cryptopia, and 2% on something else… so you spread your working capital on exchanges that have a good track record and reputation. So, if an exchange cracks it will not be 20% of your holdings that you lose but let's say 5%... But that is the price you pay for being able to trade fast."

Asked to reflect about the sheer amount of menial and mundane activities going into upkeeping this protocol and underlying trading practice, SD states that if it weren't for hardware wallets like the ones he is using, then he would not find it worthwhile to trade at all. He would stick with buying bitcoin as a long-term investment and skip trading in altcoins altogether. At the same time, he also acknowledges that the current system is still not suitable for larger scale investors who have strong security requirements. As he puts it:

"Scaling up this analogue setup (involving cold storage) would require that you trust that one person who has the keys… and that's why the large players don't want to touch this. They would have to trust a few people who have the keys and thus access to all the capital, which could be transferred in an untraceable manner if done properly (SD goes into technical details about the use of VPNs, mixing services and TOR)."

Tackling breakdowns, and reconfiguring Blockchain assemblages in the energy domain

Unlike bitcoin and other cryptocurrencies, which are entirely digital and only connected to the physical world through mining and some of the gateway services described earlier, Blockchain applications in established industries, e.g. the energy sector, are much more complex to manifest in the world. This is because they require an ongoing connection with pre-established industries. They need to permeate into these industries through a process of infrastructural grind whereby the infrastructural and technological properties of the converging infrastructures reflexively rub off on each other, ultimately resulting in embeddedness. Here the infrastructural properties of the energy sector will create both enablers, and most certainly constraints, for the permeation of Blockchain technology. Technologically, the proposed blockchain solution will have to be interoperable with pre-existing legacy systems, and legally it will have to be compliant with existing regulations in the domain, which for certain proposed applications can be a challenge.

In the case of the energy sector, the most reported potential application of Blockchain relates to distributed energy production, and related peer-to-peer marketplaces. An instance of this could be residential solar installation systems producing for the needs of the household and allowing for the transaction of excess production with neighbors via a Blockchain system. The Brooklyn Microgrid (BMG), operated by LO3 Energy, is an example of the technical feasibility of such a system. In 2015, the company did a *"sandbox experiment enabling three residents on President Street in Park Slope to participate in the first ever peer-to-peer energy transactions"*. The company is currently trying to expand on this experiment but is encountering legal constraints in the fact that *"the only option available to prosumers is net metering - counting electricity sent back to the grid as a credit against your own consumption"*. In other words, it is illegal in New York to sell electricity directly to neighbors without the intermediation of the existing grid, and the application of current rates and taxes. Waiting for possible legislative change, which might be under way in the state, the focus of BMG is now community building, and creating a demand for the solution at neighborhood level. This is done through community workshops, and engagement with local business owners in order to get them interested in buying locally produced electricity, once it becomes legal.

The start-up company Blockchain Labs for Open Collaboration (BLOC) in Copenhagen, has a similar experience in the Danish context. Here, the Copenhagen Solutions Lab (CSL), a municipal initiative, which works with *"intelligent technologies to create data-driven solutions that suit the city and its citizens"* has developed three so-called urban laboratories, one of which focuses on testing sustainable solutions for decentralized energy using Blockchain technology. This laboratory, named EnergyBlock, is a site in the north-west neighborhood of the city comprised of 3 adjacent buildings that have been chosen to become a testbed for the use of renewable energy in an urban setting, supported by Blockchain and other new technologies. Together with researchers from the Technical University of Denmark (DTU), BLOC was chosen as a partner for the implementation of the project. As it turned out the project team encountered problems on two levels: (i) legal constraints somewhat similar to the ones encountered by the Brooklyn Microgrid, and (ii) technical constraints related to the existing metering infrastructure in the buildings.

One of the partners on the project expressed it in the following words:

"In Denmark, freedom to transact energy resources is only allowed "behind the meter" and is restricted to transactions on the same building lot. This means that engaging in selling excess renewable energy generated by a solar rooftop installation can only be done within the same building. Selling it to the adjacent building would be illegal. Here you would have to feed the energy back into the grid, and the adjacent building would then be able to buy from the grid at retail price that includes taxes to the government"

Because of these laws, there is no incentive for building or house owners to generate more renewable energy than they can consume, since excess energy is essentially given away for free to the grid. The projections of a specific solar rooftop installation in Denmark therefore tends to be under-scaled in order to minimize the feedback into the grid, referred to as "leakage". One of our informants who has designed the specifications for some of the largest installations in the country explains it as follows:

"Solar production on rooftops in Denmark is optimal if it represents approximately 25% of the total yearly consumption of the building. This is because production output fluctuates a lot throughout the year at this latitude. If you generate more energy than 25% of your total consumption, then you would lose a considerable amount of energy during the summer months when yield is higher than consumption. Remember… you are not making any money on excess production. It just gets fed straight back to the grid. It is true that your share of solar during the winter months will be higher with a bigger installation, but your energy savings from that will not make up for the extra investment of installing a larger solar system. So approximately 20-25% of your overall consumption will be an ideal installation. That way over 95% of your solar production will be consumed by the residents, and only around 5% is leaked back into the grid."

Because of these legal constraints, the scope of the EnergyBlock project immediately became more limited. Whatever the outcome of the project, it would mainly serve as a demonstration of technical feasibility but would not immediately be scalable to broader commercial use under current rules. Instead the project could be conceptualized as an exercise in creating awareness about the possibilities of distributed energy generation, potentially with the purpose of influencing law makers in a direction more open to peer-to-peer energy trading.

From the perspective of BLOC, who were invited in to work on the actual Blockchain technology, the aim of the project quickly moved from being an actual scalable market-ready solution, to becoming a constructed imaginary supported by basic technological features. Since the objective, for legal reasons, could not be to scale up peer-to-peer energy trading in Copenhagen and beyond, it became a matter of designing a simple showcase solution that would be a physical manifestation of a potential future scenario. In an internal brainstorming session, the founder of BLOC emphasized the importance of creating a simple and cheap solution that would generate publicity and focus on the issues pertaining to peer-to-peer energy trading. In this connection the founder of BLOC asked the first author of this paper to re-appropriate a hardware artefact called OpenBlock, which the first author of this paper had initially created for teaching and learning purposes – OpenBlock is essentially a private Ethereum Blockchain running on Intel Edison chips on Arduino micro-controlers:

"Why don't we re-use your teaching devices (the OpenBlock hardware) and actually connect them to the smart meters in the building? That could work… It is a fully fledged live Ethereum network, right? The scale of the transactions that we will record is low, so we really don't need a fancy system… It should do the trick. It could be a quick win for all parties"

At the formal project launch workshop, there seemed to be a consensus among project partners for an approach aiming at a smaller scale technical prototype, and for the need to showcase something that would make the regulators inclined to push for change. As the project coordinator from CSL put it:

"We just want to show that it can be done technically, and that it could be an alternative to the existing centralized system."

When the practicalities of building a prototype were discussed, however, it became clear that some of the assumptions that BLOC had about the current state of the electric infrastructure of the buildings were inconsistent with reality. While smart meters were assumed, it turned out that the selected building was of older date, and that the current electricity meters were revolving disc meters rather than smart meters. These types of meters are based on a mechanical metal disk that rotates and incrementally updates an analogue display. Connecting such a meter to a Blockchain would not be possible unless it is done as a work-around solution whereby one could add a small adhesive optic sensor on the casing of the meter. This sensor would count the revolutions made by the disc and display the consumption electronically at given time intervals. This could then be connected to one of our hardware devices (OpenBlock) that could send consumption data to the

Blockchain ledger. Similarly, it was assumed that there would be proper space on the roof of the building for a solar installation, but it turned out that large parts of the roof were being allocated for an urban greenhouse project. So, in the absence of a full-scale solar installation, other ways of simulating the full solar production potential needed to be devised. A solution that was discussed involved setting up a solar irradiation sensor on the roof, which would show the real time solar irradiation per square meter. In a simple database, the irradiation measurement could then be multiplied by a scaling-up factor based on a professional projection on the roof's capacity. This production output data would then be connected to the same blockchain that would be hosting the metering data.

When going through the details of the project, it becomes clear that what started out as a lofty and potentially transformative endeavor, became a whole different kind of exercise once it was unbundled and expressed in terms of hacks, tinkering, and workarounds needed for the project to deliver the desired infrastructural narrative. The various artefacts, whether it is the OpenBlock hardware, or the optic and irradiation sensors, were used as conceptual tools in order to investigate design possibilities for future solutions carrying the desired infrastructural imaginary. Interestingly, in this case the infrastructural imaginary is not the result of a specific technological implementation, but rather it became the whole focus of the exercise. The project is not about producing a working solution, it is about producing a desired infrastructural imaginary, that can serve the ongoing interests of the involved parties, and at the same time contribute to the infrastructural trajectory of the overall blockchain infrastructure. Likewise, the assemblages of artefacts employed in the conceptualization of this infrastructural imaginary are not so much components in a remix of applied artefacts, as in the crypto-trading case, but rather they are components in the ongoing articulation of the desired imaginary. In fact, the Blockchain artefacts are entangled with the imaginary through the act of discussing potential implementation options. Even if the options end up not being implemented in the world, they will have made an impact on the imaginary through which the objectives and visions of the project are articulated. This ended up being the case with EnergyBlock. At the time of writing this paper, the options that had been discussed had indeed still not been implemented, for a complex set of reasons that fall outside the scope of this paper. The co-creative exercise of discussing implementation option, however, has influenced the imaginary that CSL uses in talking about the project, namely that it's about showing technological feasibility and having a place for experimenting with devices and connectivity (not about creating a scalable solution). Likewise, the process has influenced the pathway that BLOC has decided to pursue when it comes to Blockchain in energy. The company's CEO puts it in these words:

"If you want to have a transformative impact in the sector, it makes more sense to avoid electron-based blockchain projects. Here the road to impact is too long. Rather you should look into Blockchain applications that are non-electron, or electron-derivative. Projects that do not directly deal with the transacting of energy between peers… at least not in a European setting where regulation is so constraining."

Here she refers to engaging with projects that either focus on financing or crowdfunding of renewable energy assets, as well as projects aiming at creating carbon-based economies. In both those cases, the regulatory constraints that would limit a project's feasibility and scalability are circumvented, in the sense that it aims at strengthening the renewable energy sector without actually addressing the physical electricity being produced and transacted between peers. In this case, this new company strategy had slowly manifested as a result of the infrastructural imaginary that was crystalized when discussing implementation options on the EnergyBlock project, using tinkering and remixing scenarios involving assemblages of Blockchain artefacts. The infrastructural imaginary designed through tinkering with implementation ideas, has in fact rubbed off on the self-perception of BLOC, and influenced the strategic trajectory of the company within the energy space. We could argue that the piecemeal approach to combining various re-appropriated artefacts with the intent of creating a bare bones technical demonstration, and associated imaginary about feasibility and regulatory constraints, did indeed accelerate the company's learning about the workings of the industry, and nudged them in the direction of new use-cases within the sector. Through designing an imaginary for EnergyBlock, the company also refined their own imaginary and associated strategy.

Discussion

Our two empirical accounts from the cryptocurrency trading domain and the energy domain, demonstrate how breakdowns in the early stages of blockchain infrastructures are resolved in similar yet different ways.

Firstly, in both cases it became evident that it was impossible to distinguish between the imaginaries [37] [27] related to the infrastructure, and the infrastructure itself in the very early stages of the evolving blockchain information infrastructure. Moreover, in the energy case, where Blockchain permeates into an established industry through infrastructural grind [22], very few established blockchain solutions exist beyond proof-of-concept. This means that the associated imaginaries about future technological possibilities (e.g. peer-to-peer energy trading) are a core driver for the infrastructure, simultaneously as the technological artefacts emerge as potential solutions themselves. When breakdowns occur in these very early stages of the infrastructural development, they are as much breakdowns of proposed imaginaries as breakdowns of the technical infrastructure itself. This became apparent in the EnergyBlock case, where a breakdown of the initial imaginary surrounding peer-to-peer energy trading supported by Blockchain resulted in a major repositioning attempt by the involved start-up. The Blockchain information infrastructure includes multiple imaginaries, which are entangled with the sociomaterial [3] technology infrastructure. In such situations a question emerges about the nature and material matter of breakdowns at these very early stages of infrastructural development. Our data suggest that we must consider the infrastructural breakdowns as cuts into dynamic sociomaterial assemblages [34] mutually enacted by artefacts and imaginaries [37] [35]. We refer to these assemblages as *blockchain assemblages,* Emphasizing the relational attributes [48]. Blockchain assemblages comprise configurations of digital and analogue artefacts that are sociomaterially entangled [3] with imaginaries [37] [27] about the current and future state of the Blockchain information infrastructure [21]. These configurations are case- and domain-specific (cryptocurrency and energy produced different types of blockchain assemblages) and rely on a multiplicity of digital and analogue artefacts and practices.

Our data point to the fact that the blockchain assemblages break down when exposed to disconfirming events. Disconfirming events take different forms. Disconfirming events can result in abrupt and fundamental breakdowns, like when the basic assumption behind the EnergyBlock project was invalidated in the project launch meeting. But disconfirming events can also manifest in less dramatic breakdowns, as when our crypto-investor informant became aware of the risks associated with storing his crypto-keys on online exchanges. In the case of crypto-trading, it was evident that our informant first went from online storage of his crypto keys, to relying on a secure hardware wallet (the Ledger device), and then adding his own analogue security protocol embodied in laminated seed codes and distributed storage of these codes in fireproof bags. His evolving blockchain assemblage was dynamically entangled [3] [34] with an underlying imaginary [37] about cryptocurrency value, trading strategies, infrastructural practices and perceived risks.

So, disconfirming events can cause Blockchain assemblages to break down in early stage information infrastructures, but what are then the ways in which these breakdowns are resolved by the involved infrastructural agents? Examining our data, we notice that the involved practices to resolve breakdowns in the blockchain assemblages centered around the same kind of activity in both cases. We propose to refer to this activity as *whiteboxing*. Whiteboxing is the activity whereby blockchain assemblages are unpacked and unconcealed. It is the activity where the black box of infrastructures is opened for examination and re-organization. Whiteboxing is when the cogwheels, wires, and narratives which make up the blockchain assemblages are revealed and examined. The technology and the imaginaries which together form blockchain assemblages unfold as an artefactual multiplicity [10]. Whiteboxing allows for excavation of the bits and pieces which form the blockchain assemblages, and thus spurs activities of reconfigurations, whereby artefacts and imaginaries are simultaneously transformed. Complementing existing work on information infrastructures [41] [5] [33], the activity of whiteboxing requires detailed knowledge beyond the polished façade of narratives told about blockchain technology in a certain domain. Whiteboxing is the activity were the paths through programming code, technology, domain, and imaginaries are exercised and where the nitty-gritty details of the infrastructure is revealed. Through whiteboxing, the infrastructures of blockchain become visible and available for scrutiny. But its only possible because of the disconfirming events pushing for breakdown [47]. Whiteboxing is a response to breakdowns that implies opening up blockchain assemblage making their inner constituting parts visible [46] [6] and available for reconfiguration. Reconfiguration of blockchain assemblage involves re-aligning its multiple digital and analogue artefacts, and articulating new imaginaries that express an updated perspective. Through this process a new iteration of blockchain assemblage is produced, which the entrepreneurial agents can once more attempt to propagate to their stakeholders.

An example of enacted whiteboxing as a result of a disconfirming event is our EnergyBlock case, where BLOC's initial imaginary about the future of energy trading via Blockchain got questioned. As the legal context turned out to be unfavorable to peer-to-peer energy trading, and as the team came to realize that the actual buildings were lacking the required, and assumed, electrical infrastructure to see the project through as intended, the focus of the start-up changed. It was now looking into repositioning its blockchain assemblage by tinkering with and remixing available artefacts and through creative collaboration with the project stakeholders [6]. Specifically, we saw that BLOC through their whiteboxing process attempted to recast a particular artefact as something different than what it was initially designed for. Rather than being a tool for teaching and learning, the OpenBlock artefact would become (hypothetically) a hardware component in a larger integrated socio-technical system comprised of sensors, meters, and blockchain hardware and software. These ideas never materialized, but they allowed for the creation of controversy frames and the repositioning of BLOC's Blockchain assemblage into a different trajectory aiming at a different infrastructural intersection [22], namely crowdfunding and carbon markets.

Whiteboxing supplements the view that the entrepreneurial actions [21] of heterogeneous actors in the Blockchain domain are self-directed and comprised of engaging and circumventing activities [21]. Indeed, whiteboxing can be seen as a more granular analytical concept for explaining how entrepreneurial agents circumvent the constraints encountered when the infrastructural kernel [41] pushes back on their actions. The act of circumventing infrastructural constraints can thus be seen as an effort that is mediated by a whiteboxing process that re-configures artefacts and entangled imaginaries into new representations that better reflect a current-state world view. Iteratively, whiteboxing activities thus contribute to infrastructural consolidation, and emerging standards [20], which in turn directly impact the overall growth [21] pathway of the Blockchain information infrastructure.

In both our cases, and most clearly in the energy case, the early stage of the infrastructure is predominately imaginary rather than factual, and what drives the infrastructure forward is the iterative trial-and-error of entrepreneurial actors attempting to materialize their current situated imaginaries. We therefore see the path to increased infrastructural embeddedness [48] and kernel consolidation [41] as one that is continuously interrupted by disconfirming events resulting in breakdowns that in turn are resolved through whiteboxing. We believe that the frequency of these breakdowns will decrease over time as proper use-cases get identified and larger scale systems get deployed and solidified. Theoretically this shows us that whiteboxing distinguishes itself by being future-oriented in the context of technological infrastructures that are still at an early stage of evolution and have not yet reached embedding [48] into the fabric of pre-existing relational structures.

Conclusion

In this paper we have examined two domains within Blockchain that are at an early stage of infrastructural development, namely the cryptocurrency trading domain and the energy domain. In order to direct our investigation, we have relied on multi-sited ethnographic approaches that have informed our focus in the respective domains. The aim of our investigation was to unpack particular points of tension and breakdown in the evolution of the Blockchain infrastructure, and to assess how these were resolved by the entrepreneurial agents involved in these particular domains. Our empirical data showed us that at the early stages of infrastructural development in Blockchain, there is a considerable reliance on imaginaries about future potentials of the technology. These imaginaries are sociomaterially entangled with a multiplicity of digital and analogue artefacts developed and utilized entrepreneurial agents, as well as with specific practices, and business models. This multiplicity is configured into dynamic *Blockchain assemblages* that drive the infrastructural work of the entrepreneurial agents in question. Interestingly, we have shown that these Blockchain assemblages are iteratively manifested as stable as well as dynamic entities interrupted by assemblage breakdowns caused by disconfirming events. As breakdowns occur through disconfirming events, *whiteboxing* activities are enacted in order to open up the Blockchain assemblage and sociomaterially reconfigure its entangled parts. As an analytical concept, we show that whiteboxing is a lens through which we can better understand the iterative reconfigurations of artefacts and imaginaries that take place in infrastructural development it its very early stages, before blackboxing and full embedding into pre-existing relational arrangements.

References

1. Madeleine Akrich, Michel Callon, and Bruno Latour. 2002. The key to sucess in innovation Part 1: The art of interessement. *International journal of innovation management* 6(2): 187-206.
2. Madeleine Akrich, Michel Callon, and Bruno Latour. 2002. The key to success in innovation Part 2: The art of choosing good spokespersons. *International journal of innovation management* 6(2): 207-225.
3. Karen Barad. 2007. Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning. Duke University Press
4. James Basden, and Michael Cottrell. 2017. How Utilities Are Using Blockchain to Modernize the Grid, *Harvard Business Review*, March 2017
5. Matthew Bietz, Eric P. S. Baumer, and Charlotte P. Lee. 2010. Synergizing in cyberinfrastructure development. *Computer Supported Cooperative Work* (JCSCW)
6. Wiebe E. Bijker. 1992. The social Construction of Fluorescent Lighting, or How and Artefact was Invented in its Diffusion Phase. In Shaping Technology/Building Society: Studies in Sociomaterial Change. The MIT Press
7. Julian Bleeker. 2009. Design Fiction: A Short Essay on Design, Science, Fact and Fiction. Retrieved from http://nearfuturelaboratory.com
8. Pernille Bjørn, and Carsten Østerlund. 2014. Sociomaterial-Design: Bounding technologies in practice. Springer.
9. Pernille Bjørn, and Nina Boulus-Rødje. 2015. The multiple intersecting sites of design in CSCW research. Computer Supported Cooperative Work (CSCW): An International Journal 24(3): 319-351.

10. Pernille Bjørn, and Morten Hertzum (2011). "Artefactual Multiplicity: A Study of Emergency-Department Whiteboards." Computer Supported Cooperative Work (CSCW): An International Journal 20(1-2): 93-121.

11. Pernille Bjørn, and Nina Boulus. 2011. Dissenting in reflective conversations: Critical components of doing action research. Action Research Journal 9(3): 282-302.

12. Jeanette Blomberg, and Helena Karasti. 2013. Reflections on 25 Years of Ethnography in CSCW. Computer Supported Cooperative Work (CSCW) August 2013, Volume 22, Issue 4, pp 373-423

13. Geoffrey C. Bowker, and Susan Leigh Star. 1999. Sorting things out – Classifications and its consequences. MIT Press

14. Geoffrey C. Bowker. 1994. Science on the run: Information management and industrial geophysics at Schlumberger, 1920–1940. Cambridge: The MIT

15. Paul Dourish, Genevieve Bell. 2014. ‘‘Resistance is futile’’: reading science fiction alongside ubiquitous computing. Personal and Ubiquitous Computing, Volume 18 Issue 4, April 2014 Pages 769-778

16. Paul N. Edwards, Geoffrey C. Bowker, Steven J. Jackson, and Robin Williams. 2009. Introduction: an agenda for infrastructure studies. Special Issue on e-Infrastructure of the Journal of the Association for Information Systems, 10(5), 364–374

17. Xianyi Gao, Gradeigh D. Clark, and Janne Lindqvist. 2016. Of Two Minds, Multiple Addresses, and One Ledger: Characterizing Opinions, Knowledge, and Perceptions of Bitcoin Across Users and Non-Users, Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems Pages 1656-1668

18. R. Stuart Geiger, and David Ribes. 2011. Trace Ethnography: Following Coordination through Documentary Practices. Proceedings of the 44th Hawaii International Conference on System Sciences.

19. Gräther, Wolfgang, et. al.. 2018. Blockchain for Education: Lifelong Learning Passport. In: W. Prinz & P. Hoschka (Eds.). Proceedings of the 1st ERCIM Blockchain Workshop 2018, Reports of the European Society for Socially Embedded Technologies (ISSN 2510-259)

20. Ole Hanseth, Eric Monteiro, and Morten Hatling. 1996. Developing information infrastructure: the tension between standardisation and flexibility. Science, Technology and Human Values, 11(4), 407–426.

21. Karim Jabbar, and Pernille Bjørn. 2017. Growing the Blockchain Information Infrastructure, Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems
22. Karim Jabbar, and Pernille Bjørn. 2018. Infrastructural Grind: Introducing Blockchain Technology in the Shipping Domain. GROUP '18, January 7–10, 2018, Sanibel Island, FL, USA
23. Karim Jabbar, Deanna MacDonald, Simon Ousager. 2017. Token Gesture? FutureNautics, Issue 15, Q2 2017, Quaterly
24. Margaret Jack, Jay Chen, and Steven J. Jackson. 2017.. Infrastructure as Creative Action: Online Buying, Selling, and Delivery in Phnom Penh, Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems
25. Helena Karasti, Karen S. Baker, and Florence Millerand. 2010. Infrastructure time: long-term matters in collaborative development. Computer Supported Cooperative Work (JCSCW)
26. Erol Kazan, Chee-Wee Tan, and Eric T. K. Lim. 2015. Value Creation in Cryptocurrency Networks: Towards a Taxonomy of Digital Business Models for Bitcoin Companies. PACIS 2015 Proceedings. Pacific Asia Conference on Information Systems.
27. Yong Ming Kow and Caitlin Lustig. 2017. Imaginaries and Crystallization Processes in Bitcoin Infrastructuring, Computer Supported Cooperative Work (CSCW). DOI 10.1007/s10606-017-9300-2
28. Tue Odd Langhoff, Mikkel Hvid Amstrup, Peter Mørck, and Pernille Bjørn. 2016. Infrastructures for healthcare: From synergy to reverse synergy. Health Informatics Journal.
29. Bruno Latour. 1987. Science in action, Harvard University Press, Cambridge
30. Charlotte P. Lee, Paul Dourish, and Gloria Mark. 2009. The human infrastructure of cyberinfrastructure. Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work (pp. 483 – 492). New York: ACM Press
31. George E. Marcus. 1995. Ethnography in/of the World System: The Emergence of Multi-Sited Ethnography. Annual Review of Athropology, Vol. 24, 95-117
32. Bill Mauer, Taylor C. Nelms, and Lana Swartz. 2013. “When perhaps the real problem is money itself”!: the practical materiality of Bitcoin. Social Semiotics, 2013
33. Eric Monteiro, Neil Pollock, Ole Hanseth, and Robin Williams. 2013. From Artefacts to Infrastructures. Computer Supported Cooperative Work: The Journal of Collaborative Computing (JCSCW), 22(4), 575–607

34. Martin Müller. 2016. Assemblages and Actor-networks:Rethinking Socio-material Power, Politics and Space. Geography Compass 9/1 (2015): 27-41

35. Keith M. Murphy. 2004. Imagination as Joint Activity: The Case of Architectural Interaction.Mind, Culture, and Activity, 11(4), 267-278

36. Satoshi Nakamoto. 2008. Bitcoin: A Peer-to-Peer Electronic Cash System. Retrieved form bitcoin.org (5 February 2016)

37. Laura J. Neumann, and Susan Leigh Star. 1996. Making Infrastructure: The Dream of a Common Language. PDC'96 Proceedings of the Participatory Design Conference. J. Blomberg, F. Kensing, and E.A. Dykstra-Erickson (Eds.)

38. Volkmar Pipek, and Volker Wulf. 2009. Infrastructuring: towards and integrated prespective on the design and use of information technology. Journal of the association of information systems.Volume 10, issue 5, May 2009, 306 – 332.

39. Larissa Pschetz, Ella Tallyn, Rory Gianni, and Chris Speed. 2017. Bitbarista: Exploring Perceptions of Data Transactions in the Internet of Things, Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems

40. David P. Randall E. Ilana Diamant, Charlotte P. Lee. 2015, Creating Sustainable Cyberinfrastructures, Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems Pages 1759-1768

41. David Ribes. 2014. The Kernel of a Research Institution. Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing. Pages 574-587

42. David Ribes, and Thomas A. Finholt. 2009. The long now of infrastructure: Articulating tensions in development. In P. Edwards, G. C. Bowker, S. Jackson, & R. Williams (Eds.), Special Issue on eInfrastructure in the Journal of the Association for Information Systems, 10 (5), 375–398

43. David Ribes, and Thomas A. Finholt. 2007. Tensions across the scales: Planning infrastructure for the long- term. Proceedings of the 2007 international ACM conference on Supporting group work, Sanibel Island, Florida, USA (pp. 229 – 238). New York: ACM Press

44. David Ribes, and Charlotte P. Lee. 2010. Sociotechnical Studies of Cyberinfrastructure and e-Research: Current Themes and Future Trajectories. Computer Supported Cooperative Work (2010) 19:231–244

45. Corina Sas, Irni Eliana Kahairuddin. 2017. Design for Trust: An Exploration of the Challenges and Opportunities of Bitcoin Users, Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems
46. Susan Leigh Star, and Karen Ruhleder. 1996. Steps toward an ecology of infrastructure: design and access for large information systems. Information Systems Research, 7 (1), 111–134
47. Susan Leigh Star. 1999. The ethnography of infrastructure. American Behavioral Scientist, 43, 377–3
48. Susan Leigh Star, and Geoffrey C. Bowker. 2002. How to infrastructure. In L. A. Lievrouw & S. Livingstone (Eds.), The Handbook of New Media (pp. 151–162). London: SAGE Publications.
49. Susan Leigh Star, and James R. Griesemer (1989). Institutional ecology, translations and boundary objects: Amateurs and professionals in Berkeleys museum of Vertebrate Zoology, 1907-39. Social Studies of Science 19: 387-420.
50. Michael Bedford Taylor. 2013. Bitcoin and The Age of Bespoke Silicon CASES '13: Proceedings of the 2013 International Conference on Compilers, Architectures and Synthesis for Embedded Systems
51. David Tilson, Kalle Lyytinen, Carsten Sørensen. 2010. Digital Infrastructures: The Missing IS Research Agenda. Research Commentary. Information Systems Research, Vol. 21, No. 4, December 2010, pp. 748-759
52. Ann Zimmerman, and Thomas Finholt. 2007. Growing an Infrastructure: The Role of Gateway Organizations in Cultivating New Communities of Users. Proceedings of the 2007 international ACM conference on Supporting group work. Pages 239-248
53. Aviv Zohar. 2015. Bitcoin under the Hood. Communications of the ACM, September 2015, Vol 58, No 9, 104-113

Infrastructural Grind: Introducing Blockchain in the Shipping Domain

Karim Jabbar
University of Copenhagen
Copenhagen, Denmark
karim@di.ku.dk

Pernille Bjørn
University of Copenhagen
Copenhagen, Denmark
pernille.bjorn@di.ku.dk

This paper was presented at GROUP '18 - the ACM Conference on Supporting Groupwork in Sanibel Island, Florida. It is published in the conference proceedings and available in the ACM Digital Library. DOI: https://doi.org/10.1145/3148330.3148345

Abstract

In this paper, we present ethnographic data unpacking three different accounts of how Blockchain technology gets introduced into the shipping domain. The results demonstrate that the shipping industry is based upon an information infrastructure with a socio-technical kernel comprising transaction practices between shippers, freight forwarders, ports, shipping lines, and other actors in the shipping industry. These practices are based upon standards, which have evolved over time and are embedded within the installed base of the infrastructure. We find that because of the inertia of the shipping infrastructure, Blockchain technology cannot be seamlessly introduced directly into the shipping domain. Instead, we introduce Infrastructural Grind as the activity by which domains (e.g. shipping) intersect with new technological infrastructures (e.g. Blockchain). Infrastructural grind occurs as a result of various infrastructuring activities taking place at different intersections between the two infrastructures, and is constituted of the sum of these manifestations. We propose that infrastructural grind is enacted through activities expressing elements of consolidation, permeability, and velocity.

Introduction

Blockchain is a technical protocol that fosters trust among users through the transparent recording of transactions in an immutable and tamper-proof shared duplicated ledger. When looking at Blockchain, and its growing number of protocol extensions, in the shape of user-facing applications, it can be seen as an information infrastructure [16] growing through the entrepreneurial actions of multifaceted actors involved in the infrastructure. While Blockchain is primarily known in the area of cryptocurrencies [41] [20] [12], such as Bitcoin [26], the technology is also being considered to be used in various other domains not directly linked to currency or finance [3]. Shipping is one of these domains [17].

The shipping domain is comprised of a multitude of actors distributed along a complex supply chain, who are directly and indirectly collaborating with each other in order to process shipments across the globe. Shipping can therefore be seen as an information infrastructure [9] [35], where the actions of individual shippers, freight forwarding companies, trucking companies, customs and dock workers, shipping lines, underwriting financial institutions, and insurance companies are contributing to *infrastructuring* [27] the domain. This global and distributed collaboration among trading entities is supported by a technological installed base comprising legacy systems and standardized procedures, which have consolidated over time. The consolidation results in embeddedness [37], by which implicit shared understanding of mundane trading practices is learnt as part of shipping apprenticeship [35]. Thus, the introduction of Blockchain in shipping will have to deal with possible socio-technical constraints occurring at the intersection of the emerging Blockchain information infrastructure, and the shipping domain. With a focus on the points of intersection between these two infrastructures, we ask the following research question: *What characterizes the process whereby Blockchain technology gets introduced into the shipping domain?*

In this paper, we present data gathered over the past 20 months, focusing on the activities of heterogeneous actors operating in the shipping domain, as well as within the emerging Blockchain information infrastructure. Examining our empirical data, we find that because of the inertia of the installed base of the shipping infrastructure, Blockchain technology cannot be seamlessly introduced directly into the shipping domain. As these two infrastructures (blockchain technology, and shipping domain) converge towards each other, an Infrastructural Grind takes place, and an area of reflexive permeation is created. The infrastructures rub off on each other so to speak. The process of infrastructural grind comprises the amalgamation of various infrastructuring activities taking place at different intersections between the two infrastructures. We propose that infrastructural grind is enacted through activities expressing elements of consolidation, permeability, and velocity. These infrastructuring activities taking place at the points of intersection between infrastructures can thus simultaneously reinforce the existing infrastructural consolidation, permeate into the domain that the technology seeks to enter, and do so at varying speeds depending on the level of infrastructural push-back. The contribution of this paper is a theoretical concept that can be used to better understand the activities occurring at the intersection of converging large-scale information infrastructures, and that can supplement existing user-centric accounts in HCI/CSCW of how technology gets appropriated in various settings.

The paper is structured as follows: Firstly, we provide a background on the literature on Blockchain in HCI, and cover the related literature in the field of information infrastructures with a focus on the intersections between infrastructures. Secondly, we present our method, and account for our data collection, analysis, and limitations. Thirdly, we unpack three empirical accounts of Blockchain in shipping, each displaying different manifestations of infrastructural grind. Finally, we discuss our findings in connection to the existing literature, highlight our contribution, and conclude.

Background

Blockchain in HCI

In the literature on human-centered computing, accounts of Bitcoin and Blockchain are beginning to emerge. Here the focus of the work has primarily been on cryptocurrencies, for instance emphasizing how users in the United States understand Bitcoin principles [12], what motivates Bitcoin users in Malaysia [34], and design implications based on interviews with Bitcoin users and non-users [12] [34]. In a recent CHI paper, Bitcoin has also been used in the design of a technology probe, Bitbarista, aiming at foregrounding the data complexities that are often black-boxed in the design of connected devices [28]. Here the focus was not on Bitcoin per se, but an investigation into the perceptions of users about the data transactions occurring in IoT devices. While these investigations and their theoretical contributions enhance our understanding of user interaction with Bitcoin, they tell us little about the complex process by which the underlying technology of Bitcoin – namely Blockchain can be propagated into diverse domains such as energy and shipping [3] [17]. Blockchain technology has potential beyond cryptocurrency, and our interest is to understand the very work which goes into bringing Blockchain technology into new types of domains, exemplified by the shipping context.

Blockchain as an Information Infrastructure

The process by which new technology is colliding with new domains of use is not easily captured and understood, thus we need analytical concepts, which can help us to illuminate the challenges. Analytically, we explore the process of propagating Blockchain to the domain of shipping as investigating the intersection between two converging information infrastructures. Information infrastructures is a socio-technical relational construct [9], which emphasizes the connections across technologies, artefacts, and standards, which serve as the foundation for interaction, yet blend with the background and become unnoticed [35]. Infrastructure is the underlying technological bedrock, which serve to support multiple applications. However, it is more than the technical foundation, it also includes the foundational ever-evolving and dynamic set of socio-technical relationships that are replicated and sustained through *infrastructuring* [27]. Infrastructuring activities growing the *Bitcoin* information infrastructure have in recent literature been articulated as the mixture of self-directed entrepreneurial actions performed by heterogeneous actors pursuing each their individual goals and respective business agendas [16]. What makes the Bitcoin information infrastructure different from our study of the intersections between Blockchain and the shipping domain is, that Bitcoin is one instance of a Blockchain information infrastructure. Bitcoin is one example (the most famous) of how the Blockchain technology can be used in a particular domain (in this case cryptocurrency). However, the use-case of Blockchain goes beyond Bitcoin, and can fundamentally evolve into different types of domains. However, when we refer to the Blockchain information infrastructure, we include the Bitcoin information infrastructure as well as the hundreds of others specific instances of Blockchain technology (e.g. Ethereum, Hyperledger, Tendermint, Corda, Cosmos, Polkadot, as well as private Blockchains and Distributed Ledger Technologies developed by start-ups). Thus, when we explore the intersections between the Blockchain information infrastructure and the information infrastructure of the shipping domain, we are considering the multiple instances of Blockchain technologies (public or private; permissioned or permissionless, interoperable or closed-off, etc.), which serve as the landscape of technologies [16], which are potentially intersecting with new domains of use.

Information infrastructures are embedded into multiple socio-technical arrangements, such as technological, organizational, or interpersonal arrangement [4] [37]. Such embeddedness includes the standards, legal frameworks, policies, and procedures involved in the particular domain (in the case of shipping the legal framework, paper trails, and international law structuring shipping across international ports). Standardization of information infrastructures can thus be seen as "*a process that increases irreversibility and decreases interpretative* *flexibility of the technologies while supporting flexibility of use and openness to further changes"* [15]. The existence of standards and procedures infrastructuring the work, also serve as enablers or constraints for further infrastructural development [30]. Standards and structures allow for certain changes but not for others. Infrastructuring work is thus consolidated as the information infrastructure evolves, and its installed base gains inertia [30]. Although embeddedness is a dynamic concept, whose relational features get reinforced, and evolve over time, the concept primarily focuses on a single information infrastructure in a current state of affairs, and how it historically has been embedded into socio-technical assemblages [38] [1] [2]. Our focus is different.

We are interested in understanding the *dynamic change*, or lack of change, which is involved in the initial infrastructural activities. We want to understand what the work of infrastructuring looks like, *prior* to the achievement of embeddedness into standards and policies, and entanglement with other information infrastructures [25]. We are exploring the infrastructuring [27] work of Blockchain into shipping *in the making* – before it reaches saturation. Interestingly, this also means that while the shipping domain has a clear information infrastructure developed over many years based upon numerous of standards, policies etc. – the Blockchain information infrastructure is new and malleable and involved in an ongoing development of its kernel [30] – as its installed base gains inertia. This mean that, when we explore the intersections, where the Blockchain and shipping information infrastructures collide, we must consider how actors are synergizing [4] and aligning objectives, artefacts, and practices with relevant stakeholders, and leveraging previously developed technological, relational, and organizational networks. Further, we must also consider the potential negative impacts - the reverse synergizing process [21] - that can potentially damage the long-term stability of an information infrastructure, when the adding of incompatible new actors cracks the inertia of the infrastructure.

Method

Introduction of Blockchain to the shipping domain is taking place at multiple sites globally. Thus, we cannot simply go to one place in order to study Blockchain in shipping, but instead we must attend to the various sites of design [6], which manifest the different ongoing initiatives. Inspired by multi-sited ethnography, we trace the intersections of Blockchain and shipping within different settings as a cultural phenomenon in diverse socio-technical situations [23]. To gain access to the core of where Blockchain in shipping in being created, we volunteered and became part of the community which drives this interest, and we thus engaged in participant-observations [13]. It was only through the dedicated engagement with the field, which makes it possible to be where the decisions are made, that we are able to study the infrastructuring work involved in introducing Blockchain to the shipping domain.

Data collection

Our data collection includes 15 interviews, as well as 150 hours conducting participatory observations in various types of companies involved in the shipping industry. This includes interviews and observations in both established technology companies and in start-ups that specifically design blockchain-based solutions for the shipping industry. The individuals and companies that we engaged with are geographically distributed all over the world, in countries such as Denmark, Sweden, the Netherlands, the United Kingdom, the Unites States, Israel, Hong Kong, and Australia. In terms of area of business, the companies were freight forwarders, ports, shipping lines, trucking companies, technology vendors, and start-ups. We conducted fifteen interviews, of no less than one hour, with these informants over Skype, and followed up with field visits and observations on-site in Denmark, the Netherlands and the United Kingdom. In certain cases, we came back to the same site several times to elaborate on our previous findings. The data collection design emerged as the data collection process unfolded. While some of the initial interviews were kept very structured and were not followed up on by other activities, others created opportunities for referrals to other stakeholders, or invitations to come visit. This happened intuitively as relationships developed with the informants and could not have been anticipated. We spent in excess of 150 hours observing the work of the companies, hereunder joining in and participating in various business meetings, internal strategy meetings, technology demonstrations, and speaking events at various conferences. By being active participants in the everyday routines of several of these informants, we were able to get a nuanced understanding of the type of work involved with the introduction of Blockchain in shipping. As a supplement to our interviews and our participant observations, we also looked at the online communication of issues related to Blockchain in shipping, as well as the related discussions on the topic in various media such as Reddit, coindesk.com, and porttechnology.org. By doing so, we could follow the digital traces left by relevant stakeholders in specific fora. Data was captured in field notes, documents, downloads of discussion fora, news articles, and audio-recorded interviews, which were later transcribed.

Data analysis

Because of the intuitive and unpredictable development of relationships with informants, we performed our data analysis simultaneously with ongoing data collection, rather than sequentially [7]. On an ongoing basis, we would work with the data available up to that point, through interview transcripts, observations notes, recording of business meetings, and so on. We worked at finding categories and concepts that would help explain the infrastructuring work going on at the intersection between the two converging infrastructures (Blockchain and shipping). Thereafter we organized possible categories by recurring themes and developed interpretative write-ups of the data that could serve as the basis for further engagement with the informants, old as well as new. Through this process, we could iteratively validate our findings regarding the observed infrastructuring practices taking place as Blockchain is introduced in the shipping domain. Throughout our analyses, we had to reorient the overall framing and underlying categorizations a number of time until we reached the final results, as presented in this paper.

Results

In the following we will present our empirical findings in the shape of three different accounts of how Blockchain technology is being introduced to the shipping domain. The accounts will show that the process whereby this emerging technology is appropriated by the established shipping information infrastructure can be characterized as an *infrastructural grind* between the established installed base of the shipping infrastructure and the emerging Blockchain information infrastructure. We will show how this grind is expressed differently in each one of these accounts, and how it is constituted by various degrees of infrastructure consolidation, and permeability to Blockchain technology, as well as variable adoption velocity.

Port-to-port shipping: Blockchain as a way to digitize documentation

Today, international shipping is structured around a streamlined process ensuring that a specific shipping containment can be moved efficiently from a point of origin to a specific delivery address at any other global location. This process whereby goods are shipped around the world relies heavily on the maritime sector, which funnels these goods onboard containers from port to port via fleets of increasingly large specialized ocean vessels. This practice of transporting goods across seas and oceans has become the subject of industry consolidation, standardizations and efficiency gains, particularly with the advent of container shipping, intermodal transport, and IT supported smart-ports. While the physical means of transportation across the oceans, and means of handling cargo at the ports have become more efficient and automated, the underlying methods of handling documentation requirements pertaining to specific shipping consignments have remained roughly the same. The type of paperwork required for the legal international shipment of consignments (stamps, lists, papers etc.) is built upon decades, if not centuries, of international policies and negotiations and we are constantly witnessing how additional requirements for shipping documentation is continuously increasing. Today processing an export consignment requires up to four separate contracts covering (i) export sales, (ii) carriage, (iii) finance, and (iv) cargo insurance. Within these four contracts up to 37 different official documents will need to be added (an average consignment will have more than 20 different related documents). These documents cover all aspects related to the commercial transaction, transportation, finance, and not least government documents such as certificates of origin, import and export licenses, sanitary certificates, documents claiming preferential tariff or VAT rebate, etc.

Processing the documentation for export consignments was a largely manual process until the advent of digital shipping portals in the late 1990's, which connect the shippers and freight forwarders to the global ocean shipping digital infrastructure. Today three large privately-owned portals, INTTRA, Cargosmart, and GT Nexus, handle the bulk of data transfer between supply chain actors in the shipping industry. The underlying technology of these portals is not based on data sharing, but rather data relaying though EDI messages (Electronic Data Interchange). More specifically two global standards for EDI messages set the framework for exchange in the shipping industry: ASC X12 in the United States, and UN/EDIFACT in most other parts of the world. Both standards provide a set of syntax rules to structure, an interactive exchange protocol, and provide a set of standard messages, which allow multi-country and multi-industry exchange of electronic business documents. Currently there are over 200 specific EDIFACT messages covering all aspects of the shipping industry. On the Graphic User Interface level of the shipping portals, the users can fill in data or import it from an XML format. The systems will then create and send the appropriate EDIFACT messages, and allow for the automatic generation of important documents.

It is against this backdrop, that the world's largest shipping company Maersk Line, in collaboration with IBM, recently announced that they had finalized a Proof of Concept project, in which they had shown the potential value of Blockchain technology in digitizing the extensive and fractured paper trail in the shipping industry. For the "paper trail project", IBM and Maersk have worked with a number of trading partners, government authorities and logistics companies, in order to collectively test the use of a Blockchain-based shared ledger aiming at simplifying the process by which the numerous required documents are currently being attached to a specific shipping consignment. More specifically the project involved shipping various goods on specifically selected port-to-port stretches, and collaborating with the producing companies, as well as customs in the port of origin and at the destination port. These participating actors would have access to view and/or amend the transactions on the shared Blockchain ledger as the shipment moved from one location to the next. An example of this, is that when a shipment of electronics goods on a Maersk Line container vessel is transported from the Port of Rotterdam to the Port of Newark, involving the Customs Administration of the Netherlands, the U.S. Department of Homeland Security Science and Technology Directorate, and U.S. Customs and Border Protection – all the transactions and documents are saved on the shared Blockchain ledger, making it possible for all actors to track all data in secure ways, without the need of a portal with transaction costs.

The main focus of the 'paper-trail' Blockchain project is the core of shipping, namely the port-to-port of the shipping supply chain. The port-to-port part of shipping is incidentally also the most standardized and structured part of the whole shipping industry in terms of existing legacy systems connected by standardized EDIFACT message relaying. This was highlighted by the Maersk head of IT strategy, describing the project in an interview a few months before the project became public:

> *"From a Maersk Line perspective, we started out this project in quite a restricted way. We have looked at full container loads, and primarily port-to-port" (Head of IT Strategy, Maersk Line, Interview, January 4th 2017)*

By adopting this project framing, IBM's Blockchain solution faces the constraints of the existing installed base of the shipping information infrastructure. Namely, a web of legacy systems, established procedures and business practices, communication protocols (e.g. UN-EDIFACT and ASC X12), which have been entrenched though decades of ongoing standardization in the shipping industry.

This legacy of practices, systems, and competitive considerations, has in the past been a constraint for digitization efforts in the shipping industry. Maersk has, in fact, previously experienced the difficulties and dilemmas associated with being first movers in rolling out new digital solutions for the industry at scale. According to the Maersk's Head of IT strategy, the company has also in the past been a first mover on new digital solutions in the industry, thus they known about the potential challenges in getting industry buy-in.

> *"[Maersk] spent decades trying to roll out such solutions (...) INTTRA being one of the very large ones. A shipping portal. We were one of the founding members and we have performed equity dilution along the way, and let in other companies."*. (Head of IT Strategy, Maersk Line, Interview, January 4th 2017)

Then, as now, the highly competitive situation between shipping companies results in a default distrust reaction to industrywide collaboration initiatives initiated by a single large player. This gives us a good indication that the Maersk/IBM Blockchain project was initially created as a technology push, and not so much as "business-first" project. Rather than taking broader implementation challenges into consideration, such as the willingness of all involved parties i.e. freight forwarders, customs, ports, shipping lines, and so on, to migrate their current systems onto the proposed Blockchain, the Maersk/IBM project seems to have primarily been designed by IBM to prove the technical feasibility of a Blockchain solution. In so doing IBM and Maersk are showcasing the possibility of Blockchain to simplify the paper trail process in the shipping industry, and are given the opportunity to market their Blockchain solution, which is now available on IBM Bluemix cloud servers. This was corroborated by the Maersk Head of IT:

> *"IBM is really eager to introduce Blockchain technology to the project… We are playing along. We have IBM as a technology partner. We do not have any objections against it. But we also do not want to take a technological risk on it. If IBM can make a compelling case, then fine. We will then go forward.". (Head of IT Strategy, Maersk, Interview, January 4th 2017)*

Blockchain technology is potentially a solution to the problem of distrust among industry players, as it does not rely on a commercial third party, but on a network of equal peers. However, while IBM's proposed solution, which is based on the Linux Foundation's Hyperledger Fabric Blockchain, is today available for corporate clients on IBM's Bluemix cloud service, the uptake among actors in the shipping industry does not seem to be happening. This can be interpreted as a strong "push-back" from the installed base of the information infrastructure. Over the past decades, the current infrastructure underlying the shipping industry has been consolidated both in terms of its overall IT architecture based on EDIFACT messaging, and in terms of the practices, perceptions, and competitive considerations that perpetuate the current system. The push back by the installed base of the shipping infrastructure is thus manifested in a basic distrust in the solution provided by Maersk/IBM resulting from previous similar efforts, as well as generalized perception that the current EDIFACT-based system, despite its shortcomings in terms of administrative documentation burden and lack of transparency, works well enough.

Bill of Lading, anonymous trading, and compliance: Could Blockchain be a solution?

The *Bill of Lading* is arguably the single most important document in the shipping industry, since it acts as a cargo receipt, contract of carriage, as well as a document of title across the stages of the supply chain. Currently, the Bill of Lading can be traded as the shipment is under way. This is, for instance, very common for bulk shipping of commodities. The owner of the cargo might be a financial speculator, and the title of ownership to various cargos will thus be bought and sold all while the shipment is still under way. Basically, goods are traded during transportation in the same way as stocks and bonds are traded in the financial sector. It is part of the characteristics of shippers and traders that they usually want to remain anonymous. The wish for anonymity is not necessarily a reflection of the fact that they have something to hide, but rather an indication of the fact that they are entitled to keep their trading positions a secret from their competitors. Because of this trading practice, it is currently not possible for the public, hereunder the actors in the shipping supply chain, to know the actual real-time ownership of a given cargo at any specific time during its journey across the seas. The manual transaction of physical bills of lading is perfectly legal, and implies that the holder of an original copy of a given Bill of Lading, which has been acquired through speculative trading, will have access to the cargo upon arrival to the destination port by mere presentation of the physical document. The identity of the final cargo owner will therefore only then be revealed to the broader public. In order to ensure that it is possible for whoever has acquired a Bill of Lading for a particular cargo, through speculation or otherwise, to be in possession of it at the time of arrival of the shipment to the destination port, it is common practice to air courier all the Bills of Lading connected to a specific ship via DHL or other similar services to the final port. Needless to say that this is a costly practice. While the current system surrounding the Bill of Lading, and the possibility of trading it anonymously, is a good protection for those engaging in speculative trade of a cargo, it also represents a compliance challenge for the banks, who are underwriting a specific shipping consignment through current trade finance mechanisms. In its simplest form, trade finance works by reconciling the divergent needs of an exporter and importer. While an exporter would prefer to be paid upfront by the importer for an export shipment, the risk to the importer is that the exporter may simply pocket the payment and refuse shipment. Conversely, if the exporter extends credit to the importer, the latter may refuse to make payment or delay it inordinately. A common solution to this problem in the area of trade finance is through the issuing of a letter of credit, which is opened in the exporter's name by the importer through a bank in his home country. The letter of credit essentially guarantees payment to the exporter by the bank issuing the letter of credit upon receipt of documentary proof that the goods have been shipped. In the context of a bulk commodity cargo being traded multiple times while the shipment is under way, the banks find themselves in a situation where it is difficult for them to fully live up to their legal requirements pertaining to KYC/AML (Know your customer / Anti-money laundering). These international rules, to which banks are subjected, are designed to curb criminal financial practices, and require banks and other financial institutions to do a thorough due diligence when onboarding new customers, and to have compliance procedures in place, which allow them to track the provenance of the financial flows that they facilitate. In the current situation, the banks find themselves in a grey zone, which could potentially be remedied by a Blockchain technology solution for shipping focusing on trade finance.

In December 2016, a consortium of actors from across the shipping supply chain joined a project under the Dutch Institute for Advanced Logistics (TKI Dinalog), aiming at creating a Blockchain technology solution in specific trade finance use cases for shipment. The consortium is made up of 16 partners the main ones being ABN AMRO (bank), Port of Rotterdam (port), SmartPort (private-public organization), Royal Flora Holland (florist conglomerate), and the Technical University of Delft. The project is an initiative by the Dutch Ministry of Economic Affairs, which is part of a broader effort to create a Netherlands Blockchain Centre of Excellence. The mandate of the project is to investigate use cases within trade finance, and to develop Proof of Concept pilots based on identified problems, and a tailored technical solution based on Blockchain. In this connection, TU Delft will be looking into building an open-source Blockchain that can be tested developing a Prof-of-Concept.

One of the members of the Blockchain team at the Port of Rotterdam tells us that the consortium so far has mainly been driven by the Dutch bank ABN AMRO, and that it is them that have been pushing to get trade finance on the agenda. Furthermore, he tells us that one of the bank's current concerns is particularly linked to issues of not knowing the identities of the parties that they are underwriting as a bank. He explains:

> *"From the perspective of ABN, they want to know who is the owner (of the consignment). Who are they dealing with? If the owner ends up being on a list of companies that we cannot trade with, well then ABN has a problem… and we will know it only (the identity of the owner) when the shipment arrives here at the port". (Member of the Blockchain Team at the Port of Rotterdam, Field Visit, March 14th 2017)*

Clearly the concern for full transparency of the identity of shippers is driving ABN AMRO to push for a solution that will allow the bank to live up to its compliance requirements. Simultaneously the bank seeks to de-risk its letter of credit engagements with customers in the shipping industry through a smart contract feature in the proposed Blockchain solution, which would trigger automated payments upon delivery, thus making the current letter of credit process less cumbersome, and less risky.

Our informant at the Port of Rotterdam exemplifies this:

> *"That's the main focus of our project currently. We want to attach automatic payments through smart contracts. So, for example, if Maersk offloads a container in the (port)*

terminal, then at that specific moment they can get paid. Or at every stage of the shipment events could trigger other specific payments." (Member of the Blockchain Team at the Port of Rotterdam, Field Visit, March 14th 2017)

The ongoing discussion within the consortium is currently figuring out which technical capabilities the ideal Blockchain solution for the consortium should have in order to address the challenges described above. This means that fundamental issues, such as whether the Blockchain should be private or public is not decided yet. Private means creating a consortium Blockchain, which only partners have access to (e.g. Hyperledger), while public mean that the solution will be based upon an existing Blockchain to which everyone can post any transactions (e.g Ethereum). A public Blockchain would ensure that no specific actor would own the solution, instead it would be shared broadly as a sort of public good on which various players in the industry could potentially build the needed applications. However, there are a number of constraints both technological and legal, that would make it impossible to build a solution for shipping based on one of the established public Blockchains. One major technological constraint inherent to current public Blockchains pertains to the issue of scalability, which for Bitcoin and Ethereum for instance, means that the current technological features of these Blockchains would not be able to handle transactions in the thousands per second [15], which would be necessary if all the current trade finance transactions should be put on one of these specific Blockchains. Furthermore, legal requirements in terms of data storage would dictate that personal and sensitive data about a company's customers must be stored on servers (physical or cloud) that are fully controlled by the company itself, and not a shared ledger that is public and "ownerless". Likewise, the territoriality of transactions would ultimately also become an issue if current public Blockchains were used at scale in shipping, in the sense that these Blockchains currently do not have the capability to record the specific location of transactions. This could have legal implications in terms of which jurisdiction possible disputes would fall under. As our source at the Port of Rotterdam puts it:

"*Yes, there are quite a number of constraints. I see a semi private or private Blockchain as a faster way to go forward, both from a scalability side and also from a security or Know Your Customer side" (Member of the Blockchain Team at the Port of Rotterdam, Interview, March 14th 2017)*

A private Blockchain would indeed not be as constrained technologically. It would be able to scale faster because it could be designed with a much higher blocksize cap (allowing for more transactions per block), and it would most importantly be able to provide transparency about the identity of the participants, which today is a legal requirement in finance, as we have seen.

Paradoxically, this added transparency of the identity of participants might actually be a prohibitive factor in the mass adoption of such a Blockchain solution. Traders speculating in bulk shipments might indeed value their anonymity of transaction more than the simplified trade finance element than a potential Blockchain solution designed along those lines would afford. Based on past cases in the industry, one can indeed see that previous attempts at digitizing the Bill of Lading (Bolero, Essdocs) have not really succeeded at a larger scale. In these systems, generating and trading a Bill of Lading requires a registration with a validated identity, which might in itself deter bulk traders from using these systems. This point has been corroborated with several of our industry informants, hereunder the Head of IT Strategy at Maersk Line.

¨Container-weight rules: an opportunity for Blockchain implementation at the fringes?

In 2016, the International Maritime Organization (IMO) implemented a new regulation aimed at improving the safety onboard container ships, by putting in place reporting requirements that would ensure a proper weight balancing of containers as they are being loaded onto vessels. The intension behind this initiative by the maritime industry was to prevent accidents due to improper loading, and to avoid the loss of lives at sea. Practically speaking, this new regulation, called SOLAS VGM (Safety of Lives at Sea - Verified Gross Mass), requires an EDI data transmission of the weight of each container to the shipping line prior to the container's arrival to the loading port. This will ensure that the port can plan the loading sequence of containers in advance and be certain that the overall load balance of the vessel is within a tolerable safety range. While this regulation seems to make a lot of sense from a safety and process management perspective, it turned out that the required reporting of container weight was not enabled by the existing IT infrastructure of the shipping industry. So, as the date of entry into force of this regulation got closer, actions needed to be taken in order to update the existing infrastructure. The shipping portals and shipping lines were slow to amend their systems, thus opening up an opportunity for start-ups to build applications that could solve this imminent problem.

Marine Transport International (MTI), a UK freight forwarder and technology solutions provider, saw this imminent regulation requirement as an opportunity to introduce a Blockchain-enabled application to the market, which simultaneously aims at solving the problem of weight reporting, and as an added bonus, at fundamentally re-designing the reporting flow in the industry. The MTI solution, named SOLAS VGM to reflect the specific need it addresses, aims at leveraging the new legal requirements in order to extend the reach of the shipping infrastructure into the landside of operations, and to connect previously disconnected actors in the shipping infrastructure. As MTIs founder and CEO puts it:

"What really came as an opportunity to us, was the SOLAS VGM requirements. We now had a hook into the market that would allow us to introduce our Blockchain-based solution to the landside of the shipping supply chain". (Founder and CEO of MTI, Field Study, London, April 12th 2017)

The landside of the shipping supply chain, that the MTI founder refers to, is comprised of the multitudes of operators and intermediaries that channel the flow of physical goods from the source, be it a factory, warehouse, farm, mine, or private household downstream until the point where the goods are loaded onto an ocean vessel. During this journey, the goods will typically be subjected to so-called intermodal exchange whereby the contents of the cargo is transferred from one mode of transportation to the next. Cargo for instance, arriving on a freight train, can get transferred to a truck via a transloader. The truck then drives the cargo to a freight forward processing terminal. Here it gets added to other cargo items and put into in a standard shipping container, which is then transported to a weighbridge and then driven to the port for customs clearance, and loading onto a high tonnage container ship destined to another country or continent. This flow of goods from multiple sources and via various modes of transport is not as streamlined as the one taking place on ocean vessels travelling between major ports. The Founder of MTI explains that

"The port-to-port part of the supply chain is well established. It might be old-school and rely on EDIFACT messaging between data silos, but it works. Getting people to change their ways will be hard". (Founder and CEO of MTI, Field Study, London, May 30th 2017)

The coordination between actors involved in the port-to-port portion of shipping is indeed very much standardized by interoperable IT systems and notification procedures between relevant entities at the relevant time. The need for tugboat and piloting services, for instance, is mostly known by the ports in advance prior to the arrival of a ship, and likewise the contents of the shipments is often sent in advance for customs clearance at the destination port even prior to the departure of the vessel from the port of origin. This is particularly true for the customs procedures related to importing goods into the United States. In fact, under the rules of the US Customs and Border Protection Agency, a so-called import security filing (ISF) is required no later than 24 hours prior to loading the cargo onto the US-bound sea vessel. These examples illustrate how the highly-integrated kernel of the shipping infrastructure, albeit based on a "simple" EDI data relay structure, stands in contrast to the fragmented and unsynchronized landside supply chain that is characterized by numerous stakeholders with sporadic coordination. This lack of coordination is what MTI's Blockchain-based solution aims at addressing.

More specifically, SOLAS VGM allows for the integration with already existing weighbridges via API, and using these weighbridges as data collection points from where weight data is recorded onto a Blockchain and transmitted to the specific shipping lines in any format required. In doing so, the weighed containers will be automatically cleared to enter the loading port, the truckers using the system will avoid bottlenecks at the port gates, and they will simultaneously improve safety on the roads as overloaded trucks will be detected at an early stage. The ports will in advance know the provenance of the containers driving towards the port, and will thus be better able to plan their resources accordingly. In order to onboard users, i.e. shippers and freight forwarders on the landside, MTI offers a solution that at the application level looks exactly like what they would be familiar with, and that solves a very specific imminent problem, namely transmitting weight data. In other words, MTI primarily focuses on highlighting the simplicity and narrow practical application of their SOLAS VGM solution. However, what in reality happens at the weighbridges, is that weight data is not the only thing being recorded on the Blockchain. The mandatory weighing is in fact used as an opportunity to record more than 40 different data points that are relevant for the ongoing journey of the container downstream. These data points include, but are not limited to, container size, type and number, shipping line, haulier, commodity and its description, plus all associated paperwork, including any regulatory and customs clearance documentation. This means that an added benefit to using the SOLAS VGM system is that it not only transmits the required VGM information, but also allows to connect a whole range of upstream actors that have traditionally been unconnected due to the multitude of individualized systems used to manage various small-scale operations. In the words of MTI's founder:

> *"For us, it doesn't matter if customers work with legacy EDIFACT systems or have API connectivity. We can connect people together, whether they're carriers, agents, hauliers, ports, shippers, consignees or forwarders, sharing one version of the truth through the blockchain." (Founder and CEO of MTI, Interview, Skype, December 6th 2016)*

Practically speaking, this means that while MTI underplays the importance of the underlying technology that their solution is built on, in order to attract users for a specific imminent use-case (reporting of container weight), it is in reality working at transforming the documentation flow in the shipping industry. It is creating a "one-stop shop" for capturing all relevant data pertaining to a shipment consignment, and avoiding push back by the established system, by offering seamless interoperability with all actors through APIs. Furthermore, it is connecting actors on the landside and providing transparency into the supply chain further upstream than what was previously possible.

MTI's end goal is in many ways similar to other players in the domain, namely to transform the old EDI-based system, and allow for better data sharing and new revenue stream opportunities. The road leading to this goal is however different. Instead of focusing their attention right at the kernel of the shipping infrastructure, which we have shown has a tendency to push back, MTI is employing a roll-out strategy aimed at the fringes of the shipping information infrastructure. Furthermore, instead of focusing on the technical features of the underlying Blockchain technology, MTI is starting at the application-level first by addressing a specific problem with a user-friendly application.

Discussion

Interestingly, and perhaps not surprising, our data clearly demonstrates that to fully comprehend the potential of bringing in new technology into shipping industry, we have to address the complex socio-technical infrastructure, which makes up the very foundation of shipping. In fact, our data shows that the shipping information infrastructure has a socio-technical kernel [30] comprised of transaction practices between a diverse set of trading actors, which allow them to organize the transportation of goods across the globe. This organization of trade flows also allows for the ongoing trading of assets being shipped while en-route, as well as facilitating financial settlements related to specific shipping consignments. Furthermore, the current infrastructure is not something which is simply altered. Instead, we found that the installed base of the technologies supporting interaction in the shipping domain is based upon standards which have evolved and have been embedded [37] over time. As the actors in the shipping industry go about their mundane daily routines of processing consignments along predefined transportation pathways, by using EDIFACT-based message relaying systems, they are making the resources of the infrastructure available [30] to the millions of private shippers and business entities relying on their services. So, one could say that by compiling the required paperwork connected to a particular shipping cargo, hereunder the very important Bill of Lading, the shippers and freight forwarders are enacting a standardized procedure that will allow an exporter of a shipment of goods to have it delivered to a specific geographical location in the world.

These standardized procedures make access available to the shipping information infrastructure in terms of efficiency, intermodal integration, and legal compliance. Simultaneously, these same procedures also reinforce the existing installed base of the information infrastructure, which allow it to be sustained over time, while also unlocking enablers as well as constraints for further infrastructural embedding [4] [37]. For instance, we can argue that it is the pre-existing installed base of standardization work, embodied in a commonly agreed upon protocol and syntax (UN-

EDIFACT), which has allowed for the emergence of shipping portals such as INTTRA, through which the shippers and freight forwarders can push EDI messages to the next link in the supply chain. While the creation of INTTRA reinforces the shipping information infrastructure and sustains its installed base, it also creates constraints, as we saw in the case of Blockchain. It is the installed base of the shipping information infrastructure, which makes it difficult for Blockchain to be implemented in the shipping domain, because the inertia does not allow for penetration, such as we saw in the account of the IBM/Maersk "paper trail" project.

In order to better explore the characteristics of the ongoing interplay taking place when entrepreneurial actions [16] 'push' the Blockchain information infrastructure and the shipping information infrastructures against each other, we have introduced the notion of *Infrastructural Grind.* Infrastructural grind refers to the processes by which two information infrastructures grind against each other, and potentially how new technological infrastructures succeeds in penetrating the new domain. By introducing infrastructural grind, we propose a new way to look at the process through, which emerging technology is appropriated in established business domains.

Previous work on infrastructuring often focuses on the process by which a specific infrastructure is created and maintained through socio-technical actions [27]. However, our interest is a little different. While our overall interest is to understand the specificities of the Blockchain infrastructure, it is important that, when we study how the Blockchain infrastructure is created and maintained, we also direct our attention to the *intersection between infrastructures* (technology and domain), since the very work of constructing and evolving Blockchain is a process by which the technology wrestle with domain specific infrastructures. Infrastructural grind helps us to focus on the concrete ways this process unfolds.

Our three empirical accounts each depicted a unique case of how Blockchain technology is placed into infrastructural grind with the shipping industry with different results. Each case is thus a manifestation of an ongoing grind between infrastructures, whereby the properties of each respective infrastructure come into contact and "rub off" on each other. Infrastructural grind is different from synergizing activities [4] and reverse synergizing activities [21], in the sense that synergizing focuses on how a particular infrastructure is shaped while shaping a field, while grind activities focus on the dynamic reciprocal interplay occurring when two infrastructures intersect and exchange. In other words, the grind occurs as a result of various infrastructuring [27] activities taking place at different intersections between infrastructures, and is constituted of the sum of these manifestations. Infrastructural grind can therefore be seen as the aggregate of the simultaneously occurring processes whereby the features of Blockchain become part of the installed base of the shipping information infrastructure. To be sustainable, the infrastructural grind between infrastructures (domain and technology) must support a process of longitudes [31] [19], where every smaller attempt or experiment adds so the potential long-terms results making the Blockchain infrastructure sustainable.

Importantly, this grind not only results in Blockchain features being appropriated by the shipping domain, but also impacts the process whereby Blockchain technology itself creates new features to its kernel. As we have shown in our three accounts, Blockchain technology is not a monolithic entity, but rather a patchwork of independent and interconnected implementations catered to specific use cases. More specifically, we have shown that different technical solutions are used as underlying Blockchain, be it Hyperledger Fabric, a custom-made university-designed blockchain, or a solution developed by a small start-up. This illustrates that as infrastructural grind occurs, the actors involved in introducing Blockchain to the shipping domain will continuously develop new features to their Blockchain, and refine their specific codebase to address the specific requirements emerging from the ongoing infrastructural grind.

Our empirical accounts have shown us that the ongoing process of infrastructural grind takes place differently at different infrastructural intersections, and might take shorter or longer time to result in infrastructural embeddedness [37]. The grind can, for instance, result in a push back by the installed base of the shipping infrastructure, as we have seen in the IBM/Maersk case, where the solution has not so far moved beyond proof-of-concept. Differently, the grind can also provide an immediate opportunity to address issues of actors currently underserved by the current shipping infrastructure, as we have seen in the MTI case, where new legal issues concerning ‘weight’ turned out to be a way to enter the shipping infrastructure. Clearly, our three cases provide us with nuances inherent to infrastructural grind activities, so let us explore these in more details. Based on our data, we found that infrastructural grind was enacted through three different expressions, namely c*onsolidation*, *permeability*, and *velocity*. At each particular intersection in which the grind takes place, these enacted expressions will combine in different ways resulting in different manifestation of Blockchain in shipping. In the IBM/Maersk account, for instance, the intersection between technology and domain was centered at the core of the kernel of the shipping infrastructure. Here the level of consolidation in the existing installed base is high and its permeability on the part of a new technology such as Blockchain low. As a result of this the outcome has so far been restricted to a Proof-of Concept, and large-scale implementation of the proposed technological solution has not materialized. As we have seen the MTI account tells a different story, in which the entrepreneurial actions undertaken by the start-up have led it to address the fringe of the shipping infrastructure, where consolidation is weaker, and permeability higher, resulting in an onboarding of smaller previously underserved players on the landside of the shipping infrastructure. In these cases, the velocity at which the embedding of Blockchain technology into the installed base of the shipping information infrastructure occurs varies greatly.

As such, infrastructural grind does not have prescriptive properties, meaning that the concept and its constituting elements are not meant to imply favoring one type of enactment over another. It simply frames the infrastructuring activities taking place at the intersection of converging infrastructures (technology and domain) as an amalgamation of enactments displaying properties of consolidation, permeability, and velocity. All these enactments happen simultaneously as they are undertaken by a range of heterogeneous actors pursuing entrepreneurial goals. As this happens, permeation of Blockchain into the shipping domain will occur differently at different points of intersection, and at different speeds. This in turn results in the Blockchain information infrastructure itself appropriating elements gained from the infrastructural grind, which are then added to the collective imaginary of what Blockchain technology is, and leveraged [4] in future grinds with other domains.

Infrastructural Grind and its dimensions of consolidation, permeability, and velocity can thus be seen as theoretical concepts that can help us better understand the complex activities taking place as information infrastructures converge. Going forward, we see opportunities for further research in HCI and CSCW that aims at contextualizing occurrences of infrastructural grind in empirical cases that go beyond the shipping domain and Blockchain technology. Such mappings of infrastructural patterns of consolidation, permeability and velocity could, for instance, supplement more user-centric approaches for explaining the appropriation of a given technology into a pre-existing setting [18], and highlight the simultaneousness of ongoing entrepreneurial activities and associated enablers and constraints, which contribute to infrastructural embeddedness.

Conclusion

In this paper, we had a very specific interest in examining the process through which Blockchain technology is introduced to the shipping domain. Our focus has therefore specifically been aimed at the points of infrastructural intersection between technology and domain. Firstly, we found that shipping is an information infrastructure with a socio-technical kernel that is consolidated over time though the infrastructuring activities of freight forwarders, trucking companies, ports, shipping lines, financial institutions underwriting cargo transactions, insurance companies, and other stakeholders in the shipping industry. This consolidated infrastructural kernel tends to push back at emerging new technologies attempting to enter and become part of its installed base. Secondly, we proposed *infrastructural grind* as a concept to understand the activities taking place at the intersection between converging information infrastructures, in this case the Blockchain and the shipping information infrastructure. Infrastructural grind is the process whereby two converging infrastructures rub-off on each other though heterogeneous infrastructuring activities, which are enacted at various points of intersection between the two infrastructures. Thirdly, we've shown that the infrastructuring activities taking place at these points of intersection are displaying elements of *consolidation, permeability*, and *velocity*. This means that infrastructural grind is enacted at different points of intersection between infrastructures through a specific combination of these elements. Depending on the specific intersection, the grind will result in consolidation of existing installed bases, such as when the port-to-port portion of the shipping supply chain is the target of Blockchain deployment, or permeation, such as when Blockchain technology is aimed at the fringes of the industry and the previously unserved by the current infrastructure. These two simultaneously occurring activities result in a multi-velocity path toward embeddedness of Blockchain in shipping. Slow at the core of the infrastructure, and faster at the fringes. Collectively, these deployment activities all result in the further development of Blockchain technology per se, and the expansion of the collective understanding of what Blockchain is, and what it can do, which in turn will inform future infrastructural grinds with other domains.

References

1. Madeleine Akrich, Michel Callon, and Bruno Latour. 2002. The key to sucess in innovation Part 1: The art of interessement. International journal of innovation management 6(2): 187-206.
2. Madeleine Akrich, Michel Callon, and Bruno Latour. 2002. The key to success in innovation Part 2: The art of choosing good spokespersons. *International journal of innovation management* 6(2): 207-225.
3. James Basden, and Michael Cottrell. 2017. How Utilities Are Using Blockchain to Modernize the Grid, *Harvard Business Review*, March 2017
4. Matthew Bietz, Eric P. S. Baumer, and Charlotte P. Lee. 2010. Synergizing in cyberinfrastructure development. *Computer Supported Cooperative Work* (JCSCW)

5. Pernille Bjørn, and Carsten Østerlund. 2014. Sociomaterial-Design: Bounding technologies in practice. Springer.

6. Pernille Bjørn, and Nina Boulus-Rødje. 2015. The multiple intersecting sites of design in CSCW research. *Computer Supported Cooperative Work (CSCW): An International Journal* 24(3): 319-351.

7. Pernille Bjørn, and Nina Boulus. 2011. Dissenting in reflective conversations: Critical components of doing action research. *Action Research Journal* 9(3): 282-302.

8. Jeanette Blomberg, and Helena Karasti. 2013. Reflections on 25 Years of Ethnography in CSCW. *Computer Supported Cooperative Work* (CSCW) August 2013, Volume 22, Issue 4, pp 373-423

9. Geoffrey C. Bowker, and Susan Leigh Star. 1999. Sorting things out – Classifications and its consequences. MIT Press

10. Geoffrey C. Bowker. 1994. Science on the run: Information management and industrial geophysics at Schlumberger, 1920–1940. Cambridge: The MIT

11. Paul N. Edwards, Geoffrey C. Bowker, Steven J. Jackson, and Robin Williams. 2009. Introduction: an agenda for infrastructure studies. Special Issue on e-Infrastructure of the *Journal of the Association for Information Systems*, 10(5), 364–374

12. Xianyi Gao, Gradeigh D. Clark, and Janne Lindqvist. 2016. Of Two Minds, Multiple Addresses, and One Ledger: Characterizing Opinions, Knowledge, and Perceptions of Bitcoin Across Users and Non-Users, *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* Pages 1656-1668

13. R. Stuart Geiger, and David Ribes. 2011. Trace Ethnography: Following Coordination through Documentary Practices. *Proceedings of the 44th Hawaii International Conference on System Sciences*.

14. Ole Hanseth, and Margunn Aanestad. 2003. Design as bootstrapping. On the evolution of ICT networks in health care. *Methods of information in medicine* 42 (4), 384-391

15. Ole Hanseth, Eric Monteiro, and Morten Hatling. 1996. Developing information infrastructure: the tension between standardisation and flexibility. *Science, Technology and Human Values*, 11(4), 407–426.

16. Karim Jabbar, and Pernille Bjørn. 2017. Growing the Blockchain Information Infrastructure, *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*

17. Karim Jabbar, Deanna MacDonald, Simon Ousager. 2017. Token Gesture*? FutureNautics*, Issue 15, Q2 2017, Quaterly

18. Margaret Jack, Jay Chen, and Steven J. Jackson. 2017.. Infrastructure as Creative Action: Online Buying, Selling, and Delivery in Phnom Penh, *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*

19. Helena Karasti, Karen S. Baker, and Florence Millerand. 2010. Infrastructure time: long-term matters in collaborative development. *Computer Supported Cooperative Work* (JCSCW)

20. Erol Kazan, Chee-Wee Tan, and Eric T. K. Lim. 2015. Value Creation in Cryptocurrency Networks: Towards a Taxonomy of Digital Business Models for Bitcoin Companies. *PACIS 2015 Proceedings. Pacific Asia Conference on Information Systems.*

21. Tue Odd Langhoff, Mikkel Hvid Amstrup, Peter Mørck, and Pernille Bjørn. 2016. Infrastructures for healthcare: From synergy to reverse synergy. *Health Informatics Journal*.

22. Charlotte P. Lee, Paul Dourish, and Gloria Mark. 2009. The human infrastructure of cyberinfrastructure. *Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work* (pp. 483 – 492). New York: ACM Press

23. George E. Marcus. 1995. Ethnography in/of the World System: The Emergence of Multi-Sited Ethnography. *Annual Review of Athropology, Vol. 24, 95-117*

24. Bill Mauer, Taylor C. Nelms, and Lana Swartz. 2013. “When perhaps the real problem is money itself”!: the practical materiality of Bitcoin. *Social Semiotics*, 2013

25. Eric Monteiro, Neil Pollock, Ole Hanseth, and Robin Williams. 2013. From Artefacts to Infrastructures. *Computer Supported Cooperative Work: The Journal of Collaborative Computing (JCSCW)*, 22(4), 575–607

26. Satoshi Nakamoto. 2008. Bitcoin: A Peer-to-Peer Electronic Cash System. Retrieved form bitcoin.org (5 February 2016)

27. Volkmar Pipek, and Volker Wulf. 2009. Infrastructuring: towards and integrated prespective on the design and use of information technology. *Journal of the association of information systems*.Volume 10, issue 5, May 2009, 306 – 332.

28. Larissa Pschetz, Ella Tallyn, Rory Gianni, and Chris Speed. 2017. Bitbarista: Exploring Perceptions of Data Transactions in the Internet of Things, *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*

29. David P. Randall E. Ilana Diamant, Charlotte P. Lee. 2015, Creating Sustainable Cyberinfrastructures, *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* Pages 1759-1768

30. David Ribes. 2014. The Kernel of a Research Institution. *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing.* Pages 574-587

31. David Ribes, and Thomas A. Finholt. 2009. The long now of infrastructure: Articulating tensions in development. In P. Edwards, G. C. Bowker, S. Jackson, & R. Williams (Eds.), Special Issue on eInfrastructure in the *Journal of the Association for Information Systems*, 10 (5), 375–398

32. David Ribes, and Thomas A. Finholt. 2007. Tensions across the scales: Planning infrastructure for the long- term. *Proceedings of the 2007 international ACM conference on Supporting group work, Sanibel Island, Florida*, USA (pp. 229 – 238). New York: ACM Press

33. David Ribes, and Charlotte P. Lee. 2010. Sociotechnical Studies of Cyberinfrastructure and e-Research: Current Themes and Future Trajectories. *Computer Supported Cooperative Work* (2010) 19:231–244

34. Corina Sas, Irni Eliana Kahairuddin. 2017. Design for Trust: An Exploration of the Challenges and Opportunities of Bitcoin Users, *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*

35. Susan Leigh Star, and Karen Ruhleder. 1996. Steps toward an ecology of infrastructure: design and access for large information systems. *Information Systems Research*, 7 (1), 111–134

36. Susan Leigh Star. 1999. The ethnography of infrastructure. *American Behavioral Scientist*, 43, 377–3

37. Susan Leigh Star, and Geoffrey C. Bowker. 2002. How to infrastructure. In L. A. Lievrouw & S. Livingstone (Eds.), The Handbook of New Media (pp. 151–162). London: SAGE Publications.

38. Susan Leigh Star, and James R. Griesemer (1989). Institutional ecology, translations and boundary objects: Amateurs and professionals in Berkeleys museum of Vertebrate Zoology, 1907-39. *Social Studies of Science* 19: 387-420.

39. David Tilson, Kalle Lyytinen, Carsten Sørensen. 2010. Digital Infrastructures: The Missing IS Research Agenda. Research Commentary. *Information Systems Research*, Vol. 21, No. 4, December 2010, pp. 748-759

40. Ann Zimmerman, and Thomas Finholt. 2007. Growing an Infrastructure: The Role of Gateway Organizations in Cultivating New Communities of Users. *Proceedings of the 2007 international ACM conference on Supporting group work*. Pages 239-248

41. Aviv Zohar. 2015. Bitcoin under the Hood. *Communications of the ACM*, September 2015, Vol 58, No 9, 104-113

Permeability, Interoperability and Velocity: Entangled Dimensions of Infrastructural Grind at the Intersection of Blockchain and Shipping

Karim Jabbar
University of Copenhagen
Copenhagen, Denmark
karim@di.ku.dk

Pernille Bjørn
University of Copenhagen
Copenhagen, Denmark
pernille.bjorn@di.ku.dk

This paper was published in the ACM Transactions on Social Computing - Special Issue on Group '18 and Regular Papers, Volume 1 Issue 3, December 2018 DOI: 10.1145/3288800

Abstract

Blockchain can potentially be appropriated as a social computing technology, which enables transactions across people and artefacts via a large socio-technical information infrastructure constituted by the actions of multiple people and computers. However, Blockchain is not a social computing technology a priori; instead to emerge as one, much effort and work is required to radically transform existing domains, including wrestling with traditions, standards, and legacy. In this paper, we expand on previous work on Blockchain as an information infrastructure, and on the notion of infrastructural grind. Infrastructural grind allows us to analytically explore how the emerging Blockchain technology is appropriated into established business domains, in our case the shipping industry. We present ethnographic data unpacking three different accounts of infrastructural grind taking place at the intersection of the shipping and the Blockchain information infrastructures. The results demonstrate that infrastructural grind occurs as a result of various infrastructuring activities taking place at different intersections between the two infrastructures and is constituted of the sum of these activities. We propose a framework in which infrastructural grind is constituted of three entangled dimensions: permeability, interoperability and velocity. These socio-technical dimensions relate to infrastructural

properties such as legacy, embeddedness, and standards, as well as to technical properties of specific solutions deployed at specific points of infrastructural grind. Our analysis shows that these dimensions are enacted differently along the shipping supply chain, and depending on the dynamic interplay between them at various points of infrastructural grind. At different points in time the infrastructural grind between Blockchain and the shipping domain will thus manifest itself differently and at differential velocity.

Introduction

Blockchain is a technical protocol that fosters trust among users through the transparent recording of transactions in an immutable and tamper-proof shared duplicated ledger. When looking at Blockchain, and its growing number of protocol extensions, in the shape of user-facing applications, it can be seen as an information infrastructure [19] growing through the entrepreneurial actions of multifaceted actors involved in the infrastructure. While Blockchain is primarily known in the area of cryptocurrencies [48] [25] [14], such as Bitcoin [31], the technology is also being considered to be used in various other domains not directly linked to currency or finance [3]. Shipping and supply chain management are some of these domains [21], which have been predicted by industry observers to be ripe for transformation through Blockchain technology. This prediction of imminent adoption of Blockchain, coupled with the inherently physical nature of the shipping industry, are the main motivations for our inquiry into this domain.

The shipping domain is comprised of a multitude of actors distributed along a complex supply chain, who are directly and indirectly collaborating with each other in order to process shipments across the globe. Shipping can therefore be seen as an information infrastructure [9] [41], where the actions of individual shippers, freight forwarding companies, trucking companies, customs and dock workers, shipping lines, underwriting financial institutions, and insurance companies are contributing to *infrastructuring* [32] the domain. This global and distributed collaboration among trading entities is supported by a technological installed base comprising legacy systems and standardized procedures, which have consolidated over time. The consolidation results in embeddedness [43], by which implicit shared understanding of mundane trading practices is learnt as part of shipping apprenticeship [41]. The intersection between Blockchain and the shipping domain has previously been examined through the lens of *infrastructural grind* [20], which is the process through which an established domain-specific information infrastructure (shipping) gets into contact with an emerging technology infrastructure (Blockchain) at various points of intersection. Through this socio-technical process involving activities by heterogeneous actors engaged in infrastructuring activities, Blockchain gets introduced into the domain. In this paper, we continue this work and further unpack the constituting components of infrastructural grind, and ask the following research question: *What are the constituting elements of infrastructural grind, and how do these elements influence the enactment of infrastructural grid at different points of intersection between the shipping and the Blockchain information infrastructures?*

Exploring this question, we present data gathered over the past 20 months, focusing on the activities of heterogeneous actors operating in the shipping domain, as well as within the emerging Blockchain information infrastructure. Examining our empirical data, we find that because of the inertia of the installed base of the shipping infrastructure, Blockchain technology cannot be seamlessly introduced directly into the shipping domain. As these two infrastructures (Blockchain technology, and shipping domain) converge towards each other, an infrastructural grind takes place, and an area of reflexive permeation is created. The infrastructures rub off on each other so to speak. The process of infrastructural grind comprises the amalgamation of various infrastructuring activities taking place at different intersections between the two infrastructures. We propose that to fully understand this process, we need to pay attention to the details of infrastructural grind. We find that infrastructural grind is constituted of actors' expressions of *permeability*, *interoperability* and *velocity* in their concrete activities. These socio-technical dimensions are entangled in different ways at different points of intersection between infrastructures, and result in infrastructural grind materializing in various shapes at each one of these intersections, and at differential velocity.

More specifically, our discussion will show how *permeability* is related to infrastructural embeddedness in the sense that it acts as a driver and precursor to actual embedding - of Blockchain in this case - into multiple socio-technical arrangements. The way in which permeability is manifested is context-specific to localized areas of infrastructural grind, e.g. legacy systems, standards, regulations, competitive practices, as well as emergent as it is being enacted through the entrepreneurial actions of actors engaged in the particular infrastructural grind. Similarly, our analysis will show that *Interoperability* relates to the technological properties of the emerging technical infrastructure, and to the specifics of the technical solution deployed at a specific area of infrastructural grind. The reflexive interplay between permeability and interoperability that is enacted at the various areas of infrastructural grind results in an appropriation of Blockchain into the shipping domain at differential *velocity*. While certain

Blockchain projects, at specific point of infrastructural intersection, will display interoperability properties that enable an increased infrastructural permeation, other will result in more complex push-back scenarios and a lengthier process towards full embeddedness.

The contribution of this paper is an expansion on the theoretical concept of infrastructural grind, and an unpacking of its constituting parts. Understanding the process by which Blockchain technology can transform into a social computing technology that facilitates transactions in different domains is important, if we are to expand existing user-centric approaches within HCI and CSCW on technology appropriation, including emerging technologies.

The paper is structured as follows: Firstly, we contextualize the paper in relation to the current context of Blockchain and cryptocurrency. Here we critically divide the "hype" of cryptocurrency against the actual potential of Blockchain as a social computing technology. Moreover, we situate our work in the current literature on Blockchain within CSCW and HCI and argue for the information infrastructural lens as an approach to explore technology appropriation. Technology appropriation within social computing is a well-researched area, however we argue for how Blockchain technology challenges the ways in which we can think about technology appropriation in social computing. Secondly, we present our method, including a detailed account of our data collection, how we analyzed the data, as well as our limitations. Thirdly, in our result section, we demonstrate our empirical findings and unpack three specific accounts of Blockchain infrastructural grind in the shipping domain, each displaying different characteristics. Finally, we discuss our findings, and argue that intrastructural grind, and its constituting parts of *permeability*, *interoperability* and *velocity* can be seen as a relevant framework for understanding how emerging technologies get appropriated into new domains, and potentially evolve into fully operational social computing solutions.

The Blockchain and cryptocurrency context

At the time of writing this paper, Blockchain applied as cryptocurrency is arguably at the height of overinflated expectations, as coined by the Gartner hype cycle. What began in 2009 as an obscure protocol for peer-to-peer transactions of digital cash without the need for trusted third parties (Bitcoin), has in fact since then expanded to a global mainstream phenomenon. While our interest is in Blockchain appropriation in the shipping domain, we need to also consider the broader context of Blockchain, including the current hype of cryptocurrency. This is because the societal context of Blockchain and the general perceptions of the technology, and its applications by the broader public, impacts the concrete interest and possibilities of Blockchain appropriation in the shipping domain. The initial implementation of Blockchain as cryptocurrency, Bitcoin, has since 2009 been copied and modified into thousands of alternative digital coins (altcoins). These new protocol extensions have flourished in the shape of software wallets, vaults, point of sales (PoS) systems, Bitcoin ATMs, tracking software, online exchanges, mining pools, and so on. The breadth of the initiatives has created a complex ecosystem of services and vendors that gives cryptocurrency a materiality in the real world, despite the illusive and virtual nature of the technology. As larger segments of the population have gotten acquainted with cryptocurrencies, and intrigued by the prospective of fast speculative gains, the fiat value of Bitcoin and many other altcoins has greatly increased. So much indeed that many critics have started comparing the current state of cryptocurrency with the 17th century Dutch "tulip-mania", where speculative pressure drove the price of tulip bulbs to unsustainable highs leading to what many consider one of the first recorded bubble and burst cycles. Bitcoin, for instance, increased almost 2000% in value in 2017, peaking at almost 20.000USD/BTC in December 2017. This growing cryptocurrency-mania is further accelerated by the emergence of Initial Coin Offerings (ICOs) as a means to crowd-fund Blockchain projects through the issuing of a new coin/token. These coins/tokens are offered in sequential tranches awarding the early investors with a cheaper purchase price. The investor logic seems to be rooted in an expectation, substantiated or not, that the value of these coins will explode once they get introduced on cryptocurrency exchanges post-ICO. These ICOs are, very importantly, completely unregulated today, lacking due-diligence and accountability in terms of investor protection and guarantees that crowd-funded projects will indeed be executed as announced. Despite this fact, and the fact that scams have been abundant, ICOs have established themselves as a major investment vehicle eclipsing the venture capital model in 2017 in terms of aggregate sums invested.

In parallel to this growth and consolidation of cryptocurrency markets, the interest in the technology underlying these digital currencies has soared. The reason for this interest is the potential for broader application of the technology's principles in domains that go beyond cryptocurrency. This is also where our interest lies. At its core, Blockchain is indeed an umbrella term for systems that combine elements of (i) a replicated and shared distributed ledger, (ii) cryptographically secure transactions, and (iii) consensus algorithms for validation of these transactions. The transaction data stored on these distributed ledgers is generally bundled in blocks that are validated at specific time intervals and chained to previous blocks through a string of cryptographic hashes, thus the name Blockchain. Some more recent systems have all the above characteristics, but do not store the transaction data in chains of blocks. These are referred to as Distributed Ledger Systems (DLTs) but are generally considered part of the broader Blockchain category since they share the same underlying principles. While the original implementation of Blockchain, i.e. Bitcoin, is focused on the transaction of units of currency, Blockchains can in principle have many other uses, in the sense that virtually any form of relevant transaction data can be recorded in a shared ledger, such as for instance chain of custody records, identity documents, digital certificates, etc. Many industries have begun showing interest in the potential use of Blockchain technology, as witnessed by several large industry-specific consortia that have developed in order to investigate specific potential Blockchain use-cases. The financial sector, for instance, has launched the R3 consortium (r3.com), and several large players in the energy sector have signed up for the Web Energy Foundation (energyweb.org). Similarly, several initiatives have taken place in the shipping industry, both involving large corporates, banks, and small tech start-ups.

While most of the current hype surrounding Blockchain is primarily related to cryptocurrency, our paper targets a very specific part of the Blockchain domain, namely industry applications of Blockchain technology. More specifically our focus is on Blockchain as an emerging social computing technology, with an emphasis on the socio-technical infrastructuring activities that bring about the permeation of Blockchain into existing business domains – in this paper specifically the shipping domain.

Social computing, information infrastructures & Blockchain

In the literature on social computing, accounts of Bitcoin and Blockchain are beginning to emerge. Here the focus of the work has primarily been on cryptocurrencies, for instance emphasizing how users in the United States understand Bitcoin principles [14], what motivates Bitcoin users in Malaysia [40], and design implications based on interviews with Bitcoin users and non-users [14] [40]. This work emphasis the increased research interest in exploring the role Blockchain technology in actual use. In a recent CHI paper, Bitcoin has also been used in the design of a technology probe, Bitbarista, aiming at foregrounding the data complexities that are often black-boxed in the design of connected devices [33]. Here the focus was not on Bitcoin per se, but an investigation into the perceptions of users about the data transactions occurring in IoT devices. While these investigations and their theoretical contributions enhance our understanding of user interaction with Bitcoin, they tell us little about the underlying technology of Bitcoin – namely Blockchain. Blockchain has the potential to support social computing with areas of use where transactions play an important role. Blockchain can be appropriated as a social computing technology making transactions across people and artefacts possible through large socio-technical information infrastructures (like social computing platforms) constituted by the actions of multiple people and computers (e.g. tech entrepreneurs) [18]. However, Blockchain is not a social computing technology a priori. Instead, to become a social computing technology, the multiple heterogeneous actors engaged in the concrete domain are required to invest effort, resources, and work when trying to transform existing established domains, including wrestling with traditions, standards, and legacy. For Blockchain to be propagated into diverse domains such as energy and shipping [3] [21], there is still a long way – and current results are more likely to be imaginaries [22] rather than concrete initiatives. Blockchain technology has potential beyond cryptocurrency, and our interest is to understand the very work which goes into bringing Blockchain technology into new types of domains, exemplified by the shipping context.

To explore appropriation of Blockchain technology into existing domains and its emergence as a large-scale social computing technology, we need analytical concepts, which can help us to illuminate the challenges. We do so in this paper by investigating the intersection between two converging information infrastructures – namely the technology (Blockchain) and the practice (shipping).

Information infrastructures is a socio-technical relational construct [10], which emphasizes the connections across technologies, artefacts, and standards, which serve as the foundation for interaction, yet blend with the background and become unnoticed [41]. Infrastructure is the underlying technological bedrock, which serve to support multiple applications. However, it is more than the technical foundation, it also includes the foundational ever-evolving and dynamic set of socio-technical relationships that are replicated and sustained through *infrastructuring* [32]. In design terms, infrastructuring can be seen as long term meta design, i.e. design-after-design [12], whereby future users of Blockchain systems get recast as user-designers that customize and extend the devices and features associated with the Blockchain domain. Through these infrastructuring actions it becomes apparent that large scale information infrastructures such as Blockchain are “grown”, rather than designed in a traditional sense. In our context, we therefore see Infrastructuring activities in the Blockchain domain as expressions of design-after - design whereby the infrastructure gets shaped and sustained by a mixture of self-directed entrepreneurial actions performed by heterogeneous actors each pursuing their individual goals and respective business agendas [19].

What makes the Bitcoin information infrastructure different from our study of the intersections between Blockchain and the shipping domain is, that Bitcoin is one instance of a Blockchain information infrastructure. Bitcoin is one example (the most famous) of how the Blockchain technology can be used in a particular domain (in this case cryptocurrency). However, the use-case of Blockchain goes beyond Bitcoin, and can fundamentally evolve into different types of domains. However, when we refer to the Blockchain information infrastructure, we include the Bitcoin information infrastructure as well as the hundreds of others specific instances of Blockchain technology (e.g. Ethereum, Hyperledger, Tendermint, Corda, Cosmos, Polkadot, as well as private Blockchains and Distributed Ledger Technologies developed by start-ups). Thus, when we explore the intersections between the Blockchain information infrastructure and the information infrastructure of the shipping domain, we are considering the multiple instances of Blockchain technologies (public or private; permissioned or permissionless, interoperable or closed-off, etc.), which serve as the landscape of technologies [19], which are potentially intersecting with new domains of use.

Information infrastructures are embedded into multiple socio-technical arrangements, such as technological, organizational, or interpersonal arrangement [4] [43]. Such embeddedness includes the standards, legal frameworks, policies, and procedures involved in the particular domain (in the case of shipping the legal framework, paper trails, and international law structuring shipping across international ports). Standardization of information infrastructures can thus be seen as "*a process that increases irreversibility and decreases interpretative flexibility of the technologies while supporting flexibility of use and openness to further changes"* [18]. The existence of standards and procedures infrastructuring the work, also serve as enablers or constraints for further infrastructural development [35]. Standards and structures allow for certain changes but not for others. Infrastructuring work is thus consolidated as the information infrastructure evolves, and its installed base gains inertia [35]. Although embeddedness is a dynamic concept, whose relational features get reinforced, and evolve over time, the concept primarily focuses on a single information infrastructure in a current state of affairs, and how it historically has been embedded into socio-technical assemblages [44] [1] [2]. Our focus is different.

We are interested in understanding the *dynamic change*, or lack of change, which is involved in the initial infrastructural activities. We want to understand what the work of infrastructuring looks like, *prior* to the achievement of embeddedness into standards and policies, and entanglement with other information infrastructures [30]. We are exploring the infrastructuring [32] work of Blockchain into the shipping domain *in the making* – before it reaches saturation.

This means that we are specifically looking at the points of intersection between the shipping domain, the information infrastructure of which has developed over many decades and is based upon numerous standards, policies etc., and the Blockchain information infrastructure, which is new and malleable and involved in an ongoing development of its kernel [35] – as its installed base gains inertia. When we explore the intersections, where the Blockchain and shipping information infrastructures enter into infrastructural grind [20], we must therefore consider how actors are synergizing [4] and aligning objectives, artefacts, and practices with relevant stakeholders, and leveraging previously developed technological, relational, and organizational networks. Further, we must also consider the potential negative impacts - the reverse synergizing process [26] - that can potentially damage the long-term stability of an information infrastructure, when the adding of incompatible new actors cracks the inertia of the infrastructure. Thus, in this paper, we analytically consider the appropriation of Blockchain technology into the shipping domain and its emergence as a social computing technology that can facilitate the work practices within the shipping industry. We view it as a process by which two information infrastructures collide and both become transformed. We are interested in the infrastructural grind [20] occurring between technology and domain, and more specifically in the nature of this grind's constituting elements, and its enactment at different points of intersection between the shipping and the Blockchain information infrastructures.

Method

Introduction of Blockchain to the shipping domain is taking place at multiple sites globally. Thus, we cannot simply go to one place in order to study Blockchain in shipping, but instead we must attend to the various sites of design [6], which manifest the different ongoing initiatives. Inspired by multi-sited ethnography, we trace the intersections of Blockchain and shipping within different settings as a cultural phenomenon in diverse socio-technical situations [28]. To gain access to the core of where Blockchain in shipping is being created, we volunteered and became part of the community which drives this interest, and we thus engaged in participant-observations [16]. It was only through the dedicated engagement with the field, which makes it possible to be where the decisions are made, that we are able to study the infrastructuring work involved in introducing Blockchain to the shipping domain.

Data collection

Our data collection includes 15 interviews, as well as 150 hours conducting participatory observations in various types of companies involved in the shipping industry. This includes interviews and observations in both established technology companies and in start-ups that specifically design Blockchain-based solutions for the shipping industry. The individuals and companies that we engaged with are geographically distributed all over the world, in countries such as Denmark, Sweden, the Netherlands, the United Kingdom, the Unites States, Israel, Hong Kong, and Australia. In terms of area of business, the companies were freight forwarders, ports, shipping lines, trucking companies, technology vendors, and start-ups. We conducted fifteen interviews, of no less than one hour, with these informants over Skype, and followed up with field visits and observations on-site in Denmark, the Netherlands and the United Kingdom. In certain cases, we came back to the same site several times to elaborate on our previous findings. The data collection design emerged as the data collection process unfolded. While some of the initial interviews were kept very structured and were not followed up on by other activities, others created opportunities for referrals to other stakeholders, or invitations to come visit. This happened intuitively as relationships developed with the informants and could not have been anticipated. We spent in excess of 150 hours observing the work of the companies, hereunder joining in and participating in various business meetings, internal strategy meetings, technology demonstrations, and speaking events at various conferences. By being active participants in the everyday routines of several of these informants, we were able to get a nuanced understanding of the type of work involved with the introduction of Blockchain in shipping. As a supplement to our interviews and our participant observations, we also looked at the online communication of issues related to Blockchain in shipping, as well as the related discussions on the topic in various media such as Reddit, coindesk.com, and porttechnology.org. By doing so, we could follow the digital traces left by relevant stakeholders in specific fora. Data was captured in field notes, documents, downloads of discussion fora, news articles, and audio-recorded interviews, which were later transcribed.

Type of intervention	**Number of Organizations/companies**	**Accumulated hours of intervention**
Interviews	2 Ports, 2 shipping lines, 1 trucking company, 2 freight forwarders, 5 tech start-ups, 1 large tech vendors, 2 maritime authorities	25 hours + transcription and analysis

Workshops	3 as participant, 1 as facilitator, Total industry participants: 75	15 hours + 40 hours preparation
Participant observations	2 start-ups	150 hours + documentation and transcription
Field studies	3 times to London, 1 time to Rotterdam	25 hours of meetings during 6 travel days

Date analysis

Because of the intuitive and unpredictable development of relationships with informants, we performed our data analysis simultaneously with ongoing data collection, rather than sequentially [7]. On an ongoing basis, we would work with the data available up to that point, through interview transcripts, observations notes, recording of business meetings, and so on. We worked at finding categories and concepts that would help explain the infrastructuring work going on at the intersection between the two converging infrastructures (Blockchain and shipping). Thereafter we organized possible categories by recurring themes and developed interpretative write-ups of the data that could serve as the basis for further engagement with the informants, old as well as new. Through this process, we could iteratively validate our findings regarding the observed infrastructuring practices taking place as Blockchain is introduced in the shipping domain. Throughout our analyses, we had to reorient the overall framing and underlying categorizations a number of time until we reached the final results, as presented in this paper

Results

In the following we will present our empirical findings in the shape of three different accounts of *infrastructural grind* between the established installed base of the shipping infrastructure and the emerging Blockchain information infrastructure. We will empirically show how this grind is expressed differently in each one of these accounts, which represent different intersections between the two infrastructures. These findings will subsequently become the basis for our discussion section, where we will interpret the results through the entangled dimensions of *permeability, interoperability*, and *velocity* that we briefly presented in the introduction, and thus build out our theoretical contribution.

Port-to-port shipping: Infrastructural Grind at the core of the shipping Kernel

Today, international shipping is structured around a streamlined process ensuring that a specific shipping containment can be moved efficiently from a point of origin to a specific delivery address at any other global location. This process whereby goods are shipped around the world relies heavily on the maritime sector, which funnels these goods onboard containers from port to port via fleets of increasingly large specialized ocean vessels. This practice of transporting goods across seas and oceans has become the subject of industry consolidation, standardizations and efficiency gains, particularly with the advent of container shipping, intermodal transport, and IT supported smart-ports. While the physical means of transportation across the oceans, and means of handling cargo at the ports have become more efficient and automated, the underlying methods of handling documentation requirements pertaining to specific shipping consignments have remained roughly the same. The type of paperwork required for the legal international shipment of consignments (stamps, lists, papers etc.) is built upon decades, if not centuries, of international policies and negotiations and we are constantly witnessing how additional requirements for shipping documentation is continuously increasing. Today processing an export consignment requires up to four separate contracts covering (i) export sales, (ii) carriage, (iii) finance, and (iv) cargo insurance. Within these four contracts up to 37 different official documents will need to be added (an average consignment will have more than 20 different related documents). These documents cover all aspects related to the commercial transaction, transportation, finance, and not least government documents such as certificates of origin, import and export licenses, sanitary certificates, documents claiming preferential tariff or VAT rebate, etc.

Processing the documentation for export consignments was a largely manual process until the advent of digital shipping portals in the late 1990's, which connect the shippers and freight forwarders to the global ocean shipping digital infrastructure. Today three large privately-owned portals, INTTRA, Cargosmart, and GT Nexus, handle the bulk of data transfer between supply chain actors in the shipping industry. The underlying technology of these portals is not based on data sharing, but rather data relaying though EDI messages (Electronic Data Interchange). More specifically two global standards for EDI messages set the framework for exchange in the shipping industry: ASC X12 in the United States, and UN/EDIFACT in most other parts of the world. Both standards provide a set of syntax rules to structure, an interactive exchange protocol, and provide a set of standard messages, which allow multi-country and multi-industry exchange of electronic business documents. Currently there are over 200 specific EDIFACT messages covering all aspects of the shipping industry. On the Graphic User Interface level of the shipping portals, the users can fill in data or import it from an XML format. The systems will then create and send the appropriate EDIFACT messages, and allow for the automatic generation of important documents.

It is against this backdrop, that the world's largest shipping company Maersk Line, in collaboration with IBM, recently announced that they had finalized a Proof of Concept project, in which they had shown the potential value of Blockchain technology in digitizing the extensive and fractured paper trail in the shipping industry. For the "paper trail project", IBM and Maersk have worked with a number of trading partners, government authorities and logistics companies, in order to collectively test the use of a Blockchain-based shared ledger aiming at simplifying the process by which the numerous required documents are currently being attached to a specific shipping consignment. More specifically the project involved shipping various goods on specifically selected port-to-port stretches, and collaborating with the producing companies, as well as customs in the port of origin and at the destination port. These participating actors would have access to view and/or amend the transactions on the shared Blockchain ledger as the shipment moved from one location to the next. An example of this, is that when a shipment of electronics goods on a Maersk Line container vessel is transported from the Port of Rotterdam to the Port of Newark, involving the Customs Administration of the Netherlands, the U.S. Department of Homeland Security Science and Technology Directorate, and U.S. Customs and Border Protection – all the transactions and documents are saved on the shared Blockchain ledger, making it possible for all actors to track all data in secure ways, without the need of a portal with transaction costs.

The main focus of the 'paper-trail' Blockchain project is the core of shipping, namely the port-to-port of the shipping supply chain. The port-to-port part of shipping is incidentally also the most standardized and structured part of the whole shipping industry in terms of existing legacy systems connected by standardized EDIFACT message relaying. This was highlighted by the Maersk head of IT strategy, describing the project in an interview a few months before the project became public:

> *"From a Maersk Line perspective, we started out this project in quite a restricted way. We have looked at full container loads, and primarily port-to-port" (Head of IT Strategy, Maersk Line, Interview, January 4th 2017)*

By adopting this project framing, IBM's Blockchain solution faces the constraints of the existing installed base of the shipping information infrastructure. Namely, a web of legacy systems, established procedures and business practices, communication protocols (e.g. UN-EDIFACT and ASC X12), which have been entrenched though decades of ongoing standardization in the shipping industry.

This legacy of practices, systems, and competitive considerations, has in the past been a constraint for digitization efforts in the shipping industry. Maersk has, in fact, previously experienced the difficulties and dilemmas associated with being first movers in rolling out new digital solutions for the industry at scale. According to the Maersk's Head of IT strategy, the company has also in the past been a first mover on new digital solutions in the industry, thus they known about the potential challenges in getting industry buy-in.

> *"[Maersk] spent decades trying to roll out such solutions (...) INTTRA being one of the very large ones. A shipping portal. We were one of the founding members and we have performed equity dilution along the way, and let in other companies."*. (Head of IT Strategy, Maersk Line, Interview, January 4th 2017)

Then, as now, the highly competitive situation between shipping companies results in a default distrust reaction to industrywide collaboration initiatives initiated by a single large player. This gives us a good indication that the Maersk/IBM Blockchain project was initially created as a technology push, and not so much as a "business-first" project. Rather than taking broader implementation challenges into consideration, such as the willingness of all involved parties i.e. freight forwarders, customs, ports, shipping lines, and so on, to migrate their current systems onto the proposed Blockchain, the Maersk/IBM project seems to have primarily been designed by IBM to prove the technical feasibility of a Blockchain solution. In so doing IBM and Maersk are showcasing the possibility of Blockchain to simplify the paper trail process in the shipping industry and are given the opportunity to market their Blockchain solution, which is now available on IBM Bluemix cloud servers. This was corroborated by the Maersk Head of IT:

> *"IBM is really eager to introduce Blockchain technology to the project… We are playing along. We have IBM as a technology partner. We do not have any objections against it. But we also do not want to take a technological risk on it. If IBM can make a compelling case, then fine. We will then go forward.". (Head of IT Strategy, Maersk, Interview, January 4th 2017)*

Blockchain technology is potentially a solution to the problem of distrust among industry players, as it does not rely on a commercial third party, but on a network of equal peers. However, while IBM's proposed solution, which is based on the Linux Foundation's Hyperledger Fabric Blockchain, is today available for corporate clients on IBM's Bluemix cloud service, the uptake among actors in the shipping industry does not seem to be happening. This can be interpreted as a strong "push-back" from the installed base of the information infrastructure. Over the past decades, the current infrastructure underlying the shipping industry has been consolidated both in terms of its overall IT architecture based on EDIFACT messaging, and in terms of the practices, perceptions, and competitive considerations that perpetuate the current system. The push back by the installed base of the shipping infrastructure is thus manifested in a basic distrust in the solution provided by Maersk/IBM resulting from previous similar efforts, as well as generalized perception that the current EDIFACT-based system, despite its shortcomings in terms of administrative documentation burden and lack of transparency, works well enough.

Bill of Lading: Infrastructural Grind and technology options for trade finance

The *Bill of Lading* is arguably the single most important document in the shipping industry, since it acts as a cargo receipt, contract of carriage, as well as a document of title across the stages of the supply chain. Currently, the Bill of Lading can be traded as the shipment is under way. This is, for instance, very common for bulk shipping of commodities. The owner of the cargo might be a financial speculator, and the title of ownership to various cargos will thus be bought and sold all while the shipment is still under way. Basically, goods are traded during transportation in the same way as stocks and bonds are traded in the financial sector. It is part of the characteristics of shippers and traders that they usually want to remain anonymous. The wish for anonymity is not necessarily a reflection of the fact that they have something to hide, but rather an indication of the fact that they are entitled to keep their trading positions a secret from their competitors. Because of this trading practice, it is currently not possible for the public, hereunder the actors in the shipping supply chain, to know the actual real-time ownership of a given cargo

at any specific time during its journey across the seas. The manual transaction of physical bills of lading is perfectly legal and implies that the holder of an original copy of a given Bill of Lading, which has been acquired through speculative trading, will have access to the cargo upon arrival to the destination port by mere presentation of the physical document. The identity of the final cargo owner will therefore only then be revealed to the broader public. In order to ensure that it is possible for whoever has acquired a Bill of Lading for a particular cargo, through speculation or otherwise, to be in possession of it at the time of arrival of the shipment to the destination port, it is common practice to air courier all the Bills of Lading connected to a specific ship via DHL or other similar services to the final port. Needless to say, that this is a costly practice.
While the current system surrounding the Bill of Lading, and the possibility of trading it anonymously, is a good protection for those engaging in speculative trade of a cargo, it also represents a compliance challenge for the banks, who are underwriting a specific shipping consignment through current trade finance mechanisms. In its simplest form, trade finance works by reconciling the divergent needs of an exporter and importer. While an exporter would prefer to be paid upfront by the importer for an export shipment, the risk to the importer is that the exporter may simply pocket the payment and refuse shipment. Conversely, if the exporter extends credit to the importer, the latter may refuse to make payment or delay it inordinately. A common solution to this problem in the area of trade finance is through the issuing of a letter of credit, which is opened in the exporter's name by the importer through a bank in his home country. The letter of credit essentially guarantees payment to the exporter by the bank issuing the letter of credit upon receipt of documentary proof that the goods have been shipped. In the context of a bulk commodity cargo being traded multiple times while the shipment is under way, the banks find themselves in a situation where it is difficult for them to fully live up to their legal requirements pertaining to KYC/AML (Know your customer / Anti-money laundering). These international rules, to which banks are subjected, are designed to curb criminal financial practices, and require banks and other financial institutions to do a thorough due diligence when onboarding new customers, and to have compliance procedures in place, which allow them to track the provenance of the financial flows that they facilitate. In the current situation, the banks find themselves in a grey zone, which could potentially be remedied by a Blockchain technology solution for shipping focusing on trade finance.
In December 2016, a consortium of actors from across the shipping supply chain joined a project under the Dutch Institute for Advanced Logistics (TKI Dinalog), aiming at creating a Blockchain technology solution in specific trade finance use cases for shipment. The consortium is made up of 16 partners the main ones being ABN AMRO (bank), Port of Rotterdam (port), SmartPort

(private-public organization), Royal Flora Holland (florist conglomerate), and the Technical University of Delft. The project is an initiative by the Dutch Ministry of Economic Affairs, which is part of a broader effort to create a Netherlands Blockchain Centre of Excellence. The mandate of the project is to investigate use cases within trade finance, and to develop Proof-of-Concept pilots based on identified problems, and a tailored technical solution based on Blockchain. In this connection, TU Delft will be looking into building an open-source Blockchain that can be tested developing a Proof-of-Concept.

One of the members of the Blockchain team at the Port of Rotterdam tells us that the consortium so far has mainly been driven by the Dutch bank ABN AMRO, and that it is them that have been pushing to get trade finance on the agenda. Furthermore, he tells us that one of the bank's current concerns is particularly linked to issues of not knowing the identities of the parties that they are underwriting as a bank. He explains:

> *"From the perspective of ABN, they want to know who is the owner (of the consignment). Who are they dealing with? If the owner ends up being on a list of companies that we cannot trade with, well then ABN has a problem… and we will know it only (the identity of the owner) when the shipment arrives here at the port". (Member of the Blockchain Team at the Port of Rotterdam, Field Visit, March 14th 2017)*

Clearly the concern for full transparency of the identity of shippers is driving ABN AMRO to push for a solution that will allow the bank to live up to its compliance requirements. Simultaneously the bank seeks to de-risk its letter of credit engagements with customers in the shipping industry through a smart contract feature in the proposed Blockchain solution, which would trigger automated payments upon delivery, thus making the current letter of credit process less cumbersome, and less risky.

Our informant at the Port of Rotterdam exemplifies this:

> *"That's the main focus of our project currently. We want to attach automatic payments through smart contracts. So, for example, if Maersk offloads a container in the (port) terminal, then at that specific moment they can get paid. Or at every stage of the shipment events could trigger other specific payments." (Member of the Blockchain Team at the Port of Rotterdam, Field Visit, March 14th 2017)*

The ongoing discussion within the consortium is currently figuring out which technical capabilities the ideal Blockchain solution for the consortium should have in order to address the challenges described above. This means that fundamental issues, such as whether the Blockchain should be private or public is not decided yet. Private means creating a consortium Blockchain, which only partners have access to (e.g. Hyperledger), while public mean that the solution will be based upon an existing Blockchain to which everyone can post any transactions (e.g Ethereum). A public Blockchain would ensure that no specific actor would own the solution, instead it would be shared broadly as a sort of public good on which various players in the industry could potentially build the needed applications. However, there are a number of constraints both technological and legal, that would make it impossible to build a solution for shipping based on one of the established public Blockchains. One major technological constraint inherent to current public Blockchains pertains to the issue of scalability, which for Bitcoin and Ethereum for instance, means that the current technological features of these Blockchains would not be able to handle transactions in the thousands per second [16], which would be necessary if all the current trade finance transactions should be put on one of these specific Blockchains. Furthermore, legal requirements in terms of data storage would dictate that personal and sensitive data about a company's customers must be stored on servers (physical or cloud) that are fully controlled by the company itself, and not a shared ledger that is public and "ownerless". Likewise, the jurisdiction of specific transactions would ultimately also become an issue if current public Blockchains were used at scale in shipping, in the sense that these Blockchains currently do not have the capability to record the specific location of transactions. This could have legal implications in terms of which jurisdiction possible disputes would fall under. As our source at the Port of Rotterdam puts it:

> "*Yes, there are quite a number of constraints. I see a semi private or private Blockchain as a faster way to go forward, both from a scalability side and also from a security or Know Your Customer side" (Member of the Blockchain Team at the Port of Rotterdam, Interview, March 14th 2017)*

A private Blockchain would indeed not be as constrained technologically. It would be able to scale faster because it could be designed with a much higher blocksize cap (allowing for more transactions per block), and it would most importantly be able to provide transparency about the identity of the participants, which today is a legal requirement in finance, as we have seen. Paradoxically, this added transparency of the identity of participants might actually be a prohibitive factor in the mass adoption of such a Blockchain solution. Traders speculating in bulk shipments might indeed value their anonymity of transaction more than the simplified trade finance element that a potential Blockchain solution designed along those lines would afford. Based on past cases in the industry, one can indeed see that previous attempts at digitizing the Bill of Lading (Bolero, Essdocs) have not really succeeded at a larger scale. In these systems, generating and trading a Bill of Lading requires a registration with a validated identity, which might in itself deter bulk traders from using these systems. This point has been corroborated with several of our industry informants, hereunder the Head of IT Strategy at Maersk Line.

Container-weight rules: Infrastructural Grind at the fringes of the shipping domain

In 2016, the International Maritime Organization (IMO) implemented a new regulation aimed at improving the safety onboard container ships, by putting in place reporting requirements that would ensure a proper weight balancing of containers as they are being loaded onto vessels. The intention behind this initiative by the maritime industry was to prevent accidents due to improper loading, and to avoid the loss of lives at sea. Practically speaking, this new regulation, called SOLAS VGM (Safety of Lives at Sea - Verified Gross Mass), requires an EDI data transmission of the weight of each container to the shipping line prior to the container's arrival to the loading port. This will ensure that the port can plan the loading sequence of containers in advance and be certain that the overall load balance of the vessel is within a tolerable safety range. While this regulation seems to make a lot of sense from a safety and process management perspective, it turned out that the required reporting of container weight was not enabled by the existing IT infrastructure of the shipping industry. So, as the date of entry into force of this regulation got closer, actions needed to be taken in order to update the existing infrastructure. The shipping portals and shipping lines were slow to amend their systems, thus opening up an opportunity for start-ups to build applications that could solve this imminent problem.

Marine Transport International (MTI), a UK freight forwarder and technology solutions provider, saw this imminent regulation requirement as an opportunity to introduce a Blockchain-enabled application to the market, which simultaneously aims at solving the problem of weight reporting, and as an added bonus, at fundamentally re-designing the reporting flow in the industry. The MTI solution, which was given the same name as the regulation and the derived need it addresses, namely SOLAS VGM, aims at leveraging the new legal requirements in order to extend the reach of the shipping infrastructure into the landside of operations, and to connect previously disconnected actors in the shipping infrastructure. As MTIs founder and CEO puts it:

> *"What really came as an opportunity to us, was the SOLAS VGM requirements. We now had a hook into the market that would allow us to introduce our Blockchain-based solution to the landside of the shipping supply chain". (Founder and CEO of MTI, Field Study, London, April 12th 2017)*

The landside of the shipping supply chain, that the MTI founder refers to, is comprised of the multitudes of operators and intermediaries that channel the flow of physical goods from the source, be it a factory, warehouse, farm, mine, or private household downstream until the point where the goods are loaded onto an ocean vessel. During this journey, the goods will typically be subjected to so-called intermodal exchange whereby the contents of the cargo is transferred from one mode of transportation to the next. Cargo for instance, arriving on a freight train, can get transferred to a truck via a transloader. The truck then drives the cargo to a freight forward processing terminal. Here it gets added to other cargo items and put into a standard shipping container, which is then transported to a weighbridge and then driven to the port for customs clearance, and loading onto a high tonnage container ship destined to another country or continent. This flow of goods from multiple sources and via various modes of transport is not as streamlined as the one taking place on ocean vessels travelling between major ports. The Founder of MTI explains that

> *"The port-to-port part of the supply chain is well established. It might be old-school and rely on EDIFACT messaging between data silos, but it works. Getting people to change their ways will be hard". (Founder and CEO of MTI, Field Study, London, May 30th 2017)*

The coordination between actors involved in the port-to-port portion of shipping is indeed standardized by interoperable IT systems and notification procedures between relevant entities at the relevant time. The need for tugboat and piloting services, for instance, is mostly known by the ports in advance prior to the arrival of a ship, and likewise the contents of the shipments is often sent in advance for customs clearance at the destination port even prior to the departure of the vessel from the port of origin. This is particularly true for the customs procedures related to importing goods into the United States. In fact, under the rules of the US Customs and Border Protection Agency, a so-called import security filing (ISF) is required no later than 24 hours prior to loading the cargo onto the US-bound sea vessel. These examples illustrate how the highly-integrated kernel of the shipping infrastructure, albeit based on a "simple" EDI data relay structure, stands in contrast to the fragmented and unsynchronized landside supply chain that is characterized by numerous stakeholders with sporadic coordination. This lack of coordination is what MTI's Blockchain-based solution aims at addressing.

More specifically, SOLAS VGM allows for the integration with already existing weighbridges via API, and using these weighbridges as data collection points from where weight data is recorded onto a Blockchain and transmitted to the specific shipping lines in any format required. In doing so, the weighed containers will be automatically cleared to enter the loading port, the truckers using the system will avoid bottlenecks at the port gates, and they will simultaneously improve safety on the roads as overloaded trucks will be detected at an early stage. The ports will in advance know the provenance of the containers driving towards the port, and will thus be better able to plan their resources accordingly. In order to onboard users, i.e. shippers and freight forwarders on the landside, MTI offers a solution that at the application level looks exactly like what they would be familiar with, and that solves a very specific imminent problem, namely transmitting weight data. In other words, MTI primarily focuses on highlighting the simplicity and narrow practical application of their SOLAS VGM solution. However, what in reality happens at the weighbridges, is that weight data is not the only thing being recorded on the Blockchain. The mandatory weighing is in fact used as an opportunity to record more than 40 different data points that are relevant for the ongoing journey of the container downstream. These data points include, but are not limited to, container size, type and number, shipping line, haulier, commodity and its description, plus all associated paperwork, including any regulatory and customs clearance documentation. This means that an added benefit to using the SOLAS VGM system is that it not only transmits the required VGM information, but also allows to connect a whole range of upstream actors that have traditionally been unconnected due to the multitude of individualized systems used to manage various small-scale operations. In the words of MTI's founder:

> *"For us, it doesn't matter if customers work with legacy EDIFACT systems or have API connectivity. We can connect people together, whether they're carriers, agents, hauliers, ports, shippers, consignees or forwarders, sharing one version of the truth through the blockchain." (Founder and CEO of MTI, Interview, Skype, December 6th 2016)*

Practically speaking, this means that while MTI underplays the importance of the underlying technology that their solution is built on, in order to attract users for a specific imminent use-case (reporting of container weight), it is in reality working at transforming the documentation flow in the shipping industry. It is creating a "one-stop shop" for capturing all relevant data pertaining to a shipment consignment, and avoiding push back by the established system, by offering seamless interoperability with all actors through APIs. Furthermore, it is connecting actors on the landside and providing transparency into the supply chain further upstream than what was previously possible.

MTI's end goal is in many ways similar to other players in the domain, namely to transform the old EDI-based system, and allow for better data sharing and new revenue stream opportunities. The road leading to this goal is however different. Instead of focusing their attention right at the kernel of the shipping infrastructure, which we have shown has a tendency to push back, MTI is employing a roll-out strategy aimed at the fringes of the shipping information infrastructure. Furthermore, instead of focusing on the technical features of the underlying Blockchain technology, MTI is starting at the application-level first by addressing a specific problem with a user-friendly application.

Discussion

Based on the three empirical accounts presented in the results section, as well as on related literature on information infrastructures, we will now build our argument aimed at addressing the research question that we set out to investigate. More specifically, we will unpack *permeability*, *interoperability*, and *velocity* as being the constituting elements of infrastructural grind and show how these mutually entangled concepts are being enacted through infrastructuring activities taking place at various points of intersection between shipping and Blockchain. In order to make our argument, we will first discuss how the inertia of the installed base of the shipping infrastructure, and associated standards and procedures is a source of enablers and constraints for future infrastructuring. Second, we will zoom in at the intersection between the shipping and Blockchain information infrastructures and discuss how our three empirical accounts of infrastructural grind are a manifestation of the dynamic reciprocal interplay occurring when two infrastructures intersect and exchange. Third and last, we will present and unpack the entangled concepts of permeability, interoperability and velocity, and discuss how these concepts can allow us to have a more complex understanding of the process through which emerging technology permeates into specific industry domains.

The infrastructural properties of the shipping kernel

Interestingly, and perhaps not surprisingly, our data clearly demonstrates that to fully comprehend the potential of bringing in new technology into shipping industry, we have to address the complex socio-technical infrastructure, which makes up the very foundation of

shipping. In fact, our data shows that the shipping information infrastructure has a socio-technical kernel [35] comprised of transaction practices between a diverse set of trading actors, which allow them to organize the transportation of goods across the globe. This organization of trade flows also allows for the ongoing trading of assets being shipped while en-route, as well as facilitating financial settlements related to specific shipping consignments. Furthermore, the current infrastructure is not something which is simply altered. Instead, we found that the installed base of the technologies supporting interaction in the shipping domain is based upon standards which have evolved and have been embedded [43] over time. As the actors in the shipping industry go about their mundane daily routines of processing consignments along predefined transportation pathways, by using EDIFACT-based message relaying systems, they are making the resources of the infrastructure available [35] to the millions of private shippers and business entities relying on their services. So, one could say that by compiling the required paperwork connected to a particular shipping cargo, hereunder the very important Bill of Lading, the shippers and freight forwarders are enacting a standardized procedure that will allow an exporter of a shipment
of goods to have it delivered to a specific geographical location in the world.
These standardized procedures make access available to the shipping information infrastructure in terms of efficiency, intermodal integration, and legal compliance. Simultaneously, these same procedures also reinforce the existing installed base of the information infrastructure, which allow it to be sustained over time, while also unlocking enablers as well as constraints for further infrastructural embedding [4] [43]. For instance, we can argue that it is the pre-existing installed base of standardization work, embodied in a commonly agreed upon protocol and syntax (UN-EDIFACT), which has allowed for the emergence of shipping portals such as INTTRA, through which the shippers and freight forwarders can push EDI messages to the next link in the supply chain. While the creation of INTTRA reinforces the shipping information infrastructure and sustains its installed base, it also creates constraints, as we saw in the case of Blockchain. It is the installed base of the shipping information infrastructure, which makes it difficult for Blockchain to be implemented in the shipping domain, because the inertia does not allow for penetration, such as we saw in the account of the IBM/Maersk “paper trail” project.

Infrastructural grind between Blockchain and the shipping domain

In order to better explore the characteristics of the ongoing interplay taking place when entrepreneurial actions [19] ‘push’ the Blockchain information infrastructure and the shipping information infrastructures against each other, we refer to the notion of *infrastructural grind*, which looks at the processes by which two information infrastructures grind against each other, and potentially how new technological infrastructures succeeds in penetrating the new domain. Previous work on infrastructuring often focuses on the process by which a specific infrastructure is created and maintained through socio-technical actions [32], or through design-after-design [12]. However, our interest is a little different. While our overall interest is to understand the specificities of the Blockchain infrastructure, it is important that, when we study how the Blockchain infrastructure is created and maintained, we also direct our attention to the *intersection between infrastructures* (technology and domain), since the very work of constructing and evolving Blockchain is a process by which the technology wrestle with domain specific infrastructures. Infrastructural grind helps us to focus on the concrete ways this process unfolds.

Our three empirical accounts each depicted a unique case of how Blockchain technology is placed into infrastructural grind with the shipping industry with different results. Each case is thus a manifestation of an ongoing grind between infrastructures, whereby the properties of each respective infrastructure come into contact and “rub off” on each other. Infrastructural grind is different from synergizing activities [4] and reverse synergizing activities [26], in the sense that synergizing focuses on how a particular infrastructure is shaped while shaping a field, while grind activities focus on the dynamic reciprocal interplay occurring when two infrastructures intersect and exchange. In other words, the grind occurs as a result of various infrastructuring [32] activities taking place at different intersections between infrastructures and is constituted of the sum of these manifestations. Infrastructural grind can therefore be seen as the aggregate of the simultaneously occurring processes whereby the features of Blockchain become part of the installed base of the shipping information infrastructure. To be successful, the infrastructural grind between infrastructures (domain and technology) must support a process of longitudes [36] [24], where every smaller attempt or experiment adds so the potential long-terms results making the Blockchain infrastructure sustainable.

Importantly, this grind not only results in Blockchain features being appropriated by the shipping domain, but also impacts the process whereby Blockchain technology itself creates new features to its kernel. As we have shown in our three accounts, Blockchain technology is not a monolithic entity, but rather a patchwork of independent and interconnected implementations catered to specific use cases. More specifically, we have shown that different blockchains and distributed ledgers can be used as an underlying technological foundation for technical systems, be it (i) Hyperledger Fabric, as in the Maersk/IBM case, (ii) a custom-made university-designed blockchain, as in the Bill of Lading case, or (iii) a DLT solution developed by a small start-up, as in the Solas VGM case. This illustrates that as infrastructural grind occurs, the actors involved in introducing Blockchain to the shipping domain will continuously develop new features to their Blockchain and refine their specific codebase to address the specific requirements emerging from the ongoing infrastructural grind.

Permeability, interoperability and velocity: entangled dimensions of infrastructural grind

Our empirical accounts have shown us that the ongoing process of infrastructural grind takes place differently at different infrastructural intersections and might take shorter or longer time to result in infrastructural embeddedness [43]. The grind can, for instance, result in a push back by the installed base of the shipping infrastructure, as we have seen in the IBM/Maersk case, where the solution has not so far moved beyond proof-of-concept. Differently, the grind can also provide an immediate opportunity to address issues of actors currently underserved by the current shipping infrastructure, as we have seen in the MTI case, where new legal issues concerning 'weight' turned out to be a way to enter the shipping infrastructure. Clearly, our three cases provide us with nuances inherent to infrastructural grind activities, so let us explore these in more details. Based on our data, we found that infrastructural grind is constituted by three entangled dimensions, namely *permeability*, *interoperability*, and *velocity*, as illustrated in Figure 1. At each particular intersection in which the grind takes place, these enacted expressions will combine in different ways resulting in different manifestation of Blockchain in shipping.

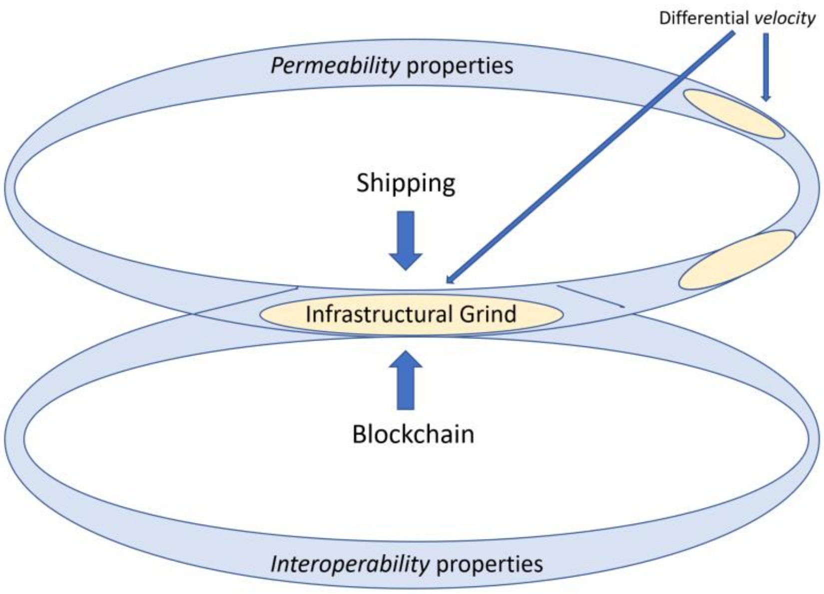


Fig. 1. Blockchain Infrastructural Grind applied to Shipping.

Permeability relates primarily to infrastructural properties of the established information infrastructure, in this case shipping i.e. kernel consolidation, legacy, standards, competitive considerations. As we have seen, these properties are unequally distributed at various areas of infrastructural grind, for instance more legacy and consolidation at the kernel of the shipping infrastructure as opposed to the fringes, such as the landside of the supply chain. Because of this, the degree of permeability between infrastructures is going to be different at different areas of intersection. In the IBM/Maersk account, for instance, infrastructural grind was centered at the core of the kernel of the shipping infrastructure. Here the level of consolidation in the existing installed base is high and its permeability on the part of a new technology such as Blockchain turned out to be low. As a result of this, the outcome has so far been restricted to a Proof-of-Concept, and large-scale implementation of the proposed technological solution has not materialized. The implementation continues to be an imaginary [22], the merits of which are negotiated with and among other relevant stakeholders. Conversely, the MTI account tells a different story, in which the entrepreneurial actions undertaken by the start-up have led it to address the fringe of the shipping infrastructure, where consolidation is weaker, and permeability higher, resulting in an onboarding of smaller previously underserved players on the landside of the shipping infrastructure. Permeability is thus related to embeddedness [43] in the sense that it is an infrastructural property of a given domain, which acts as a driver and precursor to actual embedding into multiple socio-technical arrangements [4] [43]. Rather than focusing on the grafting [39] of socio-technical features onto a solidifying information infrastructure, we see infrastructural grind, and its constituting parts, as a higher order process that shapes and alters both infrastructures (domain and technology) simultaneously. In this context, permeability can be seen not only as a feature of the domain (e.g. shipping), but also as an expression of potential future embeddedness resulting from infrastructural grind between an established domain and an emerging technology infrastructure. In that sense, permeability in the shipping information infrastructure is a manifested indication (or gauge) of the process leading to potential future technological, organizational and interpersonal assemblages, in which Blockchain will have become an integral part of the shipping infrastructure. It is thus both an enabler and a constraint [35] [15] for future embedding. Importantly, the manifestation of permeability is context-specific to localized areas of infrastructural grind, and emergent as it is being enacted through the entrepreneurial actions [19] of actors engaged in the particular infrastructural grind. In other words, permeability at a given point of intersection between infrastructures is invisible in a vacuum and can only be detected once infrastructural grind is initiated at that particular point.

Permeability occurs “in the making” as the infrastructural features of the particular point of intersection, e.g. legacy, standards, entrenched organizational practices, get challenged by a particular technical solution, e.g. a permissioned or permissionless Blockchain system. As such, permeability connotes a process rather than a state of acceptance/rejection of the new technology by the industry domain, and it furthermore implies various degrees of permeability as well as push-back, rather than a binary “permeability/non-permeability”.

Interoperability, on the other hand relates to the technological properties of the emerging technical infrastructure, and to the specifics of the technical solution deployed at a specific area of infrastructural grind, e.g. system replacement vs system adaption, permissioned system vs permissionless system. Depending on the area of infrastructural grind, into which a specific blockchain system in being deployed, as well as the state of the infrastructural properties (permeability) at that particular point of intersection, the interoperability features of the emerging technical infrastructure (Blockchain in this case) will either create a window of opportunity and thus enable [46] a higher degree of permeability, or not. One example from our results that illustrates considerations related to interoperability is the Dutch Bill of Lading case, which has shown us that the specific Blockchain options looked at by the consortium for solving KYC issues in the bulk trading business, do not only have technical feasibility implications, but also impact on the permeability at the particular area of infrastructural grind. If a public permissionless system is chosen for example, then anonymous transaction would be possible, making it easier to convince traders to use the system. This would in other words enable increased infrastructural permeability. On the flip side of that, however, such a system would not be compatible with banking regulations in the area of KYC, and would therefore not be implementable, thus seriously constraining increased permeability. Another example from our results illustrating interoperability’s impact on infrastructural permeability at the point of infrastructural grind is the Maersk case. Here the proposed solution was based on a systems-replacement logic, as opposed to a systems-adoption logic. The system would assume the migration of trade data from a multitude of existing legacy systems onto a new Blockchain powered system. While the technological features of the solution were good enough for a contained proof-of-concept project, its lack of interoperability with existing systems amplified the infrastructural push-back by actors in the shipping supply chain, and thus greatly constrained the permeability of the shipping infrastructure at the port-to-port level.

The reflexive interplay between permeability and interoperability features that is enacted at the various areas of infrastructural grind results in an appropriation of Blockchain into the shipping domain at differential *velocity.* While certain Blockchain projects, at specific point of infrastructural intersection, will display interoperability properties that enable an increased infrastructural permeation, other will result in more complex push-back scenarios and a lengthier process towards full embeddedness. As such, infrastructural grind does not have prescriptive properties, meaning that the concept and its constituting dimensions are not meant to imply favoring one type of enactment over another. It simply frames the infrastructuring activities taking place at the intersection of converging infrastructures (technology and domain) as an amalgamation of enactments displaying properties of permeability, interoperability and velocity. All these enactments happen simultaneously as they are undertaken by a range of heterogeneous actors pursuing entrepreneurial goals. As this happens, permeation of Blockchain into the shipping domain will occur differently at different points of intersection, and at different speeds. This in turn results in the Blockchain information infrastructure itself appropriating elements gained from the infrastructural grind, which are then added to the collective imaginary of what Blockchain technology is and leveraged [4] in future grinds with other domains.
Infrastructural grind and its dimensions of permeability, interoperability and velocity can thus be seen as theoretical concepts that can help us better understand the complex activities taking place as information infrastructures converge. Going forward, we see opportunities for further research in social computing that aims at contextualizing occurrences of infrastructural grind in empirical cases that go beyond the shipping domain and Blockchain technology. Such mappings of infrastructural patterns of permeability, interoperability and velocity could, for instance, supplement more user-centric approaches for explaining the appropriation of a given technology into a pre-existing setting [23], and highlight the simultaneousness of ongoing entrepreneurial activities and associated enablers and constraints, which contribute to infrastructural embeddedness.

Conclusion

As a step in better understanding how Blockchain technology can transform into a social computing technology that facilitates transactions in different domains via a large-scale socio-technical information infrastructure, our interest in this paper was to focus on the appropriation of Blockchain technology into the shipping domain. More specifically we set out to further unpack the notion of infrastructural grind, which focuses at points of infrastructural intersection between technology and domain, and to explore the constituting parts of this concept as they contribute to materializing future infrastructural embeddedness. Firstly, we found that the shipping infrastructure is consolidated over time though the infrastructuring activities of freight forwarders, trucking companies, ports, shipping lines, financial institutions underwriting cargo transactions, insurance companies, and other stakeholders in the shipping industry. This socio-technical legacy resulting from decades of enacted practices by heterogeneous infrastructuring agents has created standardized ways of making the resources of the infrastructural kernel available to various stakeholders, while simultaneously unlocking enablers and constraints for further infrastructural embedding. It is against this legacy that blockchain technology is entering into infrastructural grind. Secondly, we've shown that infrastructural grind can be seen as an amalgamation of the simultaneously occurring processes whereby the features of Blockchain become part of the installed base of the shipping information infrastructure. It is not a single occurrence, rather it is the sum of uncoordinated implementation attempts deployed by various entities across the shipping domain. Finally, we have demonstrated that infrastructural grind is constituted by the entangled dimensions of *permeability*, *interoperability* and *velocity*. More specifically we have shown how permeability is an infrastructural property of the domain (shipping), whereas interoperability is a feature of the emerging technology (Blockhain). The situated reflexive interplay between these features at specific points of intersection between infrastructures will influence the pathway of the emerging technology (Blockchain) towards full embeddedness in the appropriating industry (shipping). The velocity at which Blockchain thus gets fully appropriated into the shipping domain will depend on the specific interplay between the permeability and interoperability elements that get enacted by heterogeneous entrepreneurial actors at the specific points of intersection of the ongoing infrastructural grind. While certain deployment initiatives get push back from the kernel of the shipping information infrastructure, due to misalignment between permeability and interoperability features, others will get implemented into the shipping domain much faster. More rapid implementation of Blockchain into the shipping domain is likely to take place when the initiatives either address a more permeable section of the information infrastructure, such as the fringe of the shipping supply chain, or propose a specific technical solution that has interoperability features that are easier to adopt by the involved industry stakeholders. Once appropriated into the shipping domain, as an infrastructural socio-technical component of the shipping kernel, Blockchain can then properly emerge as a social computing technology that enables the gathering, representation, processing, use, and dissemination of information that is distributed across organizations and companies in the shipping supply chain.

References

1. Madeleine Akrich, Michel Callon, and Bruno Latour. 2002. The key to sucess in innovation Part 1: The art of interessement. *International journal of innovation management* 6(2): 187-206.
2. Madeleine Akrich, Michel Callon, and Bruno Latour. 2002. The key to success in innovation Part 2: The art of choosing good spokespersons. *International journal of innovation management* 6(2): 207-225.
3. James Basden, and Michael Cottrell. 2017. How Utilities Are Using Blockchain to Modernize the Grid, *Harvard Business Review*, March 2017
4. Matthew Bietz, Eric P. S. Baumer, and Charlotte P. Lee. 2010. Synergizing in cyberinfrastructure development. *Computer Supported Cooperative Work* (JCSCW)
5. Pernille Bjørn, and Carsten Østerlund. 2014. Sociomaterial-Design: Bounding technologies in practice. Springer.
6. Pernille Bjørn, and Nina Boulus-Rødje. 2015. The multiple intersecting sites of design in CSCW research. *Computer Supported Cooperative Work (CSCW): An International Journal* 24(3): 319-351.
7. Pernille Bjørn, and Nina Boulus. 2011. Dissenting in reflective conversations: Critical components of doing action research. *Action Research Journal* 9(3): 282-302.
8. Jeanette Blomberg, and Helena Karasti. 2013. Reflections on 25 Years of Ethnography in CSCW. *Computer Supported Cooperative Work* (CSCW) August 2013, Volume 22, Issue 4, pp 373-423
9. Geoffrey C. Bowker, and Susan Leigh Star. 1999. Sorting things out – Classifications and its consequences. MIT Press
10. Geoffrey C. Bowker. 1994. Science on the run: Information management and industrial geophysics at Schlumberger, 1920–1940. Cambridge: The MIT
11. Paul N. Edwards, Geoffrey C. Bowker, Steven J. Jackson, and Robin Williams. 2009. Introduction: an agenda for infrastructure studies. Special Issue on e-Infrastructure of the *Journal of the Association for Information Systems*, 10(5), 364–374
12. Pelle Ehn. 2008. Participation in Design Things. PDC '08 Proceedings of the Tenth Anniversary Conference on Participatory Design 2008. Pages 92-101
13. Chris Elsden, et.al. 2018. HCI for Blockchain: Studying, Designing, Critiquing and Envisioning Distributed Ledger Technologies, Workshop at CHI2018, Sunday April 22 2018 (forthcoming), Montreal, Canada
14. Xianyi Gao, Gradeigh D. Clark, and Janne Lindqvist. 2016. Of Two Minds, Multiple Addresses, and One Ledger: Characterizing Opinions, Knowledge, and Perceptions of Bitcoin Across Users

and Non-Users, *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* Pages 1656-1668

15. Jonathan Grudin and Rebecca E. Grinter (1995). "Ethnography and design." Computer Supported Cooperative Work (CSCW): An International Journal 3(1): 55-59.
16. R. Stuart Geiger, and David Ribes. 2011. Trace Ethnography: Following Coordination through Documentary Practices. *Proceedings of the 44th Hawaii International Conference on System Sciences*.
17. Ole Hanseth, and Margunn Aanestad. 2003. Design as bootstrapping. On the evolution of ICT networks in health care. *Methods of information in medicine* 42 (4), 384-391
18. Ole Hanseth, Eric Monteiro, and Morten Hatling. 1996. Developing information infrastructure: the tension between standardisation and flexibility. *Science, Technology and Human Values*, 11(4), 407–426.
19. Karim Jabbar, and Pernille Bjørn. 2017. Growing the Blockchain Information Infrastructure, *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*
20. Karim Jabbar, and Pernille Bjørn. 2018. Infrastructural Grind: Introducing Blockchain Technology in the Shipping Domain*, GROUP '18 Proceedings of the 2018 ACM Conference on Supporting Groupwork*, Pages 297-308
21. Karim Jabbar, Deanna MacDonald, Simon Ousager. 2017. Token Gesture*? FutureNautics*, Issue 15, Q2 2017, Quaterly
22. Yong Ming Kow and Caitlin Lustig. 2017. Imaginaries and Crystallization Processes in Bitcoin Infrastructuring, *Computer Supported Cooperative Work (CSCW)*. DOI 10.1007/s10606-017-9300-2
23. Margaret Jack, Jay Chen, and Steven J. Jackson. 2017.. Infrastructure as Creative Action: Online Buying, Selling, and Delivery in Phnom Penh, *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*
24. Helena Karasti, Karen S. Baker, and Florence Millerand. 2010. Infrastructure time: long-term matters in collaborative development. *Computer Supported Cooperative Work* (JCSCW)
25. Erol Kazan, Chee-Wee Tan, and Eric T. K. Lim. 2015. Value Creation in Cryptocurrency Networks: Towards a Taxonomy of Digital Business Models for Bitcoin Companies*. PACIS 2015 Proceedings. Pacific Asia Conference on Information Systems.*
26. Tue Odd Langhoff, Mikkel Hvid Amstrup, Peter Mørck, and Pernille Bjørn. 2016. Infrastructures for healthcare: From synergy to reverse synergy. *Health Informatics Journal*.

27. Charlotte P. Lee, Paul Dourish, and Gloria Mark. 2009. The human infrastructure of cyberinfrastructure. *Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work* (pp. 483 – 492). New York: ACM Press
28. George E. Marcus. 1995. Ethnography in/of the World System: The Emergence of Multi-Sited Ethnography. *Annual Review of Athropology, Vol. 24, 95-117*
29. Bill Mauer, Taylor C. Nelms, and Lana Swartz. 2013. “When perhaps the real problem is money itself”!: the practical materiality of Bitcoin. *Social Semiotics*, 2013
30. Eric Monteiro, Neil Pollock, Ole Hanseth, and Robin Williams. 2013. From Artefacts to Infrastructures. *Computer Supported Cooperative Work: The Journal of Collaborative Computing (JCSCW),* 22(4), 575–607
31. Satoshi Nakamoto. 2008. Bitcoin: A Peer-to-Peer Electronic Cash System. Retrieved form bitcoin.org (5 February 2016)
32. Volkmar Pipek, and Volker Wulf. 2009. Infrastructuring: towards and integrated prespective on the design and use of information technology. *Journal of the association of information systems*.Volume 10, issue 5, May 2009, 306 – 332.
33. Larissa Pschetz, Ella Tallyn, Rory Gianni, and Chris Speed. 2017. Bitbarista: Exploring Perceptions of Data Transactions in the Internet of Things, *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*
34. David P. Randall E. Ilana Diamant, Charlotte P. Lee. 2015, Creating Sustainable Cyberinfrastructures, *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* Pages 1759-1768
35. David Ribes. 2014. The Kernel of a Research Institution. Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing. Pages 574-587
36. David Ribes, and Thomas A. Finholt. 2009. The long now of infrastructure: Articulating tensions in development. In P. Edwards, G. C. Bowker, S. Jackson, & R. Williams (Eds.), Special Issue on eInfrastructure in the *Journal of the Association for Information Systems*, 10 (5), 375–398
37. David Ribes, and Thomas A. Finholt. 2007. Tensions across the scales: Planning infrastructure for the long- term. *Proceedings of the 2007 international ACM conference on Supporting group work, Sanibel Island, Florida*, USA (pp. 229 – 238). New York: ACM Press
38. David Ribes, and Charlotte P. Lee. 2010. Sociotechnical Studies of Cyberinfrastructure and e-Research: Current Themes and Future Trajectories. *Computer Supported Cooperative Work* (2010) 19:231–244

39. Terje Aksel Sanner, Tiwonge Davis Manda, and Petter Nielsen (2014) "Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation," Journal of the Association for Information Systems: Vol. 15 : Iss. 4 , Article 1
40. Corina Sas, Irni Eliana Kahairuddin. 2017. Design for Trust: An Exploration of the Challenges and Opportunities of Bitcoin Users, *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*
41. Susan Leigh Star, and Karen Ruhleder. 1996. Steps toward an ecology of infrastructure: design and access for large information systems. *Information Systems Research*, 7 (1), 111–134
42. Susan Leigh Star. 1999. The ethnography of infrastructure. *American Behavioral Scientist*, 43, 377–391
43. Susan Leigh Star, and Geoffrey C. Bowker. 2002. How to infrastructure. In L. A. Lievrouw & S. Livingstone (Eds.), The Handbook of New Media (pp. 151–162). London: SAGE Publications.
44. Susan Leigh Star, and James R. Griesemer (1989). Institutional ecology, translations and boundary objects: Amateurs and professionals in Berkeleys museum of Vertebrate Zoology, 1907-39. *Social Studies of Science* 19: 387-420.
45. David Tilson, Kalle Lyytinen, Carsten Sørensen. 2010. Digital Infrastructures: The Missing IS Research Agenda. Research Commentary. *Information Systems Research*, Vol. 21, No. 4, December 2010, pp. 748-759
46. Marcie Tyre and Wanda Orlikowski (1994). "Windows of Opportunities: Temporal Patterns of Technological Adaptation in Organizations." Organization Science 5(1): 98-118.
47. Ann Zimmerman, and Thomas Finholt. 2007. Growing an Infrastructure: The Role of Gateway Organizations in Cultivating New Communities of Users. *Proceedings of the 2007 international ACM conference on Supporting group work*. Pages 239-248
48. Aviv Zohar. 2015. Bitcoin under the Hood. *Communications of the ACM*, September 2015, Vol 58, No 9, 104-113