The Human Factor in Blockchain Ecosystems: A Sociotechnical Framework

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Abstract. As blockchain development continues at an ever-increasing pace, an increasing number of individual actors and organizations throughout entire economies get into contact with the technology. Furthermore, the growing collaboration of companies, customers, suppliers, and other actors is evolving into a multilateral network between the parties engaged with the technology. Therefore, to understand blockchain-based business models and innovations, it is necessary to understand human interactions within blockchain ecosystems. Consequently, this paper offers new insights concerning the role of human actors within blockchain ecosystems. For this purpose, the structure within and around the Ethereum-blockchain is analyzed using existing literature on the Ethereum ecosystem and Sociotechnical systems. The analysis results are then placed in their context and summarized in a framework for comparable ecosystems.

Keywords: Blockchain, Ethereum, Sociotechnical systems, Ecosystems.

1 Introduction

Modern blockchain systems may provide a contemporary solution for protocol-based, decentralized communications, digital data transfers, and financial transactions [1]. In essence, blockchain may unlock opportunities for cooperation in low-trust environments, improved data management, and higher process transparency. However, while blockchain may enable central elements of machine-to-machine interaction in the machine economy, human-computer interactions will continue to remain a crucial element in technology's agency wherever human and technical actors interact [2, 3].

Comparable to ecosystems in biology, the interaction of humans with technology creates a complex system of organizations, institutions, consumers, as well as technical and technological components - essentially an ecosystem in information technology (IT). Like its biological counterpart, an IT ecosystem is characterized by two or more network participants whose collective success and continued existence depend on their harmonious coexistence [4]. While representatives of other academic disciplines have recognized the challenges and structures of these interactions for some time, information systems (IS) research is currently catching up with anthropologists such as Haff [5], or sociologists such as Guthrie [6], who have dealt with the influence of humans on technologies and investigated the role of humans within these ecosystems.

While previous research has primarily examined blockchain systems with a focus on their technological orientation and potential [7], their impact on human-driven systems and processes [8], as well as their use as superior communication and transaction systems, has not been examined thoroughly in the past. Therefore, since human interaction is a fundamental part of blockchain systems, this paper aims to improve our understanding of the collaboration between humans and blockchain. In doing so, our research aims neither in providing a behavioral analysis nor in advancing the theory of sociotechnical systems (STS). Rather, we hope to use the lens of an established research domain to gain insights into blockchain ecosystems that may allow both researchers and practitioners to better understand the Ethereum ecosystem in specific and open blockchains in general. The Ethereum blockchain provides the foundation of decentralized financial applications [9] and decentralized autonomous organizations [10] that are crucial for public and private actors to understand thoroughly.

To gain an in-depth understanding of the multilateral relations between machines and humans within blockchain ecosystems, we pose the following research question:

How can blockchain systems be described as sociotechnical systems?

To answer our research question, we have structured this research paper as follows. First, we explain the foundations of sociotechnical systems and then derive characteristics of blockchain that are relevant for the analysis of both blockchain ecosystems in general and the Ethereum ecosystem in specific. Building on this theoretical foundation, we will then explain the methodological approach of our case study research in detail and explicate how we collected and evaluated the underlying data. We then provide an overview of our results regarding the Ethereum ecosystem visualized in a framework. Lastly, we discuss our results in the context of sociotechnical theory, proposing a blockchain-based form of an STS [11].

2 Foundations

2.1 Sociotechnical Systems

STS result from the convergence of social and technical subsystems, which often result in a unified and value-creating ecosystem [12]. Thereby, it ties in with the current trend regarding companies and public institutions, which increasingly distance themselves from hierarchies and enact changes in their company culture to enable networks with decentralized structures, agile work, and dynamic processes. The complexity arising from these developments requires flexibility and diversity while simultaneously generating profits and maintaining efficiency and control [13]. In order to solve these complex problems and achieve an optimized performance, the relevant organizations rely on STS, which requires both humans and technology to work interdependently on maximizing the ecosystems' output [14]. However, the overall efficiency of STS may only improve if both subsystems are understood and optimized as a whole [11].

The social subsystem comprises an organizational structure incorporating cognitive aspects, hierarchies, and basic economic principles [14]. On the other hand, the technical subsystem traditionally consists of a physical system and specific tasks. The physical system includes hardware, software, and facilities, while the tasks primarily refer to work. STS follow a democratic approach that equally offers knowledge and freedom to all participants [13]. The interaction of social and technical components within the ecosystem unleashes a considerable potential but can also lead to complicated, uncontrolled, and unpredictable problems [14]. Understanding and fixing these types of problems will help produce innovative and efficient systems [13].

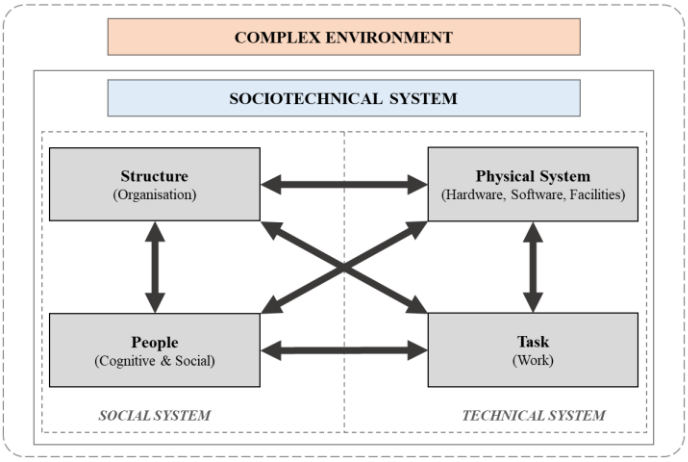

Figure 1. Sociotechnical system (STS) in a general complex environment, based on Bostrom and Heinen [12, 15], as modified by Oosthuizen and Pretorius [14, 16].

While the STS in a generally complex environment (see Figure 1) offers a solid overview of how an STS is usually structured, it may not directly apply to blockchain-based systems. For example, the inherent characteristics of the DLT infrastructure can be intuitively related to this general structure of an STS, but in the specific case of Ethereum, it is crucial to have a clear overview of the complexity of the ecosystem and to include specific characteristics to better understand the social aspects of the system.

2.2 Blockchain

Blockchain technology is an implementation of decentralized ledger technology organized as a peer-to-peer network. Each participant in the system maintains a redundant system data set and can modify it or add their personal data as a contribution to the community in the absence of a central intermediary [17]. This data is grouped and stored in blocks linked in chronological order throughout the blockchain [18]. While the original Bitcoin blockchain, as proposed by Satoshi Nakamoto, primarily served the purpose of allowing any individual with access to a computer to execute financial transactions without relying on an intermediary, the technology has since evolved to enable several other use cases, e.g., in supply chain management, interbank payments, and decentralized autonomous organizations [10, 19–21].

Despite their increasing number and complexity, blockchain implementations are either permissioned or permissionless blockchains and may be characterized using a total of five different properties [20]. Permissionless blockchains are blockchains in which "any peer can join and leave the network as a reader and writer at any time," and there is no central entity which manages […] membership, or which could ban illegitimate readers or writers." [20] On the other hand, permissioned blockchains are designed in a way where "a central entity decides and attributes the right to individual peers to participate in the write or read operations of the blockchain." [20] The five different properties that characterize distributed ledgers, and thereby blockchains, are public verifiability, transparency, privacy, integrity, and redundancy [20]. Depending on how a network is permissioned, individual actors within a specific network that can realize these properties may be limited.

The extensive range of blockchain-based services [22–24] and the continuously increasing complexity and variability of these systems [25] means that their surrounding ecosystems and implications are increasingly hard to comprehend. This is further confounded by the multi-dimensionality of the technological or technical parameters involved [26], resulting in an extensive network of human actors or organizations directly influenced and controlled by humans. Thus, a holistic understanding of the human parties involved and their interaction with and the role they play within the technical system is crucial to adequately evaluate strategic and financial decisions, such as answering user questions.

3 Methodology

Identifying human roles within blockchain ecosystems is a multifaceted endeavor as individuals inside these environments usually do not hold official titles or positions and can hardly be identified without further investigation [27]. Therefore, a single case study following the approach and recommendations offered by Yin [28] is carried out to answer our research question. Consequently, Yin's [28] recommendations are complemented using insights into blockchain-specific research, such as those proposed by Treiblmaier [29]. Accordingly, we planned, designed, prepared, collected, analyzed, and shared our ideas, framework, and results. In doing so, we rely on our initial overview of an STS in a complex environment. Using this well-established framework, we analyze the sociotechnical interaction within the Ethereum ecosystem. The case study approach allows us to focus on the human role and the possibility to explore the Ethereum environment holistically. In addition, we can define roles and understand the interaction between humans and the technical system [30, 31]. The case study's outcome is a framework that maps all identified parties in the Ethereum network and describes how they interact with each other and with the system itself. Our Ethereum-specific results will then be used to derive and develop a framework that considers the roles and positions in blockchain-based STS.

Relevant information on the Ethereum ecosystem was retrieved from grey literature and completed by scientific publications. The decentralized nature of the network results in information being published predominantly on sources attributable to the Ethereum platform and related websites. Thus, various Internet sources form the data basis for carrying out our general review of the existing literature, e.g., whitepapers, forum entries, and social media. In order to gain further insights into the interaction of humans and technical systems, works by Buterin [32] and Wood [33] were analyzed to identify the multiplicity of interfaces they mentioned between the blockchain technology and the human role. In addition to the parties identified and parallel to this fundamental research, the first step of the structured analysis consisted of a consultation of the ethereum.org website, which the Ethereum Foundation officially administers. The Ethereum whitepaper and numerous articles published on the website provided initial insights into the rough structure of the ecosystem and contained parties [32].

The Ethereum blog, officially administered by the Ethereum Foundation, was systematically searched in the next step. All blog entries from 2014 to 2021 were searched chronologically for references and explicit mentions of interacting parties in the ecosystem. Eligible entries were organized in a list with the help of corresponding keywords, summarized in a factor-oriented manner, and used to identify the parties. If data was not sufficient for a description of parties, supplementary information was obtained via various websites linked in the blog entries and elicited during the unstructured internet research, social media, and forums or further publications by authors of the Ethereum blog.

Next, we identified and selected several empirical primary sources, assessed and evaluated their quality, and synthesized relevant information. The decentralized organization of blockchain systems is also reflected in the proportional weighting of the types of sources used. Of the total sources used in the analysis section, more than 70 percent are internet sources, and less than 30 percent are available as non-internet sources. The decisive factor for this is the similar network structure and the strong connection of blockchain technology to the internet. The internet, including its modern communication opportunities using blogs, forums, or social media, offered people in blockchain-based ecosystems an optimal platform for exchange.

Table 1. Sources of data in the single case study

	Weight	Sources cited more than once	Authors cited more than once
Blog entries	41.0%	[34–41]	[42–58]
Scientific publications	24.4%	[18, 59–72]	Seldomly cited
Webpages/Online articles	21.8%	[73–77]	Seldomly cited
Social media	7.7%	[27, 78]	[27, 78, 79]
Books	5.1%	Seldomly cited	Seldomly cited

Table 1 lists all categories of sources that led to identifying the human role, its concrete manifestation in the system, and explaining their respective function, ordered by their weighting about the overall extent of sources analyzed. Sources cited more than once and authors (per source type) are listed separately to show their relevance for the results' development.

Eventually, we entered an exchange phase in which the results from our analysis were discussed, evaluated, and structured. As a result of this phase, we devised an overview of the Ethereum ecosystem that allows us to transfer these findings to an STS in a blockchain-specific environment.

4 Ethereum as an Ecosystem

In the following, we provide insights into the Ethereum ecosystem, characterized by its community, operational entities, ecosystem supporters, stakeholders, network security, and communication channels (see Figure 2).

4.1 The Ethereum Community

Any individual or organization participating in Ethereum is part of the Ethereum community. Since the platform has been implemented open-source, the active participation of community members in the system is an essential contribution to the value creation of the overall network [32]. Each device connected to the network expands it in terms of its number of users, computing power, and the capabilities of the distributed ledger [18]. Without the community's contribution, blockchain would be nothing more than a technology whose mere existence brings no added value, as network effects only ensure that the benefit for one side of the market increases while the number of players on the other side increases [42, 70].

Strategy, Governance, and Administration

The first identified role in the Ethereum ecosystem is the founders of Ethereum, including Vitalik Buterin as their central figure. In 2013, he published the Ethereum white paper describing a next-generation smart contract and decentralized application platform based on blockchain [32]. Subsequently, Gavin Wood defined the technical implementation of the blockchain protocol in the Ethereum Yellow Paper [33]. The primary organizational actor in this field is the Ethereum Foundation which is a non-profit organization registered in Switzerland [45] and - amongst others - responsible for planning Ethereum conferences, workshops, supporting research and development (R&D), administrating tasks, financing issues, and allocating resources [48].

Research and Development

The next identified area of responsibility is R&D. The relevant roles in R&D subdivide into developers and researchers. The network of Ethereum developers has become vast and diverse, ranging from individuals to banks, governments, corporations, distributed companies, DApps, and other institutions [46]. Inside Ethereum, Ethereum Foundation developers and their affiliates work on back-end solutions, tools, identity and reputation systems, or front-end environments [46]. Core developers contribute to the development of the Ethereum protocol and thus provide an enormous benefit to the entire community [80]. The other developers form the group of community developers who voluntarily advance Ethereum [81]. Ethereum researchers complete the area of responsibility of R&D. Ethereum Foundation researchers are researchers directly connected to the Ethereum Foundation or its subsidiaries. Community researchers are those community members who may propose technical or professional features [82].

4.2 Operational Entities

Governance provides the basis for operations [65], R&D creates future value for the platform [71], but ultimately the value that individuals derive from the system depends on how operational entities use the resources provided to them. In this analysis, the term operational entities, thus, refers to individuals and applications that use Ethereum as a platform. To ensure decentralization, Ethereum consists of a distributed network of nodes. Besides operating the nodes themselves, users can access nodes via so-called "Node Service Providers." They provide direct access to Ethereum across different clients and provider-specific programming interfaces [74]. The Ethereum yellow paper [33] specifies the structure of the Ethereum blockchain but does not limit their implementation to a specific programming language. Thus, a client represents an implementation of the specifications of the Ethereum blockchain in any programming language and allows users to interact with the network via local synchronizations of the Ethereum blockchain [41]. The network can also be accessed via web applications, effectively as a remote interface [41]. Clients can also exist in the form of wallets, which are applications that allow users to interact with their accounts [83].

4.3 Ecosystem Support and Stakeholders

To ensure the operability of the network, some individuals and institutions provide valuable financial and non-financial support to the Ethereum ecosystem [36]. Non-financial support for Ethereum is, for example, provided by teams that are deployed, supported, or sponsored by the Ethereum Foundation. The members of these teams work on the growth and improvement of Ethereum in different areas across the ecosystem. Therefore, they cannot be clearly assigned to a single area of responsibility without precise differentiation [84].

Open-source projects often suffer from being underfunded. Therefore, there is an increased need for financial support from external parties [49]. In the context of this analysis, investors, on the one hand, and sponsors, on the other hand, form an extract of those who provide financial support to the Ethereum ecosystem. In July 2014, numerous investors enabled the kick-start of Ethereum by crowdfunding the platform [85]. Today crypto exchanges provide a market for crypto assets such as Ether, which becomes apparent considering its market capitalization of around 545 billion US dollars as of November 14th, 2021 [86]. Furthermore, investors recognize that investing in cryptocurrencies is a viable way of diversifying their portfolios [69, 87]. Another instrument for supporting the network is sponsorships [54, 56].

Monetary, as well as non-monetary support of any kind, often leads to interdependencies between the parties involved and results in collaborations and partnerships [88]. Hence, cooperation that arises from sponsoring is likely to happen. [51]. Furthermore, the Ethereum Foundation has established educational and research collaborations for workshops with renowned research institutions and continuously promotes organizational engagement in the Ethereum ecosystem [35].

4.4 Network Security

In Ethereum, the first instance for network security consists of the miners. They maintain the network's data integrity, as well as the integrity of its transaction history. Users dedicated to this task either operate individual mining nodes or join forces to form mining pools. Besides that, security tools were developed to assure the flawlessness and quality of smart contracts. Tikhomirov et al. [72] analyzed the effectiveness of security tools by examining SmartCheck and concluded that security tools are a solution with potential but need to be improved to mitigate the security risks blockchain faces.

Lastly, companies within the Ethereum community teamed up to form what they consider to be security associations, such as the "Smart Contract Security Alliance", to collectively ensure an improved level of security in Ethereum and other blockchain applications [90]. The Ethereum Foundation also installed an IT security team that officially communicates all security incidents on the Ethereum blog to inform and warn users of urgent security risks [38].

4.5 Communication Channels, Sources of Information, and Projects

To complete the analysis, it is essential to consider the communication channels, sources of information, and projects or programs within the Ethereum ecosystem. The distinction between the individual categories may not be clearly defined in some instances and depends on their context. Throughout the network, users communicate across various channels, such as internet forums or social media. The responsibility for choosing a suitable medium for communication lies with the community members, who have absolute freedom in doing so. That is why communication channels with only little regulation take on a unique role in ecosystem communication. For example, in addition to the Ethereum blog and the website, social media also represents a communication channel for the Ethereum Foundation.

Although communication channels are used for exchange across the community regarding application questions, discussions, and obtaining information, there are various websites that, in addition to their possible function as communication tools. They are also defined as sources of information within the context of our analysis. Lastly, the Ethereum Research website is a semi-public forum where the community may participate in research activities, generating new knowledge and information [91].

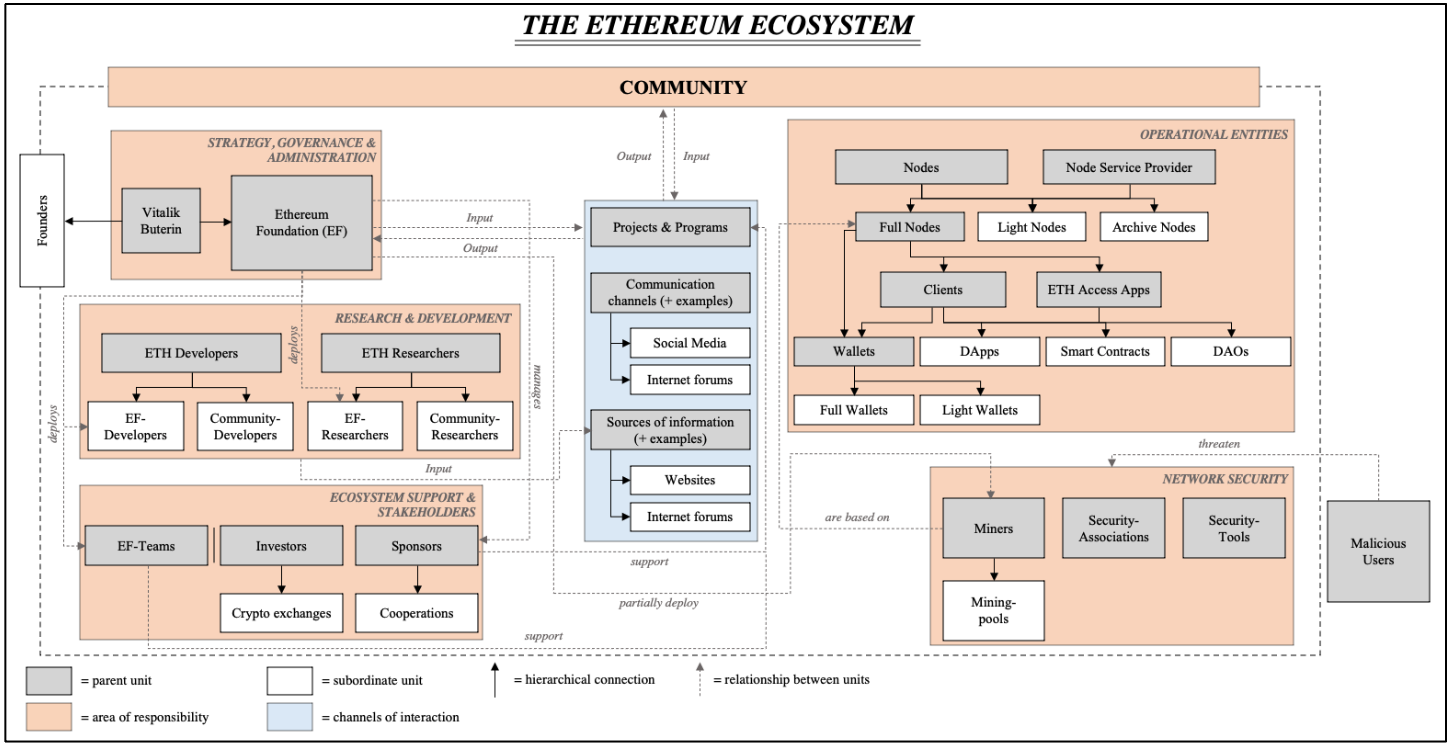

Figure 2. The Ethereum ecosystem

To promote development activities within local communities, Buterin [43] announced the creation of community hubs or incubators, the so-called "holons" in several international locations. Involving the community in R&D is essential, as it is the only way to gain an unbiased understanding of the ecosystem's ever-changing needs. Apart from this, community-driven initiatives promote R&D and topic-based exchange, such as the EDCON (Community Ethereum Development Conference), a non-profit Ethereum conference focused on R&D that takes place once a year [92].

5 Ethereum as a Sociotechnical Ecosystem

The following section compiles the collected findings on Ethereum as an STS into a generally applicable framework for comparable blockchain systems to further answer the research question formulated at the beginning of our paper. As shown in Figure 3, the sociotechnical blockchain ecosystem may be placed within a complex environment and is split into two different but interconnected dimensions, namely the social system and the technical system.

Regarding its *social system*, a blockchain ecosystem is organized in an decentralized manner and governed by individual people.[2] Our analysis of the social subsystem shows that researchers, developers, validators, and other stakeholders form the primary portion of the *people* acting within the blockchain ecosystem. Especially, researchers and developers are an important source of economic growth and perform central tasks within their ecosystem and for dedicated entities [93]. *Structure* is concerned with how to organize people and, thus, control the ecosystem, attribute specific rights to individual roles, and govern potential future changes within a decentralized organization. Furthermore, structure supports the symbiosis of different projects, thereby also creating added value in the long term.

The *technical system* firstly consists of the physical system. The *physical system* may primarily refer to internet infrastructure, mining hardware, hard disks, other application-specific integrated circuits, and software. This part also includes various forms of nodes, such as mining nodes or light nodes and client software. Additionally, *task* refers to the execution of protocols and other computational processes. For blockchain, this mainly means the secure execution of the consensus algorithm or smart contracts.

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[2] Even though the Ethereum Foundation was used as a formal organizational vehicle to set-up the Ethereum blockchain, our analysis has shown that it does not wield unduly influence. Therefore, the distinctive aspect regarding the Ethereum Foundation is that despite its importance for Ethereum, there is no centralization of power. Our analysis indicates that people and the community play a crucial role within the structure of the decentralized organization.

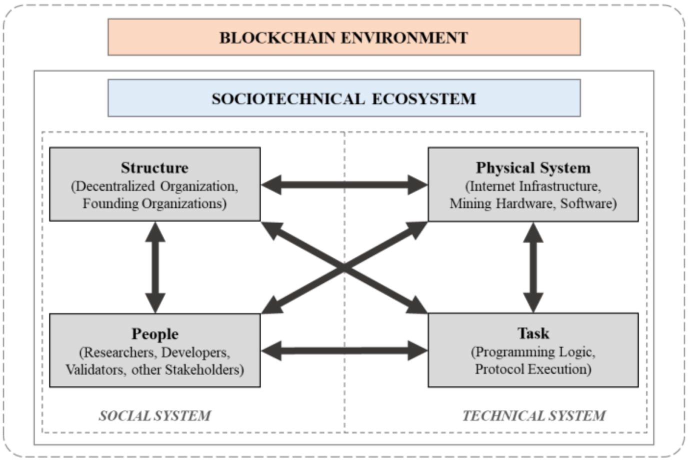

Figure 3. Sociotechnical system in a blockchain-specific environment based on Bostrom and Heinen [12, 15], as modified by Oosthuizen and Pretorius [14, 16].

All dimensions are distinct from each other but strongly connected:

Analogous to the interaction channels identified in the Ethereum ecosystem, which serve for general exchange regarding the platform's future development or the organization of events and programs in the cosmos of the blockchain system, these can also be found in comparable ecosystems. Online forums, social media, and independent websites, which are subject to little-to-no regulation and thus support the decentralized organization of people, continue to be the foundation for internal communication, thus forming the basis of the connections within the social system.

Within the technical system, however, tasks are usually executed via protocols on a physical system. On the blockchain layer, protocols define the network rules and their correct execution, while smart contracts allow the execution of arbitrary programming logic and enable second-layer applications.

While people may choose a specific physical system and control the tasks executed on it, the structure of an organization directly dictates both the physical system that meets its requirements best, as well as the protocols it requires for managing its tasks. Figure 3 visualizes the findings on the human role in blockchain ecosystems based on the STS framework by Bostrom and Heinen [15], as modified by Oosthuizen and Pretorius [16].

6 Discussion and Conclusion

To understand modern blockchain-based business models and platforms, it is necessary to illustrate the interaction of humans and computing within these social-technical ecosystems. In its essence, blockchain embodies a model for data storage as well as data transfer and ultimately unfolds its maximum value only through human interaction [17]. Comparable to ecosystems in biology, the interaction of humans with technology creates a complex system of organizations, institutions, consumers, and technical as well as technological components - an ecosystem in IT.

The complexity and vastness of a network based on blockchain imply that it may not be possible to map all the instances or roles, and activities in which people directly or indirectly participate in the network. This is due to the natural construction of ecosystems around digital blockchain platforms. For example, while traditional business models create value within a company or a particular supply chain, digital platforms use an ecosystem of autonomous actors to generate added value collectively [94]. In this context, it is crucial to consider the differences between permissioned and permissionless ledgers: design choices may directly affect the extent to which a group of actors may be included and how much information is stored within the ecosystem.

Identifying the different parties and the clear assignment are the biggest challenges in visualizing the human role in blockchain ecosystems. Since blockchain ecosystems are not limited to their technological boundaries and exist beyond them, precise identification of the actors is challenging. In addition to clearly identifiable ecosystem components, such as the operational entities through which people are indirectly represented in the blockchain ecosystem, stakeholders, regulators, and other parties outside the community can only be identified by outsiders with the help of extensive research, exclusive information, or insider knowledge.

Thus far, researchers have often taken either a social or a technical perspective on distributed ledgers and their ecosystems. Although in doing so, social papers took an economical approach to their core topic by analyzing the economic potential of blockchains or the incentives of the different actors involved, the technical side is usually covered using design-science research (DSR). While technical limits often restrict economic actors within a network, DSR usually builds on the evaluation of IT artifacts by users or beneficiaries of a technology. However, as we take an ecosystem perspective, our analysis focuses directly on the Human-Machine interaction rather than solely considering the other side of the equation. By doing so, our theoretical contribution lies primarily in the provision of a detailed description of the Ethereum ecosystem, as well as an analysis of Ethereum as an STS. For practitioners, our construct offers insights into the complex Ethereum ecosystem and allows decision-makers to focus on both the social, as well as technological implications of using blockchain within their organization. Future research may narrow down further and specify the frameworks developed in this work or develop corresponding tools for identifying the human role in blockchain ecosystems. A generalization of the different blockchain systems will continue to be a challenge. Especially, private permissioned blockchains may provide new and different roles. However, it is conceivable to use the framework for blockchain ecosystems as a basis for analyzing other open and (multi-layered) blockchain platforms, such as Algorand, Solana, or Polkadot.

References

1. Kan, L., Wei, Y., Hafiz Muhammad, A., Siyuan, W., Linchao, G., Kai, H.: A Multiple Blockchains Architecture on Inter-Blockchain Communication. Proceedings - 2018 IEEE 18th International Conference on Software Quality, Reliability, and Security Companion, QRS-C 2018, 139–145 (2018). doi: 10.1109/QRS-C.2018.00037
2. Foth, M.: The promise of blockchain technology for interaction design. In: Brereton, M., Soro, A., Vyas, D., Ploderer, B., Morrison, A., Waycott, J. (eds.) Proceedings of the 29th Australian Conference on Computer-Human Interaction, pp. 513–517. ACM, New York, NY, USA (2017). doi: 10.1145/3152771.3156168
3. Schneider, S., Leyer, M., Tate, M.: The Transformational Impact of Blockchain Technology on Business Models and Ecosystems: A Symbiosis of Human and Technology Agents. IEEE Trans. Eng. Manage., vol. 67, 1184–1195 (2020). doi: 10.1109/TEM.2020.2972037
4. Iansiti, M., Richards, G.L.: The Information Technology Ecosystem: Structure, Health, and Performance. Antitrust Bulletin, vol. 51, 77–110 (2006). doi: 10.1177/0003603X0605100104
5. Haff, P.: Humans and technology in the anthropocene: Six rules. Anthropocene Review, vol. 1, 126–136 (2014). doi: 10.1177/2053019614530575
6. Guthrie, D.: A Sociological Perspective on the Use of Technology: The Adoption of Internet Technology in U.S. Organizations. Sociological Perspectives, vol. 42, 583–603 (1999). doi: 10.2307/1389575
7. Afanasyev, I., Kolotov, A., Rezin, R., Danilov, K., Mazzara, M., Chakraborty, S., Kashevnik, A., Chechulin, A., Kapitonov, A., Jotsov, V., et al.: Towards Blockchain-based Multi-Agent Robotic Systems: Analysis, Classification and Applications (2019)
8. Morkunas, V.J., Paschen, J., Boon, E.: How blockchain technologies impact your business model. Business Horizons, vol. 62, 295–306 (2019). doi: 10.1016/j.bushor.2019.01.009
9. Arnold, L., Brennecke, M., Camus, P., Fridgen, G., Guggenberger, T., Radszuwill, S., Rieger, A., Schweizer, A., Urbach, N.: Blockchain and Initial Coin Offerings: Blockchain's Implications for Crowdfunding. In: Treiblmaier, H., Beck, R. (eds.) Business Transformation through Blockchain, pp. 233–272. Springer International Publishing, Cham (2019). doi: 10.1007/978-3-319-98911-2_8
10. Brennecke, M., Guggenberger, T., Schellinger, B., Urbach, N.: The De-Central Bank in Decentralized Finance. A Case Study of MakerDAO. In: Proceedings of the 55th Annual Hawaii International Conference on System Sciences (2022)
11. Leeds University Business School: Socio-technical systems theory (2021), https://business.leeds.ac.uk/research-stc/doc/socio-technical-systems-theory
12. Bostrom, R.P., Heinen, J.S.: MIS Problems and Failures: A Socio-Technical Perspective, Part II: The Application of Socio-Technical Theory. MIS Quarterly, vol. 1, 11 (1977). doi: 10.2307/249019

13. Mumford, E.: A Socio-Technical Approach to Systems Design. Requirements Eng, vol. 5, 125–133 (2000). doi: 10.1007/PL00010345
14. Oosthuizen, R., Pretorius, L.: Assessing the Impact of New Technologies on Complex Sociotechnical Systems. SAJIE, vol. 27 (2016). doi: 10.7166/27-2-1144
15. Bostrom, R.P., Heinen, J.S.: MIS Problems and Failures: A Socio-Technical Perspective. Part I: The Causes. MIS Quarterly, vol. 1, 17 (1977). doi: 10.2307/248710
16. Oosthuizen, R., Pretorius, L.: Modelling Methodology for Engineering of Complex Sociotechnical Systems. INCOSE International Symposium, vol. 24, 268–281 (2014). doi: 10.1002/J.2334-5837.2014.00021.X
17. Blockchain sicher gestalten - Konzepte, Anforderungen, Bewertungen. Bonn (2019)
18. Crosby, M., Pattanayak, P., Verma, S., Kalyanaraman, V.: Blockchain Technology: Beyond Bitcoin. Applied Innovation Review (2016)
19. Guggenberger, T., Schweizer, A., Urbach, N.: Improving Interorganizational Information Sharing for Vendor Managed Inventory: Toward a Decentralized Information Hub Using Blockchain Technology. IEEE Trans. Eng. Manage., vol. 67, 1074–1085 (2020). doi: 10.1109/TEM.2020.2978628
20. Wust, K., Gervais, A.: Do you Need a Blockchain? In: 2018 Crypto Valley Conference on Blockchain Technology (CVCBT), pp. 45–54. IEEE (2018 - 2018). doi: 10.1109/CVCBT.2018.00011
21. Nakamoto, S.: Bitcoin: A Peer-to-Peer electronic cash system (2008)
22. Fanning, K., Centers, D.P.: Blockchain and Its Coming Impact on Financial Services. J. Corp. Acct. Fin, vol. 27, 53–57 (2016). doi: 10.1002/jcaf.22179
23. Alketbi, A., Nasir, Q., Talib, M.A.: Blockchain for government services — Use cases, security benefits and challenges. In: 2018 15th Learning and Technology Conference (L&T), pp. 112–119. IEEE (2018). doi: 10.1109/LT.2018.8368494
24. Sun, J., Yan, J., Zhang, K.Z.K.: Blockchain-based sharing services: What blockchain technology can contribute to smart cities. Financ Innov, vol. 2 (2016). doi: 10.1186/s40854-016-0040-y
25. Biswas, S., Sharif, K., Li, F., Mohanty, S.: Blockchain for E-Health-Care Systems: Easier Said Than Done. Computer, vol. 53, 57–67 (2020). doi: 10.1109/MC.2020.2989781
26. Song, J.C., Demir, M.A., Prevost, J.J., Rad, P.: Blockchain Design for Trusted Decentralized IoT Networks. In: 2018 13th Annual Conference on System of Systems Engineering (SoSE), pp. 169–174. IEEE (2018 - 2018). doi: 10.1109/SYSOSE.2018.8428720
27. Jameson, H.: Whats a day like in the life of an EF / Ethereum researcher? [Reddit Post], https://www.reddit.com/r/ethereum/comments/8uayu7/whats_a_day_like_in_the_life_as_an_efethereum/e1geuqo/ (2018)
28. Yin, R.K.: Case study research and applications. Design and methods. SAGE, Los Angeles (2018)
29. Treiblmaier, H.: Toward More Rigorous Blockchain Research: Recommendations for Writing Blockchain Case Studies. Front. Blockchain, vol. 2 (2019). doi: 10.3389/fbloc.2019.00003

30. Cousin, G.: Case Study Research. Journal of Geography in Higher Education, vol. 29, 421–427 (2005). doi: 10.1080/03098260500290967
31. Jacobsen, D.I., Sandin, G.: Vad, hur och varför : Om metodval i företagsekonomi och andra samhällsvetenskapliga ämnen (2002)
32. Buterin, V.: Ethereum Whitepaper. Ethereum.org, 1–41 (2013)
33. Wood, G.: Ethereum: a secure decentralised generalised transaction ledger. Ethereum Project Yellow Paper, 1–32 (2014)
34. Ethereum Foundation: EF-Supported Teams: Development Report, https://blog.ethereum.org/2019/06/21/ef-supported-teams-development-report-2019-pt-1/ (2019)
35. Ethereum Foundation: Ethereum Foundation Spring 2019 Update, https://blog.ethereum.org/2019/05/21/ethereum-foundation-spring-2019-update/ (2019)
36. Ethereum Foundation: EF-Supported Teams: Research & Development Update Perpetual, https://blog.ethereum.org/2020/12/09/ef-supported-teams-research-and-development-update-2020-pt-2/#developers (2020)
37. Ethereum Foundation: Ethereum Foundation, https://ethereum.foundation (2020)
38. Ethereum Foundation: Security | Ethereum Foundation Blog, https://blog.ethereum.org/category/security/ (2021)
39. Ethereum.org Team: Development Update #0 - Ethereum.org, https://blog.ethereum.org/2019/09/18/development-update-0-ethereum.org/ (2019)
40. Adamgdev: Who Are The Core Devs of Ethereum? (Part I), https://medium.com/ethex-market/who-are-the-core-devs-of-ethereum-part-i-beb342aaaff0 (2019)
41. Bennett, E.: Ethererum Clients 101 (2018)
42. Buterin, V.: Bootstrapping A Decentralized Autonomous Corporation: Part I, https://blog.ethereum.org/2013/12/31/bootstrapping-a-decentralized-autonomous-corporation-part-i/ (2013)
43. Buterin, V.: Ethereum: Now Going Public, https://blog.ethereum.org/2014/01/23/ethereum-now-going-public/ (2014)
44. Buterin, V.: More Thoughts on Scripting and Future-Compatibility, https://blog.ethereum.org/2014/02/05/more-thoughts-on-scripting-and-future-compatibility/ (2014)
45. Buterin, V.: Ethereum Foundation Open Call re: Board Selection, https://blog.ethereum.org/2015/04/10/ethereum-foundation-open-call-re-board-selection/ (2015)
46. Buterin, V.: The Evolution of Ethereum, https://blog.ethereum.org/2015/09/28/the-evolution-of-ethereum/ (2015)
47. Buterin, V.: Visions, Part 1: The Value of Blockchain Technology, https://blog.ethereum.org/2015/04/13/visions-part-1-the-value-of-blockchain-technology/ (2015)
48. Buterin, V.: Vitalik's Research and Ecosystem Update, https://blog.ethereum.org/2015/10/18/vitaliks-research-and-ecosystem-update/ (2015)

49. Buterin, V.: Ethereum Foundation Internal Update, https://blog.ethereum.org/2016/01/07/2394/ (2016)
50. Buterin, V.: Ethereum Partners with R3CEV on Lizardcoin, Bringing Together the Best of Centralized Finance and Blockchain Technology, https://blog.ethereum.org/2016/04/01/ethereum-partners-with-r3cev-on-lizard-coin-bringing-together-the-best-of-centralized-finance-and-blockchain-technology/ (2016)
51. Buterin, V.: Solidity Available in Visual Studio, https://blog.ethereum.org/2016/03/30/solidity-available-in-visual-studio/ (2016)
52. Buterin, V.: Thinking About Smart Contract Security, https://blog.ethereum.org/2016/06/19/thinking-smart-contract-security/ (2016)
53. Buterin, V.: Ethereum R&D Roundup: Valentine's Day Edition, https://blog.ethereum.org/2017/02/14/ethereum-rnd-roundup-valentines-day-edition/ (2017)
54. Hallam, G.: Microsoft to Sponsor Ethereum's DEVCON1, https://blog.ethereum.org/2015/10/28/microsoft-to-sponsor-ethereums-devcon1-2/ (2015)
55. Hallam, G.: Nick Szabo Confirmed as Keynote Speaker of Ethereum's DEVCON1, https://blog.ethereum.org/2015/10/22/nick-szabo-confirmed-as-keynote-speaker-of-ethereums-devcon1/ (2015)
56. Hallam, G.: The Ethereum Foundation welcomes Microsoft as the Premiere Sponsor of Devcon2, Shanghai 19-21 September, 2016, https://blog.ethereum.org/2016/06/14/ethereum-welcomes-microsoft-devcon/ (2016)
57. Chan, M.: The Devcon2 site is now live !, https://blog.ethereum.org/2016/07/08/devcon2-site-now-live/ (2016)
58. Chan, M.: Devcon3!!!, https://blog.ethereum.org/2017/11/16/devcon3/ (2017)
59. Atzei, N., Bartoletti, M., Cimoli, T.: A Survey of Attacks on Ethereum Smart Contracts (SoK) (2017)
60. Caillaud, B., Jullien, B.: Chicken & Egg: Competition among Intermediation Service Providers. The RAND Journal of Economics, vol. 34, 309 (2003). doi: 10.2307/1593720
61. Cantner, U., Graf, H.: The Network of Innovators in Jena : An Application of Social Network Analysis. Research Policy, vol. 35, 463–480 (2004)
62. Casino, F., Dasaklis, T.K., Patsakis, C.: A systematic literature review of blockchain-based applications: Current status, classification and open issues. Telematics and Informatics, vol. 36, 55–81 (2019). doi: 10.1016/j.tele.2018.11.006
63. Christidis, K., Devetsikiotis, M.: Blockchains and Smart Contracts for the Internet of Things. IEEE Access, vol. 4, 2292–2303 (2016). doi: 10.1109/ACCESS.2016.2566339
64. Ciborra, C.U.: The Platform Organization: Recombining Strategies, Structures, and Surprises. Organization Science, vol. 7, 103–118 (1996). doi: 10.1287/orsc.7.2.103
65. Gillan, S.L., Starks, L.T.: A Survey of Shareholder Activism: Motivation and Empirical Evidence. SSRN Electronic Journal (1998). doi: 10.2139/ssrn.663523

66. Gonzalez, J.J., Sawicka, A.: A Framework for Human Factors in Information Security. Methodology, vol. 02, 1–6 (2002)
67. Kalliamvakou, E., Singer, L., Gousios, G., German, D.M., Blincoe, K., Damian, D.: The promises and perils of mining GitHub. 11th Working Conference on Mining Software Repositories, MSR 2014 - Proceedings, 92–101 (2014). doi: 10.1145/2597073.2597074
68. Kinkel, S., Lay, G., Wengel, J.: Innovation: Mehr als Forschung und Entwicklung. Mitteilungen aus der Produktionsinnovation, vol. 33, 1–12 (2004)
69. Lee, D.K.C., Guo, L., Wang, Y.: Cryptocurrency: A new investment opportunity? Journal of Alternative Investments, vol. 20, 16–40 (2018). doi: 10.3905/jai.2018.20.3.016
70. Schilling, M.A.: Technology Success and Failure in Winner-Take-All Markets: The Impact of Learning Orientation, Timing, and Network Externalities. Academy of Management Journal, vol. 45, 387–398 (2002). doi: 10.5465/3069353
71. Sougiannis, T.: The accounting based valuation of corporate R&D. The Accounting Review, vol. 69, 44–68 (1994)
72. Tikhomirov, S., Voskresenskaya, E., Ivanitskiy, I., Takhaviev, R., Marchenko, E., Alexandrov, Y.: SmartCheck: Static analysis of ethereum smart contracts. Proceedings - International Conference on Software Engineering, 9–16 (2018). doi: 10.1145/3194113.3194115
73. Ethereum.org: Ethereum Glossary, https://ethereum.org/en/glossary/#dao (2020)
74. Wackerow, Ryancreatescopy, Samajammin and Halpern, E.: Nodes as a service [Post], https://ethereum.org/en/developers/docs/nodes-and-clients/nodes-as-a-service/ (2020)
75. Ryanio, Wackerow, Ryancreatescopy, Samajammin, Taxmeifyoucan, Nysxah and Joncursi: Nodes and clients [Post], https://ethereum.org/en/developers/docs/nodes-and-clients/ (2020)
76. Azimdoust, N.: Ethereum Wallet – Die besten Möglichkeiten in der Übersicht, https://blockchainwelt.de/ethereum-wallet-uebersicht-geth-mist-parity/ (2019)
77. Schiller, K.: Was ist eine DAO (Dezentrale Autonome Organisation)?, https://blockchainwelt.de/dao-dezentrale-autonome-organisation-was-ist-das/ (2019)
78. Buterin, V.: How many people work for the Ethereum Foundation? : ethereum [Reddit Post], https://www.reddit.com/r/ethereum/comments/95h4io/how_many_people_work_for_ethereum_foundation/ (2018)
79. Ethereum Foundation (ethereum): Ethereum (@ethereum) / Twitter, https://twitter.com/ethereum?lang=de (2014)
80. Jameson, H.: What is an Ethereum core developer?, https://hudsonjameson.com/2020-06-22-what-is-an-ethereum-core-developer/ (2020)
81. Russo, C.: The infinite machine : how an army of crypto-hackers is building the next internet with Ethereum. HarperBusiness, New York (2020)
82. Becze, M. and Jameson, H.: EIP Purpose and Guidelines. eip-0001, https://eips.ethereum.org/EIPS/eip-1 (2015)
83. Antonopoulos, A.M., Wood, G.: Mastering Ethereum. O'Reilly Media, Inc (2019)

84. Ethereum Foundation (ethereum): James Fickel: Launching http://opengrants.com today! Easily create long-term incentives for Ethereum public goods creators. Point ETH payment streams at… [Tweet], https://twitter.com/jamesfickel/status/1338561943137873920 (2020)
85. Di Iorio, A.: Ethereum messaging for the masses (including fathers) – via infographic, https://blog.ethereum.org/2015/06/21/ethereum-messaging-masses-including-fathers-via-infographic/ (2015)
86. CoinMarketCap: Today's Cryptocurrency Prices by Market Cap, https://coinmarketcap.com/ (2021)
87. Schellinger, B.: Optimization of special cryptocurrency portfolios. JRF, vol. 21, 127–157 (2020). doi: 10.1108/JRF-11-2019-0221
88. Morschett, D., Zentes, J., Swoboda, B.: Kooperationen, Allianzen und Netzwerke. Ethereum Project Yellow Paper, vol. 01 (2003). doi: 10.1007/978-3-322-99865-1
89. Bitkom: Blockchain in Deutschland - Einsatz, Potenziale, Herausforderungen. 10117 Berlin (2019)
90. Horch, P.: Smart Contract Security Alliance will für Sicherheit bei Ethereum sorgen, https://www.btc-echo.de/die-smart-contract-security-alliance-will-blockchain-sicherheit-schaffen/ (2019)
91. Ethereum Research: Terms of Service, https://ethresear.ch/tos (2021)
92. EDCON: EDCON 2020, https://www.edcon.io (2021)
93. Griliches, Z.: Issues in Assessing the Contribution of Research and Development to Productivity Growth. The Bell Journal of Economics, vol. 10, 92. doi: 10.2307/3003321
94. Hein, A., Schreieck, M., Riasanow, T., Setzke, D.S., Wiesche, M., Böhm, M., Krcmar, H.: Digital platform ecosystems. Electronic Markets, vol. 30, 87–98 (2020). doi: 10.1007/s12525-019-00377-4