Intersecting Imaginaries: Visions of Decentralized Autonomous Systems

CAITLIN LUSTIG, University of Washington, USA

Sociotechnical imaginaries are futures that people envision might be possible and desirable. They have a real impact on how systems are designed and what values they have embedded in their design. This article examines imaginaries about autonomous systems, decentralized systems, and decentralized autonomous systems. Through a discussion of the literature on autonomous and decentralized systems and how these imaginaries play out in the blockchain community based on my qualitative research, I demonstrate how decentralized autonomous systems are related to imaginaries about the organization of and the future of work. I identify three framings of imaginaries about autonomous systems: (1) autonomous technology as physical objects, (2) as mathematical rules, and (3) as artificial mangers. I also identify two sometimes conflicting framings of imaginaries about distributed and decentralized technology: these technologies as a new form of production and as freedom from control. These imaginaries intersect in decentralized autonomous systems, and I examine what they can tell us about the design and governance of such technologies. Lastly, I suggest ways of using the concept of imaginaries in participatory design.

CCS Concepts: • **Human-centered computing → Computer supported cooperative work**.

Additional Key Words and Phrases: autonomous systems; distributed systems; decentralized autonomous systems; imaginaries; blockchain; Bitcoin; participatory design

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1 INTRODUCTION

As autonomous technology becomes more prevalent in society, it is increasingly important that CSCW researchers examine the design considerations and ethical implications of not only the technologies themselves, but the possible futures we imagine for these technologies. The visions of autonomous technology in popular media and science fiction have primarily focused on the application level—how they will impact the future of work and collaboration in domains such as autonomous vehicles, security robots, and the Internet of Things.

In recent years, researchers and popular media have been increasingly focusing on the algorithmic infrastructure that sits below this application level (e.g., the algorithms that determine what users see on their Facebook's news feeds [16, 38], Google's search algorithms [3], algorithms for predicting likelihood to predict a crime [107], and advertising algorithms [111]. See [49] for a comprehensive list of articles.)

However, other components of autonomous systems are "closer to the metal" [15], such as communication protocols and hardware, and the design considerations and values of these lower

Author's address: Caitlin Lustig, celustig@uw.edu, University of Washington, USA, 428 Sieg Hall, Campus Box 352315, Seattle, Washington, 98195.

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level components remain under-theorized. Autonomous technologies come in many variations in terms of both their software governance and infrastructures, and these differences shape the design considerations and interventions required for improving these systems; therefore, it is imperative that researchers study a variety of such systems, including decentralized and distributed systems. This paper examines the blockchain protocol, which was designed to autonomously store transaction data in a transparent, decentralized, and distributed system. This examination provides a new perspective of possible futures for autonomous systems that is not predicated on centralized governance or architecture.

In this paper, I focus on the sociotechnical imaginaries of the blockchain protocol and the blockchain open source community's perspectives on the blockchain as a decentralized autonomous system—one they imagine could herald in a future in which people are no longer needed to execute and enforce legal contracts, a future in which trust between parties is completely "outsourced" to an automated system. The imaginaries of the wider blockchain community range from that of the blockchain as an invisible and largely apolitical infrastructure for simply recording data and providing additional security and privacy measures to data storage—to that of the blockchain as a decentralized political tool for stopping governmental corruption, automating jobs across a wide range of sectors, and transforming organizational structures. These imaginaries are not mutually exclusive or discrete, but rather, they represent any combination of possible futures. The blockchain community is currently debating the possible roles of humans in blockchain systems and the degree to which these sociotechnical systems are (de-)centralized and autonomous. I argue that the definitions of decentralization and autonomous are fluid in the greater blockchain community, as people use them in reference to actants at multiple levels of these sociotechnical systems.

The assumptions of this community—such as, the imagined beneficiaries of such a future or the criteria by which a system could be considered decentralized and autonomous—can provide us a better understanding of how these systems are (and will be) designed. I contribute a historical view of the imaginaries of autonomous systems, imaginaries of decentralized and distributed systems, and their intersection.

2 BACKGROUND

In the following, I give a definition of sociotechnical imaginaries and how they relate to CSCW literature on design and decentralized/distributed systems, as well as blockchain imaginaries.

2.1 Imaginaries in Sociotechnical Systems, Design, and CSCW

There is no unified definition of "imaginaries" in literature on sociotechnical systems—it has been used to refer to collective visions of the future [4, 40, 41] and the present or past [91]; it has been used to describe collective visions at different scales: groups [60, 86, 92], professions [41], and cultures [12]; and it has been used to describe a collective vision that uses metaphors and groups to enable diverse stakeholders to come together for goal-oriented activities [86, 92] and to describe "social constructions consisting of a set of cultural notions, predicaments, and anxieties" [91].

In this paper, I use "imaginaries" to describe a community's "collective visions of desirable and feasible (technoscientific) futures" [4]. These imaginaries are not necessarily goal-oriented or even tied to shared metaphors and objects, but rather have often indirect influences on the design and infrastructuring of sociotechnical systems. The word "imaginaries" "encourages reflection on the prescriptive power of imaginaries regarding futures that "ought" to be attained, while simultaneously raising the question of whether or not, and to whom, the particular societal futures attainable through these technoscientific changes seem worth attaining" [40]. Imaginaries are often about high-stakes, contested topics [74]. Sociotechnical imaginaries may challenge or support existing power structures, as they are motivated by both utopias and ideologies—"ideology legitimizes power, whereas utopia constitutes an alternative to the power in place" [41].

Imaginaries have been examined in the context of CSCW. Notably, Wong and Jackson [123] have argued that imaginaries should matter to the CSCW community because they help us with "understanding how infrastructures imagine and shape social and technological development, presenting a policy-centered resource for design, and analyzing how imagined futures and cultural values are mutually reflected and embedded in both technology and policy" [123]. Lindtner et al. [77] examined how transnational imaginations influence cultural appropriation of technology. As discussed later, Kow and Lustig examined the imaginaries of the Bitcoin community [69].

More broadly, the design of large-scale distributed systems [97] (some of which have decentralized governance) has garnered attention in the CSCW community with research on groupware [93], collaboration through cloud computing (e.g., Google Docs) [61], collaborative computing [125] (such as many citizen science projects), and peer-to-peer CSCW [95, 124]. Design involves imagination: "Design is a fundamentally imaginative act that involves picturing the world as other than it is. Many forms of design (e.g. scenarios, personas, sketches, speculative design and design fictions) can be thought of as research fictions, in the sense that they are imaginative responses to questions" [14]. Literature shows that this process of imagining allows for community development of alternative ways of social organizing through appropriation of already designed technology [70, 77]. But one issue that these systems raise is that people can often have contrasting or conflicting visions that must then be debated and discussed [69]. One example of a space where there are competing political visions, involving both distributed and autonomous systems, is blockchain technology.

2.2 Blockchain

Decentralized systems and autonomous systems, and their intersection—decentralized autonomous systems—have captured the imaginations of technologists and the wider public (e.g., imaginaries about freedom of information through distributed networks that cannot be shut down, robots taking away jobs from humans, malevolent artificial intelligences that gain sentience in the singularity, personal assistants, and smart contracts). In this paper, I examine a particular kind of decentralized autonomous system: blockchain technologies—the most famous being Bitcoin and Ethereum, which are the case studies I explore. In this section, I primarily focus on Bitcoin, as it is both the technology that introduced blockchain protocols and the most widely used blockchain technology. However, many types of blockchains exist, which I discuss later.

In 2008, Satoshi Nakamoto first introduced the concept of a "blockchain" in the whitepaper "Bitcoin: A Peer-to-Peer Electronic Cash System" [90]. The true identity of Satoshi (as they are referred to in the Bitcoin community) is a mystery, and it has been suggested that Satoshi may either be a group of people working together or perhaps one of the cryptographers who has written about related ideas. (As of the time of writing, many have been suspected of being Satoshi, but none have been confirmed.) Satoshi created Bitcoin in response to the flaws they perceived in the current mechanisms used to enable online commerce. Conventional methods of conducting commerce online utilize third parties in order to prevent "double spending". Double spending refers to online transactions in which "many copies of the same bitstring are spent at different merchants" [57]. Traditional currencies use trusted third parties to verify that online transactions are not conducted with double spent money. However, Bitcoin eliminates the need for a trusted third party by utilizing a peer-to-peer network for verifying transactions. The network verifies that transactions are not double spent by checking transactions against a public, pseudonymous ledger called a blockchain.

In order to incentivize users to use their computing power in this network, there is a chance that while running software that performs calculations on transactions, users may be rewarded with newly generated ("mined") bitcoins. This method of generating bitcoin means that Bitcoin does not rely on a government or a centralized company to issue currency. This decentralization can make the currency appealing to people who distrust banks or governments.

Bitcoin's blockchain records currency transactions and its contents are completely public, although identifying information is obscured. Bitcoin's blockchain protocol also provides a kind of perceived governance through code: anyone can join Bitcoin's distributed computing network, but the protocol has consensus mechanisms to make it nearly impossible (in theory) for actors to alter the ledger for their own gain. Thus, Bitcoin advocates have referred to blockchain protocols as "trustless" because the protocols encode trust in the decision-making of the network as a whole rather than in any individual actors. Bitcoin has gained a reputation for being a subversive technology, and was, at some points in time, associated in the public's mind with illegal activity. (While it is difficult to accurately survey people about their illegal activities, a 2013 survey showed that most users of Bitcoin did not use it for illegal purposes [105] and this finding is also supported by my qualitative data.) Other uses of the blockchain protocol include storing records of ownership (e.g., property or securities) and "smart contracts".

Smart contracts are code stored on blockchains that execute when certain conditions are met. "Smart contract" does not have a single definition, and the term has been used to describe "physical objects that change their behavior based on some data. More recently, the term has been used for the exact opposite: to describe computation on a blockchain which is influenced by external events such as the weather" [51]. It is worth noting that smart contracts cannot take into account the social context in which they are executed [75].

The most promising uses for smart contracts come from the Internet of Things (IoT) domain. For example, smart locks: locks with digital keys that are only valid for the duration that someone has paid to use a property, such as a reoccurring monthly rent payment or a one-time payment for a hotel room[1]. IoT machines might also use a blockchain to buy and sell things to one another, such as excess energy, using a neutral platform that is not owned by any company and can be accessed by all machines running the blockchain protocol. These uses of the blockchain are sometimes referred to as "decentralized autonomous organizations" (DAOs) [18], and they have sparked imaginaries of a world without the need for lawyers or governments, or even the need for humans in the service industry.

One imaginary of the Bitcoin community is that the currency will become the de facto international currency and will weaken the power of governments—on the one hand, this techno-utopian imaginary may describe a world where people are empowered in countries with unstable or oppressive governments with currencies that are often volatile, on the other hand, it describes a libertarian world in which wealthy people and organizations can avoid paying taxes. Thus, an imaginary may be shared by a group which has differing ideas about whom would benefit from that imagined future.

While there has been some research on the imaginaries of the Bitcoin community, there has been less focus on the imaginaries of the wider blockchain technology (notable exceptions include [36, 45], which are discussed further in this work). Maurer et al. [83] argued that Bitcoin users place their trust in Bitcoin's code to produce and distribute bitcoins correctly, as opposed to trusting a government or a central organization to do so. One reason for this trust is the transparency of Bitcoin's code—users trust the code because of "their collective ability to review, effectively evaluate, and agree as a group to changes to it". Maurer et al. suggested that users can trust the code because of "the fact that such decentralization, as well as the public-key encryption of users' identities, is hardwired into the system". Mallard, Méadel, and Musiani [80] suggested that trust in Bitcoin is distributed through several sociotechnical mechanisms, one of which is the underlying

[1] http://www.slock.it

algorithms of Bitcoin's code, in particular because it is a peer-to-peer (P2P) system. To use a P2P system, users must actively participate by pooling together resources, which builds trust. Users also trust in the resilience of P2P networks and trust in Bitcoin's core developers.

Bitcoin has been described as a techno-utopian project, which advocates erroneously view to be a "horizontal network" that is free of politics, when in fact, it concentrates power in the hands of a few [34, 67]. Swartz [110] argues there is not a singular vision of Bitcoin, but rather two main techno-economic imaginaries of Bitcoin: *digital metallism* (first introduced in [83]) and *infrastructural mutualism.* Digital metallism refers to "a theory of money in which the only truly sound money is one backed by a commodity like gold, which derives its intrinsic value from the market", but in this case, it is backed by computational power and trust in math and the market. And infrastructural mutualism refers to using Bitcoin not only as an alternative currency but also as "an alternative to private payment intermediaries that seek to control and survey its passage" and has a "cooperativist vision".

In CSCW, Kow and Lustig [69] studied blockchain technology in the context of imaginaries: the ways that participants shape the development in the technology in accordance with their competing visions. In that work, Kow and I focused on the concept of crystallization from Neumann and Star [92], in other words, stakeholders communicate imaginaries to one another to determine whether a design is feasible and then determine whether they will change their design. We argued that when participants are unable to come to a crystallization point, their imaginaries branch and they create new technologies that embody their imaginaries, such as the various cryptocurrencies that have forked off of Bitcoin due to ideological differences. We defined an imaginary as something abstract (e.g., a vision) that "a social purpose of enhancing communication within large-scale collaboration" [69].

In contrast, in this work, I treat "imaginaries" as collective visions that do not necessarily have a purpose. I move beyond the ethnographic lens to interrogate how imaginaries are first set on their intersecting courses. I illuminate the origins of blockchain technology's imaginaries, namely, those concerning"distributed systems", "decentralized governance", and "autonomous systems", focusing on concordant and discordant aspects of the futures they describe. I then investigate how different imaginaries are incorporated into the principles behind blockchain technology and how various debates within the blockchain community are informed by the same imaginaries. Finally, I examine the imaginaries of blockchain technology itself, and how they compare with their ideological predecessors.

3 METHODS AND PARTICIPANTS

Over 2013-2017, I conducted research on what I refer to as the (English language speaking) blockchain community; I acknowledge that there is no singular community, as there are many different types of blockchains with their own community cultures based on the values designed into the protocols of each blockchain and there also may be schisms in those communities (e.g., the debate between /r/bitcoin and the splinter community /r/btc [103]). When I refer to the "blockchain community", I mean the wider community of people who engage with blockchain-related forums, conferences, meet ups, and technology development. While the values and imaginaries of stakeholders in this community vary, we can say some things about cultural similarities between sub-communities. The blockchain community is a "recursive public" that consists of users[2], entrepreneurs, investors, developers, "miners", and legal experts:

[2]Here, blockchain user refers to people who make transactions on a blockchain. As of today, blockchain protocols are not infrastructure, and "users" only encompasses people who consciously use these technologies; however, in the future, if adopted as infrastructure, it may become more difficult to determine who is a user.

> A recursive public is a public that is vitally concerned with the material and practical maintenance and modification of the technical, legal, practical, and conceptual means of its own existence as a public; it is a collective independent of other forms of constituted power and is capable of speaking to existing forms of power through the production of actually existing alternatives. [64]

This community is actively involved in shaping the trajectory of blockchain technologies in terms of: their underlying protocols, the capabilities of the technologies, the values that the technologies are designed to have, and the technologies' governance structures and distributions of power.

The blockchain community has provided a wealth of public information for scholars, as part of its culture promotes active participation from all actors. Blockchain projects are generally open-source, therefore, important discussions are typically well-documented and take place in archival spaces. As a result, those data are readily available for examination and research purposes. Many users are experts on blockchain technology in their own right. My study primarily focused on Bitcoin, and looking at the online activity of just the Bitcoin community alone gives a sense of just how knowledgeable and invested (both financially and emotionally) the community is in Bitcoin and blockchain technology. The English language community has multiple sizeable subreddits (e.g., /r/bitcoin and /r/btc), online forums (e.g., Bitcoin Forum), blogs where lively debates take place in the comment sections, mailing lists (e.g., bitcoin-developers), books written by community members, and a community of researchers, both academics and non-academics who publish papers, some of which Mallard et al. refer to as "hybrids", in other words: "not clearly falling into the category of scientific article, nor of generalist press" [80].

In order to learn more about this community, I conducted a survey of over 600 Bitcoin users in 2014, which was shared via /r/bitcoin on Reddit and Bitcoin Forums, the main sites of Bitcoin discussion at the time, and it primarily contained demographic questions and open-ended short answer questions about why people used Bitcoin. The respondents to the survey were generally expert users. Over video chat, instant message, email, and in-person, I conducted 29 interviews with a subset of survey participants who gave me permission to contact them. I also had countless informal interviews with developers and financial cryptography researchers and attended multiple small cryptocurrency events hosted by the Institute for Money, Technology & Financial Inclusion and four blockchain-related conferences: the key conference (<200 people) in the financial cryptography field, Financial Cryptography and Data Security 2016, which included a Bitcoin workshop and was attended by blockchain researchers and developers (2016); two smaller conferences that gave me a feel for the local Southern California blockchain community (the State of Digital Money geared towards business people (2015) and The Blockchain Future (2017) for people in the tech sector); and Inside Bitcoins, which billed itself as the largest worldwide conference on blockchain technology with roughly 1,000 users, developers, and business people (2015). I also analyzed debates and tensions in the community through inductive coding of the bitcoin-developers mailing list during the month of May 2015, when major debates about the future of Bitcoin began; and analyzed online posts about the Ethereum "DAO hack" in the month after it happened in 2016.

My research is informed by my empirical work, but in this paper I primarily draw on previous research on sociotechnical imaginaries of autonomous systems (Section 4) and distributed and decentralized systems (Section 5). I place these imaginaries in a historical context and describe how they come together today in decentralized autonomous systems (Section 6), thereby contributing understandings how these imaginaries intersect. Based on my empirical research, I used inductive thematic analysis to identify themes about imaginaries of blockchain systems, which I had begun to explore in my prior works [69, 78], and these themes guided how I categorized the works that I cite in this paper.

I gathered my literature through snowballing sampling [122], with a starting set of works on the politics and governance of protocols (i.e., [31, 32, 44, 79]) based on recommendations from colleagues, as my work had originally intended to focus on how or if people with multiple viewpoints can effectively govern and scale a technology together through protocols, using Bitcoin's blockchain protocol as a key example. Through the course of my research, I increasingly found the issue of imaginaries to be of key importance to how people understood distributed autonomous protocols as mechanisms that shape governance, and I chose to focus my attention on that topic. I added literature on sociotechnical imaginaries to my starting set as well (e.g., [41, 52]). I used backwards snowball sampling (i.e., seeing what works a paper or book cites) and forwards snowball sampling (i.e., using a tool such as Google Scholar to see what works cite a paper or book) [122].

4 SOCIOTECHNICAL IMAGINARIES OF AUTONOMOUS SYSTEMS

Understanding how people participate in the use and formation of technology means understanding the discourse and the context of such discourse around a technology:

> Looking at participation in terms of "media dispositive" means that the various aspects, both discursive and non-discursive, human or non-human, would be related to each other by power structures, knowledge about technology and its design and appropriation, the discursive representation of socio-political issues, and the transformations taking place through the interaction and relation of all participants. [101]

In the following, I describe *user* perceptions, particularly blockchain users, of autonomous systems. In popular media, the term "autonomous technology" conjures visions of fantastical and sometimes frightening use-cases for technology. Conversely, imaginaries of autonomous technology may portray a future in which the technology seamlessly integrates into our everyday lives (e.g., ubiquitous computing [9]). This conceptualization, which believes automation is integrative, does not depict the role of technology as necessarily introducing radical changes to everyday life. Instead, automation is simply thought to makes our daily tasks more efficient. In this vision, technology does not create great societal upheaval or provoke anxieties but may reinforce cultural norms. For example, researchers often first propose uses for novel autonomous ubiquitous technology in domestic settings, such as "smart kitchens", before branching out to other application domains [35]. Indeed, the success of autonomous technology is often measured in terms of augmenting what humans already do [112]. In this paper, I define "autonomous systems" as systems that are designed such that some decisions are delegated to technology, which is often, but not always, designed to appear "seamless" [58]. Note: I am not arguing that autonomous technology does not have "humans-in-the-loop" or that AI is never designed to simply *assist* human decision-making, but rather that the purpose of such technology is often to *appear* seamless.

In recent years, there has been significant focus in the HCI community on machine learning and recommender system algorithms [53], which are often portrayed in popular media as ephemeral, invisible forces. Prior to the advent of the fields of FAT* and critical algorithm studies[3] (as well as increased participation in discussions about algorithmic systems from fields such as anthropology and law) around 2014, corporations often portrayed algorithms as simultaneously objective and neutral, natural, mysterious and opaque, authoritative, powerful, and automatic [100]. These fields have changed the discussion in academia and industry around autonomous systems with greater public debate about their ethical implications; however, the imaginaries of the blockchain community are rooted in some of these earlier imaginaries, which often take a less critical view

[3] FAT* is an interdisciplinary community of researchers and practitioners on Fairness, Accountability, and Transparency in algorithmic systems. Critical algorithm studies tackles similar topics and tends to take approaches that are based on qualitative methods and theory.

of autonomous decision-making in which autonomous technologies are imagined as both purely objective mathematical rules and as artificial managers.

4.1 Autonomous technologies as things

Mark Weiser's original vision of ubiquitous computing was that of technology fading into the background and seamlessly supporting *human-to-human* interactions rather than *human-to-computer* interactions [120]. The original conception of the Internet of Things (IoT) extended this vision through the imaginary that the Internet would free humans from needing to collate and enter information—instead, things would do it for us: "If we had computers that knew everything there was to know about things—using data they gathered without any help from us—we would be able to track and count everything, and greatly reduce waste, loss and cost. We would know when things needed replacing, repairing or recalling, and whether they were fresh or past their best" [2]. IoT repurposed ubiquitous computing's visions of smart places into the concept of connected places, such that "the vision is less about wholesale intelligent homes and more about embedding networked computing in mundane objects to deliver new applications and services to the connected home, largely through the harvesting of personal data" [26, 47].

Robots, such as (semi-)autonomous vehicles, provide another vision of autonomous technology as things, in which the "thing" has a more perceptible agency. Autonomous vehicles have been imagined for over half a century, and it is only recently that they have begun to become a reality. Advocates of AI systems imagine a world in which humans are freed up to do what matters most to them; and menial tasks, such as driving, are offloaded to machines, which can do them more safely and efficiently and in a more environmentally-friendly way. However, there are also imaginaries of the future (and current-day realities) based on how Langdon Winner described autonomous technology: "the *belief* that somehow technology has gotten out of control and follows its own course, independent of human direction" (emphasis added) [121]. It has been feared that these technologies will have a range of terrible consequences–anywhere from the fall of society due to the singularity to suffering from programming errors that could have disastrous consequences, such as security breaches or humans accidentally instructing an AI to do something they had not intended (e.g., driving in an unsafe manner to go somewhere "as quickly as possible") [33].

4.2 Autonomous technologies as purely objective mathematical rules

Within the blockchain community, algorithms and protocols have been portrayed as completely autonomous bits of code, free from human intervention [78]. This portrayal aligns with some corporate imaginaries of algorithms. These imaginaries obscured the decisions and labor that are required to design algorithms; thereby hiding the role of programmers, infrastructural and technological constraints, and stakeholders in designing algorithms: "When algorithms are mentioned at all, platform providers often encourage the notion that their algorithms operate without any human intervention, and that they are not designed but rather "discovered" or invented as the logical pinnacle of science and engineering research in the area" [100].

This presentation of algorithms describes them as laws of nature or mathematical theorems that have only recently been discovered. And like nature and mathematics, they are portrayed as objective and politically neutral. This presentation is particularly common for Bitcoin; a speaker at one of the local blockchain conferences that I attended described Bitcoin as "the sun and the stars—it is a force of nature, it exists". One of my survey participants wrote that "money is about trust and math is much more trustworthy than humans". The notion that algorithms are free from subjectivity is alarming when taken with another way that algorithms have been described: as ways to limit people's choices, frequently in ways that are invisible to the people who they have control over and discriminatory against certain social groups. If we were to believe that algorithms are objective and natural, then discrimination that is institutionalized through existing social structures and further reified through algorithms may be considered to be free from bias and simply part of the natural state of the world. Researchers [23, 116] suggest that even when companies try to make their algorithms blind to demographics, algorithms still made the same discriminatory decisions based on correlated variables.

4.3 Autonomous technologies as artificial managers

Algorithms and platforms are increasingly being portrayed as stand-ins for human workers, particularly managers [108]. There are now algorithmic journalists who produce content that is virtually indistinguishable from those written by humans [21]; algorithmic taxi dispatchers in the form of Uber [72]; and algorithmic banking systems in the form of Bitcoin. In the case of each of these three systems (i.e., algorithmic journalists, Uber, and Bitcoin), algorithms are portrayed as automatically producing content and making decisions. However, research has exposed the ways in which these algorithms are more than just code—they are also reliant on human judgment and work. Amazon Mechanical Turk's "artificial artificial intelligence" is one method for giving algorithms the appearance of complete autonomy. Uber drivers must rely on sense-making activities to understand how to interact with an algorithmic system that assigns them to passengers, manages their fare rates, and evaluates their performances. Research shows that once drivers understand the algorithm they can attempt "workaround strategies that helped them maintain control that the automated assignment did not support as part of the existing system functionality" [72]. Blockchains also require users to contribute their power to the peer-to-peer network. Despite the necessity of these interventions, this (human) work is rendered largely invisible in blockchain discourse, and the protocol is typically seen as the only actor with authority in these systems [78].

5 SOCIOTECHNICAL IMAGINARIES OF DECENTRALIZED AND DISTRIBUTED NETWORKS

The history of distributed networks is intertwined with that of the Internet [1]. When the ARPANET was being created, its developers took notice of the work on distributed packet switching by computer scientists, such as RAND company employee Paul Baran, and integrated their ideas into the ARPANET. In computer science, discussions about the definition of decentralization usually begin with Baran's 1964 paper "On Distributed Communications Networks" [5], which contains an iconic diagram shown in Figure 1. (In fact, a Bitcoin Forum member with whom I communicated sent the diagram in order to make sure that I understood the difference.)

In a system with a distributed architecture, nodes communicate directly with one another rather than going through a central node. In such a network, information about the state of the system, for example—what files each computer has available to share—is not maintained by a central node; rather, this information needs to propagate throughout a distributed network. Each node may need to maintain a copy of information about the state of the network (e.g., information about Bitcoin transactions) and must send updates to other nodes (e.g., when a new transaction is made). Due to network latency, nodes may have different information about the state of the network; mechanisms for handling inconsistent information about the state of the network are called "consensus protocols". Blockchain consensus protocols are one of the most novel aspects of blockchain technology.

In this article, I define these terms along two axes: governance and architecture. In terms of governance, centralized systems have a one or few entities in control. Decentralized systems have many entitles with control. "Control", in this case, refers to the ability to modify the physical infrastructure, code, or standards used by a system. On a technical level, a system may either be

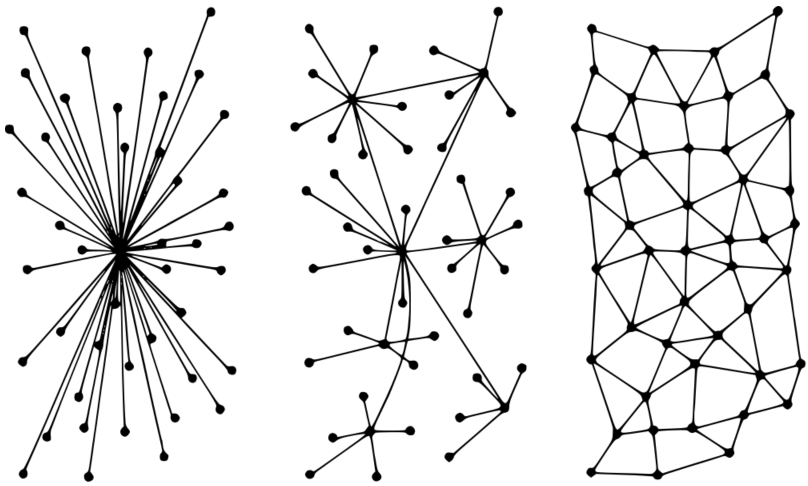

Fig. 1. Baran's model of the different kinds of networks

a distributed or centralized architecture. Distributed architectures have no centralized node(s). Systems with a distributed architecture can be governed in centralized or decentralized ways.

Every system is built upon layers of infrastructures and platforms that may be centralized or decentralized to some extent. Although the narrative is that the Internet was developed to be a P2P system in which every node could communicate directly (and, later when a server/client model gained traction, every node was, in theory, able to be both a server or client), even in P2P systems "some are more equal than others" [94]. One might visualize a three-dimensional matrix in which layers of Table 1 are stacked upon each other. Agre explains this stack:

> ...[E]ach layer in the Internet protocol stack is defined in a general way, and end users can create new layers atop the old ones. But it also shifts complexity away from the centralized expertise of network engineers, placing it instead on the desktops of the people who are least able to manage it. Much of the Internet's history, consequently, has consisted of attempts to reshuffle this complexity, moving it away from end users and into service providers, Web servers, network administrators, authentication and filtering mechanisms, firewalls, and so on. The P2P character of the TCP/IP protocols has remained much the same; the reshuffling takes place mostly on other layers. Thus, a decentralized network can support centralized services, and vice versa. For example, the asymmetrical client/server architecture of the Web sits atop the symmetrical architecture of the Internet. [1]

Table 1. Examples of how centralized, decentralized, and distributed are used in this paper.

	Centralized Governance	**Decentralized Governance**
Centralized Architecture	Client-server systems (e.g., Microsoft Exchange)	Commons-based peer production (e.g., Wikipedia)
Distributed Architecture	Closed source peer-to-peer protocols (e.g., Skype protocol)	Peer-to-peer systems (e.g., BitTorrent)

Without some degree of invisibility, a layer cannot gain wide usage. By this I mean that if users are constantly managing the complexity of a system, many will be deterred or prevented from using it.

The following briefly describes these two imaginaries about distributed systems. These particular imaginaries have much in common with the many theories about the role of technology in shaping new dominant modes of production (e.g., the "information economy"), flattening corporate structures (from "vertical bureaucracies to the horizontal corporation" [22]), and changing democratic modes of participation (see: [119] for an overview of these theories). While these theories are at different points on the continuum between techno-determinism and social determinism and on the continuum between techno-utopian and techno-dystopian, in general they all focus on the affordances of information communication technology and the effects of constant connectivity. However, in the following imaginaries, the focus is on a lower level—on how the unique technical properties of distributed architectures could enable future social change.

While much of the literature I cite came from the early- to mid-2000's, these predictions about the future still drive narratives today about the sociotechnical impacts of distributed networks. In a way, the imaginaries of people who work in the P2P space are enduring because they are related to what Gregory refers to as an "incomplete utopian project"—projects that "outlive any particular attempt at realization, nor is any particular failure sufficient to spell the end of a utopian quest" [52], as well as Bell and Dourish's concept of a "proximal future"—in which certain imaginaries of the future will finally be realized soon, but the "soon" is perpetually just out of reach [9]. In reference to the concept of "the information society", which is only possible because of distributed networks, Webster [119] notes that, "Commentators increasingly began to talk about 'information' as a distinguishing feature of the modern world thirty years or so ago [from 2014]. This prioritisation of information has maintained its hold now for several decades and there is little sign of it losing its grip on the imagination." And we can find concerns about the ethical implications of the imaginary of a "data bank society" (a precursor to Big Data) as early as 1970 [118].

5.1 Distributed networks as a new form of production

Distributed networks, P2P systems in particular, are widely associated with both a type of technical architecture and a certain ethos about how society should be organized [88]. In this first imaginary, technological networks operate as "distributed forms of management" [44]. In 2005, Bauwens, founder and director of The P2P Foundation, predicted that P2P will not just be a type of technical architecture, but also "a new human dynamic" that will upend old models of political economies [8]. Bauwens describes a "third mode of production" in which "use-value [is produced] through the free cooperation of producers who have access to distributed capital" through self-governed communities that "make use-value freely accessible on a universal basis, through new common property regimes. This is its distribution or 'peer property mode': a 'third mode of ownership'." Bauwens argued that this new kind of political economy would only be feasible because of P2P infrastructure. In this imaginary, peer-to-peer systems operate as a stand-in for traditional governance because they decentralize "not just features, but costs and administration as well" [104], and, despite the hierarchical nature of Internet protocols, the Internet is widely accessible to the public because of lower barriers to entry (e.g., computers becoming relatively affordable and Internet access becoming fairly ubiquitous in many parts of the world). Distributed communication protocols allow for "autonomous communication" and "autonomous content production that may be distributed without the intermediary of the classic publishing and broadcasting media" [8].

Similarly, some academics and some of my participants have promoted the idea that Bitcoin's development mirrors that of the World Wide Web (WWW) [42]. "In addition to its simplicity, [the WWW] has a deliberately decentralized nature. Nobody needs to ask permission to create a webpage and link to other websites. There is no central database or authority which needed to be updated or maintained", and they argued that "the Bitcoin system allowed for the same in the currency space" in part because it was open source. Participants also felt that Bitcoin was to currency as email was to physical mail: "the email of currency"—and felt that it was just the first application of many blockchain technologies; others compared blockchain protocols to TCP/IP.

The original promise of the Internet as an "unmediated public sphere" quickly became dominated by for-profit platforms. While they provided some degree of simplification of the web experience (which, based on my earlier discussion of Agre [1], I would argue is necessary for widespread usage), they also changed the dominate narrative of the Internet, instead creating a moderated and monitored space: "platforms do, and must, moderate the content and activity of users, using some logistics of detection, review, and enforcement" [48]. Blockchain proponents also have concerns about what Srnicek refers to as "platform capitalism" [106], in other words, the commodification of data into a new kind of business model. One of the reasons that blockchain technology was introduced was to limit the amount of information given to "trusted third parties" in financial transactions, and other uses of blockchain technology, such as "self-sovereign identity" seek to give ways to people to control who has access to information about their identity and for how long. Imaginaries about blockchain technology are more in-line then with the visions of the early Internet; however, they may perpetuate platform capitalism, as explained by Bauwens in the following.

The Bitcoin source code was originally published on Bauwens' website, the P2P Foundation, and he later shared his thoughts on Bitcoin, arguing that "this technology is potentially a game changer by bringing down the transaction cost for self-organization" through smart contracts and decentralized autonomous systems [7]. However, he also cautioned that it could lead to more inequality and transfer wealth to people with extreme libertarian views, "which allied with venture capital and the oligarchies that invest in Bitcoin, alters the balance of power away from emancipatory and progressive political forces." He argued that disintermediation is inevitable because in peer-to-peer systems with no mechanisms for enforcing equality, "Again and again, I see the potential disintermediation of power, which may affect established powers, creates new intermediaries, such as the platform monopolies". Thus, open source peer-to-peer systems, like those built upon the blockchain protocol, run the risk of giving effective tools to large institutions to centralize control when there are no mechanisms for preventing them from co-opting the technology or for preventing these institutions from taking over the majority of the network. The following imaginary takes a more optimistic view of the ability of distributed software to circumvent centralized control; however, this imaginary also runs into issues with determining what exactly is meant by "centralized control".

5.2 Distributed networks as freedom from centralized control

The first imaginary I described was focused on the revolutionary nature of a distributed architecture with which users actively engage to subvert hegemonic systems. The second imaginary I will describe is also focused on this revolutionary nature, but using "revolutionary" in a way that is more akin to an industrial revolution rather than to a revolutionary uprising, in which modes of production are changed and these new ways of doing work are embedded into society seamlessly. In section 6, I will return to these imaginaries and argue that these tensions between them are based on a disagreement about whom these distributed systems are for and whether becoming infrastructure is the community's goal for the software or its antithesis.

Agre argues that dominant imaginary of P2P is that it "delivers on the Internet's promise of decentralization. By minimizing the role of centralized computing elements, the story goes, P2P systems will be immune to censorship, monopoly, regulation, and other exercises of centralized authority." [1] In the face of legal and social challenges, P2P systems have had to become increasingly distributed in order to work towards this imaginary of "delivering on the Internet's promise". Early

P2P systems were decentralized rather than distributed [87]. However, by maintaining some degree of centralization, the organizations running the central node of early decentralized and P2P networks were culpable for any illegal activity facilitated by their network—such was the case with Napster [87] and e-gold [62], an early digital currency. After Napster was shut down, developers of the following generations of P2P software were increasingly focused on preserving the privacy of users and using distributed network architectures, rather than decentralized ones. Furthermore, by developing open source P2P protocols, developers could create new applications every time one was shut down [87].

Thus, open source protocols allow for a diversity of systems built upon them that are easy to produce and customize. While the developers of the original project may eventually step away or the original program built upon these protocols may be shut down for other reasons, open source protocols give a blueprint for new projects that may similarly be built upon and adapted to avoid censorship. Open source protocols also give dissentient developers an opportunity to "fork" the code to create alternative versions of a particular software. However, forking is generally not considered an ideal way of handling conflict.

In order to prevent forks, open source communities have to come to some kind of consensus about changes to the code. This consensus may require stakeholders to change other technology to support interoperability with the new protocols, require users and companies to take up technology that utilizes the new protocols, and require consensus among the developers, organizations, or governments developing the new protocols. For the blockchain community, consensus refers to more than social agreement in decision-making processes, but it also refers to a technical concept that is embedded into the protocol of a blockchain itself. Nodes in the network "vote" on which versions of the software they would like to use and which transactions go into a globally shared ledger (a blockchain). This protocol allows for distributed decision-making and trust through consensus. Furthermore, if some stakeholders disagree with a technical decision, they can also create their own alternative protocols, as later discussed in this paper. These protocols may have their own consensus rules, based on different own values, and may have different governance structures.

While these imaginaries (i.e., distributed networks as a new form of production and distributed networks as freedom from centralized control) are based on many of the same values—open access, freedom, sharing—they are related to two different hacker genres as identified by Coleman and Golub [24]. Crypto-freedom is based on civil disobedience and "individual autonomy, self-reliance, and self-control"; whereas, free and open source software is based on the belief that software development is best governed by "a community maintained through shared norms and values" [24]. The debates that I discussed demonstrate a tension between those that view distributed networks as freedom from centralized control, including that of any group of developers, with open source code as a means of freedom—and those who view distributed networks as collaboration tools for democratic decision-making and community consensus [110].

6 INTERSECTING IMAGINARIES: DISTRIBUTED + DECENTRALIZED + AUTONOMOUS

In the previous sections, I discussed imaginaries about systems that are managed through decentralized governance with distributed architecture, and I also discussed imaginaries about systems that are autonomous. In this section, I discuss the intersection.

6.1 The past and future of blockchain technology

The concept of decentralized autonomous systems is inextricably tied to blockchain technology, as evidenced by the trajectory that proponents see for blockchain technology. Swan [109] argued

Table 2. Summary of imaginaries presented in this paper.

Imaginaries of autonomous systems	Imaginaries of distributed and decentralized systems
Autonomous systems as things	Distributed networks as a new form of production
Autonomous systems as math	Distributed networks as freedom from centralized control
Autonomous systems as artificial managers	

that blockchain technology will have three waves: Blockchain 1.0, Blockchain 2.0 (which, at the time of writing, is the most accurate description of the current state of the blockchain ecosystem), and Blockchain 3.0. In Blockchain 1.0, blockchains were simply used for currencies (e.g., Bitcoin). In Blockchain 2.0, code is stored on a blockchain that runs under certain conditions (e.g., smart contracts). Many smart contracts may be used to create decentralized applications ("dapps"), such as decentralized cloud storage (Storj[4]), a forecasting market (Auger[5]), or "decentralized autonomous organizations" (DAOs) and "decentralized autonomous corporations" (DACs), which I describe further in this section. By and large, these applications have low usage and are primarily "proof of concepts". Blockchain 3.0 "articulates decentralized principles of governance and justice throughout society, underpinned by the diffusion of blockchain technology" [109]. The focus in 3.0 less about the blockchain itself, and more about the ideas that it inspires and how they might be used to create new kinds of infrastructures, new kinds of relationships between humans and machines, new ways of viewing the world, and new forms of governance. To understand how this imaginary came to be, I must briefly discuss the history of smart contracts.

Long before the creation of the blockchain protocol, smart contracts were first formally introduced by Nick Szabo in 1994. He described them as:

> A smart contract is a computerized transaction protocol that executes the terms of a contract. The general objectives of smart contract design are to satisfy common contractual conditions (such as payment terms, liens, confidentiality, and even enforcement), minimize exceptions both malicious and accidental, and minimize the need for trusted intermediaries. Related economic goals include lowering fraud loss, arbitration and enforcement costs, and other transaction costs. [113]

Smart contracts can be used to enforce contracts on currency, rights, and property ownership. Keeping a global ledger of these rights is difficult because it must be immutable and safe from malicious or buggy behavior—in other words, these smart contracts need to be governed somehow. At the time they were introduced, there was a debate about whether the governance of these contracts should involve a trusted third-party or be completely decentralized through consensus protocols. Mark S. Miller proposed an "e-rights" model of smart contracts: "The property rights approach divides ownership of the resource among the individuals and creates abstract rules that govern the exchange of rights between owners" [85]. Similar to Szabo, Miller imagined a system in which each of the parties of a smart contract would agree on various terms, such as the source code of the contract, but different from Szabo, Miller also proposed that a trusted third party run the code of their contract. Szabo's vision of smart contracts eventually became the vision most commonly associated with imaginaries about distributed autonomous systems, in part because after many discussions with Miller, Szabo was able to demonstrate that trusted third parties were security risks [115]; however, as described in previous sections, this resistance against using trusted third parties also has political implications.

[4]http://storj.io/
[5]http://www.augur.net/

6.2 Examples of imaginaries of decentralized autonomous systems

In this section, I break up a quote from Vitalik Buterin, co-founder of the smart contract platform Ethereum, into four parts [20]. It gives a clear idea of how multiple decentralized autonomous systems might interact with one another in his particular view of the future of governance and labor:

> You wake up, and see that $17.27 was automatically deducted from your primary wallet, as you had authorized to happen every day, to pay the rent for your apartment; if you canceled the authorization, then, after a warning period, ownership in the land-registry contract would automatically transfer back to the landlord, and the door lock would no longer recognize signatures signed by your smartphone's private key as valid for letting you in. Of course, your landlord is bound by the same restrictions. If he shuts off his account that pays the local government $6.60 land-value tax per day, then he loses ownership and the contract automatically switches over so you are renting from the government instead. [20]

Decentralized autonomous systems employ automatic decision-making based on "smart contracts" that define the rules for how the system should behave in certain conditions; a simple example is distributing bonuses to all stakeholders when a certain level of profit is reached. The autonomous decision-making is verified and recorded through a consensus protocol (e.g., blockchain) run on a distributed network. The benefit of such a system is that rules of the organization are open source and cannot be changed without consensus from stakeholders. Transactions of the organization are transparent and recorded publicly on the blockchain. These applications take advantage of the unique properties of the blockchain—its ability to store data securely, without the risk of any one person or organization deleting or manipulating it, or data being lost or misplaced.

6.2.1 Decentralized autonomous systems as freedom from centralized governance, replaced with math and artificial managers of material objects to form new means of production. This imaginary was unifying within the blockchain community; most of my participants supported at least some part of this imaginary regardless of political affiliation. As discussed in the next section, during the "scaling debate" these feelings of unity began to break down once community members recognized the "politics" inherent in what they had, up until then, viewed as a purely mathematical system.

While the imaginary of freedom from control has a more anti-establishment tone that includes freedom from governments and markets, imaginaries about distributed autonomous systems tend to take the stance that freedom is freedom from governments and not "freedoms against the tyranny of the market" [45].

> The government itself is simply a large decentralized organization, and you can see in real time the $6.60 moving on the blockchain and eventually getting into an account to pay for a medical-research program trying to extend the human lifespan from 170 years to 230. The Internet that you are using to access this information is based on a decentralized and incentivized mesh-networking platform; you paid $0.0009 to access the information, but your laptop also earned $0.0014 transmitting other people's packets at the same time. [20]

In imaginaries about a society run by decentralized autonomous organizations and corporations, DAOs and DACs solve what is perceived by many as one of most important issues with current autonomous systems (i.e., large corporations using black box algorithms that invisibly affect many facets of society); this imaginary is of a world in which humans have more agency with regard to technology, not less, despite increased automation. Proponents believe that DAOs/DACs will provide the ability for parties to freely and consensually enter into fully transparent contracts with one another, and these contracts will automatically execute without human judgment (i.e., the imaginary of autonomous technology as math), thus being more "fair" and efficient. In this imaginary humans are freed "to use [automation] to devote our further energies to non-economic purposes" [45] (referring to decentralized autonomous society supporters' use of a quote from Keynes [65]), and governments are simply large systems of contracts that officials make with one another and citizens make with the government: it can all be reduced to code. It is a society in which code is literally law, rather than code as de facto law in situations when governments cannot easily regulate systems [73]. These imaginaries have varying degrees of human involvement, including imaginaries in which autonomous agents are able to hire humans when they cannot complete a task themselves or hiring other autonomous agents to do tasks for them (i.e., the imaginary of autonomous technology as managers).

As then-lead Bitcoin developer Jeff Garzik described at a conference on the future of money I attended, smart contracts could be used in IoT. Building upon one of Szabo's original descriptions of a vending machine as a primitive smart contract [114], Garzik described a service in which users could order drinks to be delivered to their location by drone—the smart contract, running on a blockchain, could ensure that the system has rules for accepting money for an item and upon acceptance of the money, deliver the item. In a 2013 talk, another former lead Bitcoin developer, Mike Hearn, proposed a vision of driverless cars that essentially own themselves—they make decisions about how to spend the money they earn, and when to hire people to repair them or improve their code [56]. "Because it uses a digital currency like Bitcoin, it can open a 'bank account' without a social security number, drivers license or any other credential that a person is required to today" [55]. Supply chain management is another typical proposed use case of blockchains. Blockchain technology is appealing for this use case because of its "transparency, traceability, and security" [99]; a group of companies could all have access to a single ledger, thus providing a method of determining data provenance that is not controlled by any one company, which may result in more sustainable (i.e., "green") supply chains [68, 99] or increased food safety [10].

> You get into your Mastercar self-driving car to go to work (originally, all self-driving cars were made by Google, but Master Corporation, a decentralized autonomous entity that automatically uses a combination of futarchy and liquid democracy to determine how the company should spend its funds each day, proved that its governance mechanism was so efficient that it overtook Google on some core services within three years, and alt-Mastercorps took over most of its other operations). You get in, and Mastercar runs a [sic] optimized version of the A* search algorithm (for which James Wilbur automatically got a bounty of $782,228 worth of MSC from the Master Contract) to determine the optimal path to your primary workplace. [20]

In this imaginary, Buterin mentions two concepts for alternative governance structures—futarchy and liquid democracy—that are worth explicating further here to illustrate the kinds of governance shifts that blockchain proponents are imagining. Liquid democracy refers to a voting system that is neither direct democracy or representative democracy, but somewhere in between: "Citizens can freely choose to either vote directly on individual policy-issues, or to delegate their votes to issue-competent representatives who vote on their behalf. This delegation is policy-area specific and can be retracted instantly" [13]. Although hardly new, this concept was popularized by the Pirate Party [96], as well as some blockchain advocates. Current tools may be insufficient for implementing such a system because they "depend on a single centralized server that all users must simply trust, and offer no cryptographic protections either to ensure the integrity of the deliberation process, or to offer privacy, anonymity, or coercion-resistance to voting users" [43].

Some in the blockchain community have argued that liquid democracy might finally be able to be implemented online via a blockchain.

Futarchy is another governance system that blockchain advocates imagine could successfully implemented through blockchain technology (see: [19, 84]). It is "a two-level process by which individuals first vote on generally specified outcomes (like "increase GDP"), and second, vote on specific proposals for achieving these outcomes" [109]. In this system, voters decide on criteria that are important to them (e.g., increasing GDP), and using statistical information and recommendations from experts, market speculators bet on which strategies would bring about an outcome that match those criteria. In the situation where the bets clearly favor one strategy, the strategy would become policy. Advocates of such a system argue that betting markets are generally are more consistently accurate than statistical models built from polls or other public information sources, in part because the betters have financial incentive to make the right predictions [54]. While these specific views are not necessarily held by large number of those in the blockchain community, futarchy and liquid democracy demonstrate the scopes of the futures that some imagine will be possible because of blockchains. Therefore, imaginaries of DAOs describe a future in which authority is given to experts and statistics to determine (generally utilitarian) policies that autonomous agents will carry out in a transparent fashion.

> Given that your self-tracking app has detected that you value your own time (or, rather, the delta between time spent in a car versus time spent at home or work) at an average of $14.18 per hour, the Mastercar's algorithm chooses a route that takes an extra eleven minutes in order to avoid road tolls and also on the way moves a shipment from one side of the city to the other. You drive out, and thirty minutes later you have spent $1.04 on electricity for your car, $1.39 on road tolls, but receive a reward of $2.60 for moving the shipment over. You arrive at work—a location which is a hybrid living/working space where 'employees' of five different alt-versions of Master Corporation are spending most of their time, except that you chose to live at home because you have a family. You then get to work, running simulations of a proposed new scalability algorithm for the now community/DAO-driven Ethereum 6.0. [20]

The Internet of Things features heavily in these imaginaries as well. Taken together with imaginaries about governance, these two imaginaries suggest that companies and governments will become more efficient and the average person will be freed from managing both the kinds of tasks that can be completed by the Internet of Things and from making important decisions that they are not qualified to make. These are not new imaginaries. A similar imaginary was described by Steven Levy in 1984 at the dawn of the "spreadsheet way of knowledge" in which the average person no longer needed accountants to make business decisions because they could rely on spreadsheets to make such decisions using quantitative data; they could use them to convincingly make arguments to follow certain policies and make certain deals. He argued that "the imaginary business that they create on their computers are just that—imaginary. You can't really duplicate a business inside a computer, just aspects of a business. And since numbers are the strength of spreadsheets. The aspects that get emphasized are the ones easily embodied by numbers. Intangible factors aren't so easily quantified" [76]. The imaginaries Levy describes are echoed by imaginaries of decentralized autonomous systems.

As we have seen in the years since Levy's article, certain kinds of manual jobs have largely been replaced by computers in the Global North, but there has been a proliferation of what Graeber [50] calls "bullshit jobs". A notable difference between Levy and Buterin's imaginaries is that in Buterin's imaginary not only manual labor will be replaced by automation, but management will be replaced well. Buterin asks: "can we approach the problem from the other direction: even if we still need human beings to perform certain specialized tasks, can we remove the management from the equation instead?" [17] A humorous example of this imaginary comes from Maurer's interaction with a young Bitcoin advocate: "I have to admit I didn't quite understand how a distributed ledger would benefit machine-led, automated construction. He shifted to another example: ice cream shops, which "self-replicate and own themselves... you could get rid of the cashier, too." But who will stock the shelves, I asked? "I guess robots could do that, too."" [82] This imagined future intersects with two of the previously discussed imaginaries, in that it proposes using algorithms as managers as a means of obtaining freedom from centralized control. But who should be accountable when algorithms are decentralized managers? In centralized cases, we can point to the companies that develop the algorithms, but in this intersecting imaginary it is unclear how one might assign blame. Indeed, as I examine in the following section, the Ethereum community faced this issue with The DAO hack, in which someone exploited a mistake in the programming of the organization's smart contract that allowed them to steal 3.6 million of the cryptocurrency ether, which at the time was worth around $70 million USD.

6.2.2 Tensions between decentralized autonomous systems as control and as freedom from control. When Ethereum experienced The DAO hack in 2016, the community was uncertain how to proceed. In order to reverse the transactions that stole the ether, Ethereum itself, rather than The DAO, would need to roll back the transactions that took place after the theft. (While "DAO" typically refers to a generic decentralized autonomous organization, confusingly, in this case, a crowdfunding platform was named "The DAO".) Therefore, the entire Ethereum community would have to come to a decision about to address an issue that impacted only part of the community. This was an unprecedented suggestion and flew in the face of the values of a large portion of the community: the appeal of Ethereum and blockchain technology was that it was immutable, had supposedly decentralized governance, and that trust was in the code [83], not the people who developed the code (although, there is significant implicit trust in the humans involved in maintaining blockchain technologies [36, 78]). The community "voted" on a decision about whether to adopt a "fork" that would reverse the transactions. Many felt that this was akin to bailing out banks and large businesses, and that anyone who invested in The DAO knew the risks. Furthermore, this "hack" was due to poor programming, and some argued that this money was taken legitimately. Mining pools, the hubs of verification of transactions, put this to a vote. In the end, the reversal happened, but the "imaginaries branching" [69] led to dissonant members of the community creating their own currency out of the fork not taken, called "Ethereum Classic".

Similarly, Bitcoin has faced a governance challenge that began in 2015 and continues to some extent at the time of writing (2019) based on what was essentially changing a variable in the code. This conflict, referred to as "the scaling debate", was over whether the Bitcoin block size should be expanded in order to make space for more transactions, as it was estimated that only a maximum of seven transactions per a second could fit into a block (i.e., 1 MB) [27]. This limitation conflicted with the imaginaries of those that hoped that Bitcoin would be the new Visa (average of 2,000 transactions per a second [27]) and could support, as Jeff Garzik put it, processing the transactions for "all the world's coffees" [46] as invisible infrastructure [28]. Others hoped that it would remain a more visible, special use, and disruptive technology. Furthermore, if the block size was increased, it would benefit large mining operations the most, which would further centralize mining, potentially making the system less secure. Lead developers at the time began proposing their own solutions (e.g., Bitcoin XT) when the community ran into trouble deciding on a solution, causing imaginaries branching and the perception that they were trying to act as "benevolent dictators".

These debates demonstrate how decentralized governance and distributed networks are both intertwined and conflated with one another. As earlier discussed, these systems attempt to use code as law [73] (sometimes literally), but there is no reason that governance must be decentralized for distributed technology. In debates about Ethereum and Bitcoin, which have played out in significantly different ways, there are similar imaginaries of a future in which technology is governed purely by code. However, other imaginaries are of technology governed by experts who intervene in times of crisis. Many of these imaginaries hope for a future in which blockchain technology becomes widespread (e.g., as widespread as Visa) and infrastructure is homogenized (what Swartz refers to as Bitcoin's imaginary of "infrastructural mutualism" [110]).

7 DISCUSSION

Sociotechnical imaginaries can be unifying visions, such as those that led from ubiquitous computing to IoT or those that led from the promise of the Internet to P2P software [1] to blockchain technology [42]. At the same time, proponents of a technology can have conflicting imaginaries; imaginaries branching [69] leads to technology forks as seen with the aftermaths of the Bitcoin scaling debate and the Ethereum DAO "hack". Imaginaries about what a technology is used for also prescribe what types of users would use said technology—such as the debates about whether Bitcoin is more useful for the Global North or the Global South; whether Bitcoin should be used for everyday purchases as a replacement for Visa or as an anti-government currency; or whether blockchain technology should be used as closed corporate infrastructure or as a subversive open technology.

7.1 How we got here: standardization and formalization

As discussed at the beginning of this paper, Wong and Jackson argue that the CSCW community should be "analyzing how imagined futures and cultural values are mutually reflected and embedded in both technology and policy" [123]. A key goal of my research was to understand imaginaries at the protocol-level, as protocols shape the levels above them in the technological (OSI) "stack".

In the following, I describe how the design of computer protocols are related to specific forms of power: standardization and formalization. Computer protocols are often likened to natural languages (see: [31, 44, 102]): languages take arrangements of letters (bits) and arrange them into meaningful structures—words (data structures), and grammars (code) describe the valid uses of a word in the context of a sentence. However, this metaphor falls short when we consider that computer protocols do not develop organically: in natural languages, words change over time, they gain different meanings in different regions and different contexts, and they are shortened and combined with other words and borrowed by other languages. Furthermore, the metaphor does not take into account the centralized power inherent in the construction of protocols.

Computer protocols are more akin to the "pure" forms of language that are standardized through language academies, dictionaries, and other authoritative entities. Like computer languages, this standardization is created through "a linguistic public sphere: a series of real or virtual places of encounter and channels of communication through which members of the academies allegedly openly, rationally and democratically discuss linguistic issues of common concern and design and implement policy through consensus." [29] In the quest for "purity", language academies may invalidate the language practices of minority groups and may be a form of neo-colonialism (e.g., the attempt of the RAE to standardize Spanish across Spanish-speaking countries, in other words, former Spanish colonies). Research on the politics of computer protocols has also found that protocols also perpetuate some of these same inequalities. For example, some debates centered over whether website URLs could be made up of characters from languages that do not use Roman characters [31].

Like linguistic public spheres, protocols are designed for long-term use in the hopes that they will eventually evolve into infrastructure. "While design-for-future-use as infrastructuring and design-for-use as practical system design are different – one opens up questions and possibilities, while the other narrows possibilities through practical design moves – the two can complement each other and coexist as a means of expressing the attachments between publics" [71]. Imaginaries about protocols are not only focused on attempts to influence infrastructuring, but also on a protocol's practical and specific uses—thus there is a tension between opening up to certain futures and closing off to others.

Researchers in STS and critical theory have suggested that distributed network protocols are methods for control rather than freedom from control. Galloway [44] described how we live in a post-decentralization world—a "control society" (referring to Deleuze's "Postscript on Control Societies" [30])—that is governed through protocols and the infrastructures they shape (and are shaped by). The Internet is possible because organizations have agreed upon using common, open protocols to format the information that is sent across the Internet at various levels of its stack. As long as hosts use the same protocol, they can communicate, and thus, Galloway argues, protocols are a means to control and homogenize distributed networking. In the imaginaries that have been discussed, distributed networks are associated with liberalism, but for Galloway, distributed networks are created through "adistributed, bureaucratic institutions—be they entities like ICANN or technologies like DNS" [44]. He argues that there is a contradiction as the control protocols exert is "based on openness, inclusion, universalism, and flexibility" [44]. Furthermore, "stories about standards are necessarily about power and control—they always either reify or change existing conditions and are always conscious attempts to shape the future in specific ways" [98].

7.2 Governance and protocols

I briefly describe the two main strands of research in the area of governance and protocols (i.e., governance of protocols and governance through protocols), and I provide a third alternative that examines the relationship between control and distributed network protocols.

Governance of protocols: previous work on governance and Internet protocols has focused on how protocols are developed and governed through technical decision-making of standards groups such as the IETF [31, 79], or the private sector may regulate them through the supposed invisible hand of the market [73]. This research often takes the perspective that users have little ability to decide on what they want the Internet to look like, as control becomes increasingly hierarchical and centralized.

Governance by protocols: recent research has also pointed to how protocols are designed in ways such that they can be used as mechanisms of control (e.g., for government monitoring). This research focuses on "governance *by* Internet infrastructure, rather than governance *of* Internet infrastructure" (emphasis in original) [32]. This research examines both powerful governments or organizations coopting Internet infrastructure for their own political purposes, and the attempts to make alternative distributed network protocols that cannot be centrally governed [89].

Governance shaped by protocols: in the first strand of research, governance is enacted onto distributed network protocols by governments, organizations, or "the market"; in the second strand, governance is enacted onto users through the technical configurations developed by governments and organizations; and in this third strand I introduce here, instead of governing users of the protocol, the protocol itself shapes the structures of governments and organizations. This strand is not focused on the governance of protocols or governance by protocols, but on how governance structures themselves are shaped by technical protocols. Research has shown that Internet protocols influence the governance, organization structures, and ability to innovate of the corporations that develop hardware components of the Internet's infrastructures [117]. To explore this third strand, I examined how imaginaries of decentralized autonomous systems envision using blockchain protocols to shape the governance of institutions.

7.3 Future directions: participatory design and imaginaries of protocols

Deciding who a technology is meant for has real consequences when it comes to power dynamics between users and non-users, and users and designers. Therefore, examinations of imaginaries and their lineages can clue us into who might have power in future versions of a technology and lead to corrective measures to design technology using intersectional approaches that take into account these power dynamics (e.g., design justice [25], feminist speculative design [81], and postcolonial computing [59]). It is important for designers to use these approaches because "Design is a terrain on which social groups advance their interests. It proceeds through bringing together layers of function corresponding to the various meanings actors attribute to the artifact" [39]—designers (and stakeholders of technology in general) cannot ignore the imaginaries that bring "together layers of function".

I believe that participatory design could be one useful approach for thoughtfully designing around some of the thorny issues inherent in intersecting and conflicting imaginaries. Some strands of participatory design have a focus on "design after design", which is to say, long-term infrastructuring projects and their future uses, and creating space for innovation borne out of agonistic interactions [11, 63]. There are no simple answers, and there should not be when dealing with complex sociotechnical systems; however, I can recommend ways in which imaginaries might help us unpack some issues that arise in the attempt to design infrastructure:

(1) *Future design*: Examine imaginaries and their *pasts* in order to establish a common language between participants in speculative design for the *future* (i.e., "infrastructures of the imagination" [6]).
(2) *Historical impact*: Researchers and designers should determine which parties have been negatively impacted by past technologies in the historical arc of an imaginary. However, this examination should not end there; we should be asking: what are the alternatives to past harms? What are the ways to immediately work toward rectifying the holdovers from the harm? And what radical new imaginaries are possible?
(3) *Design throughout the OSI stack*: After determining who is impacted by a nascent technology, *if it is appropriate to use and if those impacted desire interventions*, then designers and researchers should examine imaginaries at all layers of the technological stack, not just at the application layer, in order to understand power dynamics throughout a sociotechnical system and what futures those configurations of power may open or close off.

As I discussed, the future of blockchain technology has been imagined as governance shaped by protocols, in other words: "decentralized autonomous systems as freedom from centralized governance, replaced with math and autonomous managers of material objects to form new means of production". How can understanding this imaginary (and the many others associated with blockchain technology) help us to design more equitable blockchain technology (assuming that we are to design blockchain technology at all)? What futures are we opening up and what futures are we closing off in this imaginary, and do those futures align with ones that are "anti-oppressive" (and for whom)?

In the case of blockchain technology:

(1) *Future design*: I have identified common and contrasting imaginaries which can be used to create a common language with stakeholders when coming together to design new blockchain technology.
(2) *Historical impact*: Using imaginaries of autonomous systems, I saw that human labor is often rendered invisible in distributed autonomous systems, and these systems may be seen as being governed through "objective" decision-making, thus creating less transparent systems. Therefore, it is imperative that researchers and designers examine ways to make smart

contracts easier to interpret and create ways to address inequitable applications of smart contracts (intentional or not) instead of simply viewing smart contracts as “law”.

(3) *Design throughout the OSI stack*: What are the imaginaries of the people who shape the underlying infrastructure? Researchers and designers should engage with those involved in the infrastructure of blockchain technology (i.e., miners, which have been largely ignored by researchers (with the exception of [66], and developers). Furthermore, future research should also examine how the design of blockchain technologies could impact people who do not directly interact with these technologies, and it should engage with those people. To date, nearly all studies of blockchain stakeholders have focused on users.

These recommendations have the potential to create equitable systems; however, I also caution researchers and designers to consider that many problems are not well-suited to blockchain solutions, and I hope taking an imaginaries approach will help to illuminate where similar technologies have failed (and succeeded) in the past.

Using imaginaries in participatory design does have challenges that researchers should take into account. It may be difficult to determine who will be impacted by nascent technology. Furthermore, tensions between those with differing imaginaries may complicate participatory design. Future work should address these challenges, and it could also explore what imaginaries can tell us about the tensions between design and infrastructuring and further develop the concept of “governance shaped by protocols”.

8 CONCLUSION

In this paper, I identified imaginaries about autonomous systems (specifically on IoT and algorithmic systems) and imaginaries about systems with distributed networks and/or decentralized governance. I examined how these imaginaries intersect in distributed autonomous technology and how there are tensions between those who view distributed technology as a means of control and those who view it as freedom from control. These imaginaries can inform the design of a technology, such as the initial work on Blockchain 2.0 and 3.0 technologies that incorporate the Internet of Things into domains such as shipping technology or smart locks, with the vision of someday creating vast networks of devices all sharing information on blockchains (see [37] for an overview of applications). Furthermore, these imaginaries inform the community’s internal governance of blockchain technologies.

Using imaginaries as an analytical tool will help the CSCW community to examine how the past informs the future of design and how tensions between competing imaginaries influence design, as well as shed light on why and how existing technologies are appropriated. In particular, I urge the CSCW community to go beyond looking at applications and infrastructure, and examine the imaginaries of deeper levels of the technical stack. In this work, I have examined imaginaries about protocols and algorithms. Imaginaries can help us to understand how policy is formed and enacted [123] and can help provide context when using methods such as participatory design, design fiction, and probes. Lastly, imaginaries may shed light on the power dynamics in the creation of technology (e.g., who is imagined to use a technology and who will it benefit?)

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