Performance Analysis of a Hyperledger Iroha Blockchain Framework Used in the UK Livestock Industry

Konstantinos Ntolkeras
Blockchain Department
Breedr Ltd
London, UK
kostas@breedr.co

Hossein Sharif
Newcastle Business School
Northumbria University
Newcastle upon Tyne, UK
hossein.sharif@northumbria.ac.uk

Soroush Dehghan Salmasi
Newcastle Business School
Northumbria University
Newcastle upon Tyne, UK
soroush.salmasi@northumbria.ac.uk

William Knottenbelt
Department of Computing
Imperial College London
London, UK
w.knottenbelt@imperial.ac.uk

2021 IEEE International Conference on Blockchain (Blockchain) | 978-1-6654-1760-0/21/$31.00 ©2021 IEEE | DOI: 10.1109/BLOCKCHAIN53845.2021.00070

***Abstract*— This investigation focuses on the performance analysis of one of the most nascent Blockchain frameworks, Hyperledger Iroha. This paper evaluates the performance of the Hyperledger Iroha framework based on three parameters: (a) total requests per seconds (RPS) over time; (b) response times in milliseconds over time; and (c) number of users in the network over time. The results indicate that the integration of Hyperledger Iroha with a major livestock management and trading platform in the UK, can support at least 200 participants with no errors in the network. Additionally, the total requests per second can reach as high as 40.6, and the response times are in the order of a fraction of a second. This research and its results can assist scholars and practitioners regarding selection of an ideal Blockchain framework for their problem setting.**

Keywords*— *Blockchain, Supply Chain Management, Livestock Industry, Hyperledger Iroha, Response Time, Scalability

I. Introduction

Recently, there has been an increasing surge of attention to digitizing supply chains with the aim of increasing transparency and visibility, while enhancing profits by improving the matchmaking of its participants and allowing access to credit by using supply chain records. This is especially important now as Covid-19 has severely plagued supply chains throughout the world [1]. In this light, many supply chains have embraced Blockchain technologies so as to guarantee further transparency and trust within the industry [2].

Blockchain, at its heart, is about maintaining a distributed record of transactions in lieu of the central architecture which has been prevalent until now [3]. Technologically, Blockchain reckons aspects of distributed computing and cryptography which implement an operational protocol (incentive mechanism) based on Game Theory principles [4]. One of the earliest manifestations of the power of this technology is Bitcoin which is a self-regulated currency platform capable of handling transactions remarkably faster, safer, cheaper, and more traceable than conventional legacy financial systems [5]. Having gained ground in financial industries [6], Blockchain technologies have enthralled many minds in other fields whose problem domains can benefit from increased transparency and/or more efficient transactions. Based on these new application domains, Blockchain's annual expansion rate in the supply chain has been estimated to grow by 87% which increases from $45 million in 2018 to $3,314.6 million by 2023 [7]. The escalating adoption rate of the Blockchain-powered solutions within supply chains have been substantiated through increased transparency and more streamlined transactions which all lead higher productivity and profitability.

One of the sectors that most recently has started exploring the potential of Blockchain is the livestock industry. The present research provides a report on the first major application of Blockchain technology for the livestock industry in the UK which is now active and running. The project was envisioned and then executed through a consortium comprising of one of the leading Blockchain research centres in the UK, a global livestock tracing and trading platform (Breedr), one of Europe's largest meat processors and the UK government. After much deliberation and consultation with industry experts, Hyperledger Iroha was chosen as the Blockchain framework for this project to be implemented within Breedr. This is despite much more widespread usage of other Blockchain frameworks, such as Ethereum and Hyperledger Fabric, for a similar problem domain. Overall, Hyperledger Iroha outperformed other alternatives in our case because of its consensus algorithm (also referred to as YAC or Yet-Another-Consensus algorithm), highly supportive community, robust permission system, simple deployment as well as ease of maintenance. Despite its superior performance, Hyperledger Iroha has not received significant attention among researchers and practitioners. In such a setting, this research presents a unique report of the performance of this Blockchain framework in a major real-world commercial situation.

The rest of the paper is organized as follows. Section II explains the integration of Iroha with the UK's major livestock tracing and trading platform (Breedr). Section III describes the methodology in three steps: The Blockchain Framework and

978-1-6654-1760-0/21/$31.00 ©2021 IEEE
DOI 10.1109/Blockchain53845.2021.00070

Hardware Setup, Benchmark Framework Implementation, and Performance Results. The results obtained from these tests are presented and discussed in Section VI. Lastly, Section V provides conclusions, limitations, and future work.

II. The Integration of Iroha Within the Breedr Livestock Platform

The Livestock in the UK predominantly reliant on small farmers whose approach to their farming activity is more of a lifestyle choice rather than a profit-driven business. This can be observed through families who have been running small livestock farms across multiple generations spanning going as far back as 1700s. Another feature of this sector has been their resistance towards technology adoption, for business reasons, e.g. costs and sophistication, and non-business reasons, e.g. preserving their way of life and social structure. On the other hand, changes in governance philosophies and economic policies, e.g. market-driven policies and increased privatization, as well as major events, such as Bovine Spongiform Encephalopathy (BSE or the Mad Cow Disease), Foot and Mouth Disease and most recently exiting of the EU (Brexit) and the Covid-19 pandemic and the subsequent changes in regulation and consumer behavior have acted as major drivers for technology adoption.

All the aforementioned drivers have let do more adaptive atmosphere in the UK's livestock sector for disruptive innovation through platform business models and Blockchain technology. In this regard, government funding and regulatory support for this specific project, have acted as catalysts further facilitating the transformation of the UK's livestock sector.

On a more specific note, considering the actual implementation of a commercial Blockchain-based solution, project partners conducted an evaluation of existing Blockchain frameworks and none proved to be mature and/or resilient enough to address project requirements. Eventually, after consultation with industry experts, Hyperledger Iroha was identified as a promising option. This framework was then adopted for development of a prototype solution. Consequently, given the satisfactory results of this prototype, Hyperledger Iroha was then formally adopted as part of the Breedr livestock tracing and trading platform.

System configuration of the Blockchain solution is presented in Fig. 1. Firstly, we developed and employed an Iroha network so as to foster trust among stakeholders and also to guarantee the transparency and security of interactions. Also, an Application Programming Interface (API) was developed via the Iroha Python library [8], to ensure the accessibility of the Iroha Blockchain through web-based and other applications.

Furthermore, a stand-alone web application was developed in order to address information inquiries, retrieval, and display from the Iroha network. The Blockchain Explorer, which utilizes the API generated by us to interact with Iroha, was developed based on the Flask web framework [9]. The Blockchain Explorer can be employed for data retrieval from the Blockchain, by such system stakeholders as farmers, lenders, regulators, and processors, according to their permissions.

Additionally, the main functionality of our solution was integrated into the Breedr platform. Thus, the Breedr back-end, which is built utilizing Django [10], was modified and developed. Also, the platform database, PostgreSQL [11], was utilized to store and retrieve the details of certain user and animals. Moreover, the Breedr Administrator Interface was modified so as to interact with the Blockchain and also to facilitate software integration. However, we were not able to modify the Breedr client interface as they did not have access to it.

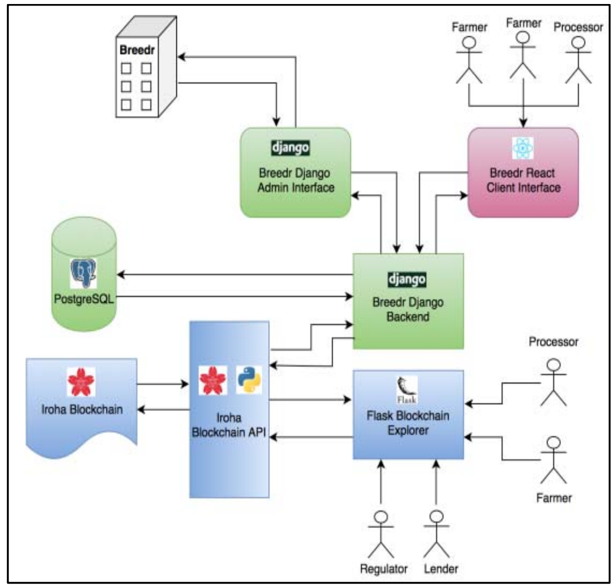

Fig. 1. System configuration demonstrating the interaction of various elements. Blue elements are created; green elements are modified, and red elements are existing and unmodified.

III. Methodology

As mentioned previously, evaluating the performance of a Hyperledger Iroha Blockchain framework is unique to this research, and is not addressed in any other research paper. For this project, we intend to evaluate the performance the Hyperledger Iroha using Locust. All the steps taken to execute this benchmark testing and performance evaluation are described thoroughly in this section.

A. Step 1: The Blockchain Framework and Hardware Setup

This performance evaluation experiment is conducted on a MacBook Pro, Retina, 2015 model, with the Intel® Core™ i5 Dual-Core CPU @ 2.7GHz, 8 GB RAM, 121 GB hard disk drive and running macOS Catalina Version 10.15.4. The Blockchain framework that we have chosen to test for this experiment is Hyperledger Iroha. More specifically, Hyperledger Iroha is one of several Blockchain frameworks and tools managed by the Linux Foundation. This is based on the adoption of the source code originally developed by the Japanese FinTech company Soramitsu after they made it available to the public as an open source project [12]. Iroha is constructed as a general purpose permissioned Blockchain framework developed in C++. It uses a Byzantine Fault Tolerant (BFT) ordering service and a BFT consensus algorithm referred to as Yet-Another-Consensus (YAC) algorithm. More specifically, Hyperledger Iroha offers special support and features for development of mobile applications and provides a modular design that adopts the command-query separation principle. The initial design and architecture of this framework was heavily inspired by Hyperledger Fabric [13], while attempting to outperform it through a simple, reliable and high-throughput solution supporting permissioned Blockchain web and mobile applications. Moreover, this framework provides a set of C++ libraries to other Hyperledger projects [14]. One the key features of Iroha compared to other frameworks is that it enables a situation where each user can be given varying permissions when transacting within the Blockchain network [12]. In this project, we have tested the Hyperledger Iroha version 1.1.

B. Step 2: Benchmark Framework Implementation

The performance of the Iroha network transaction speed as measured by Garifullina [15] and Dimant [16]. The conditions of conducting the performance tests were as follows: 1. One node in the network; 2. Eight different clients with a total of 32,000 requests; and 3. One transaction sent per request in which 0.01 USD was transferred to a test account. The testing framework which was employed to simulate users and transactions was Locust [17]. The results of a performance test conducted by Garifullina [15] and Dimant [16] showed that Iroha can support about 300 Transactions Per Seconds (TPS). The results of the performance test are presented in Fig. 2.

We took this analysis a step further by testing the performance of Iroha for a specific use case, the Blockchain API that was developed for the livestock industry. Also, we utilized Locust as our testing framework for the purpose of consistency. Given the available computing power, the configuration below was used to make the test scalable:

- 1. Users to simulate: 200
- 2. Hatch rate (users spawned per second): 5
- 3. 1 Atomic Batch of transactions sent per request. For every request an atomic batch of transactions was sent as defined in our API implementation. We test for (a) Generating a farmer or processor account; (b) Registering an animal to a farmer's account, and (c) Querying and retrieving the account information from the Blockchain.

C. Step 3: Performance Results

In this step, we have collected our experimental performance outputs in one table and three graphs, which were generated by Locust. As mentioned before, we measured performance in terms of three metrics including 1. total requests per seconds over time; 2. response times in milliseconds over time; and 3. number of users in the network over time.

IV. Results and Disscusion

Performance test results are illustrated in Fig. 3. There were 0 failures in the transactions sent to and processed by the network, with the total RPS reaching as high as 41. A more in-depth analysis of our results indicates that Iroha can settle about 7 RPS for generating farmer or processor accounts and 10 RPS for registering animals to farmer accounts. Furthermore, Iroha is quite high-performant in querying and retrieving information from the Blockchain. As Fig. 3 illustrates, Iroha can obtain about 24 RPS in retrieving account information from the Blockchain.

A more thorough analysis of the results can be offered by examining Figs. 4, 5, and 6. Fig. 4 shows the total requests per second, while Figure 5 demonstrates the response times in milliseconds, and Fig. 6 the number of network users. These figures make a comparative analysis of the results possible and elaborate on the performance of our software.

Another significant factor that should be taken into consideration when opting for a particular Blockchain technology is its *scalability* potential. Figs. 3, 4, 5, and 6 illustrate the results of the performance tests conducted against our software. The results assure us that our solution can scale up well to multiple network users and can support many RPS. Furthermore, as Fig. 3 demonstrates, since our software faces 0 failures in the performance tests conducted, it can be concluded that it is completely robust.

Moreover, Iroha makes the configuration of the network before utilization possible so as to better meet the particular needs, requirements, and features of the use case in question. A very significant factor affecting network scalability is the max proposal size, which determines the maximum number of transactions that can be stored in one proposal. If the system faces many transactions per second, then it is essential to increase this factor when the network is configured. This makes greater performance and better scalability of our solution possible. Lastly, vote delay is another important factor that should be configured before employing the Blockchain solution. The vote delay factor determines the waiting time before a peer sends its vote to the next node. When this factor is being configured, we should consider for the overall number of nodes within the system. This factor expresses the trade-off between high throughput performance and the frequency of failures in the consensus mechanism. Thus, vote delay is another essential factor in determining solution scalability. TABLE I demonstrates a general evaluation of the Hyperledger Iroha.

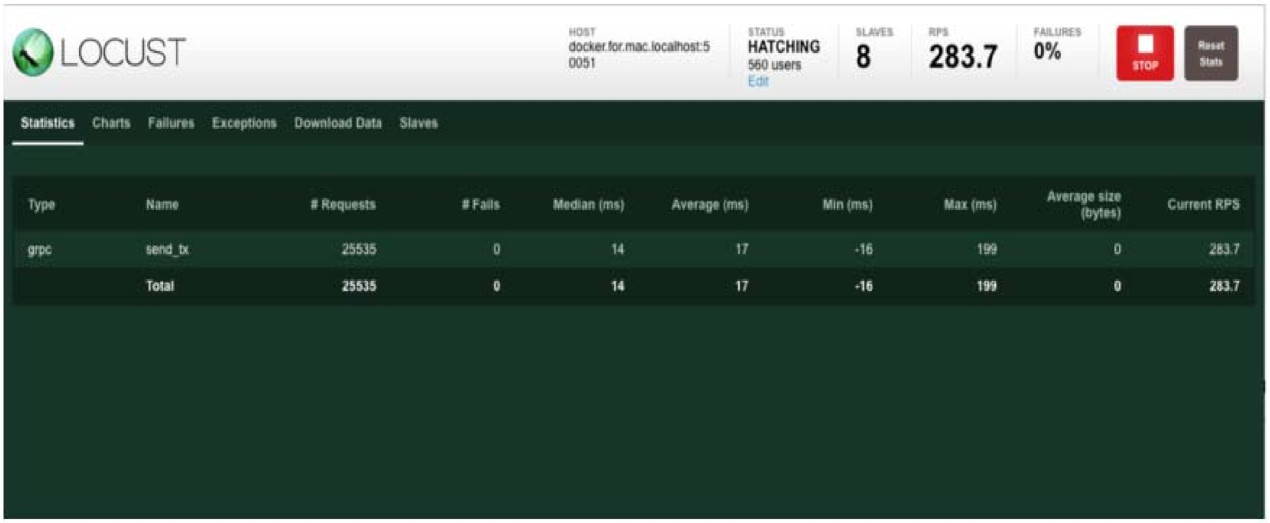

Fig. 2. Performance tests on Iroha recording the TPS of the network

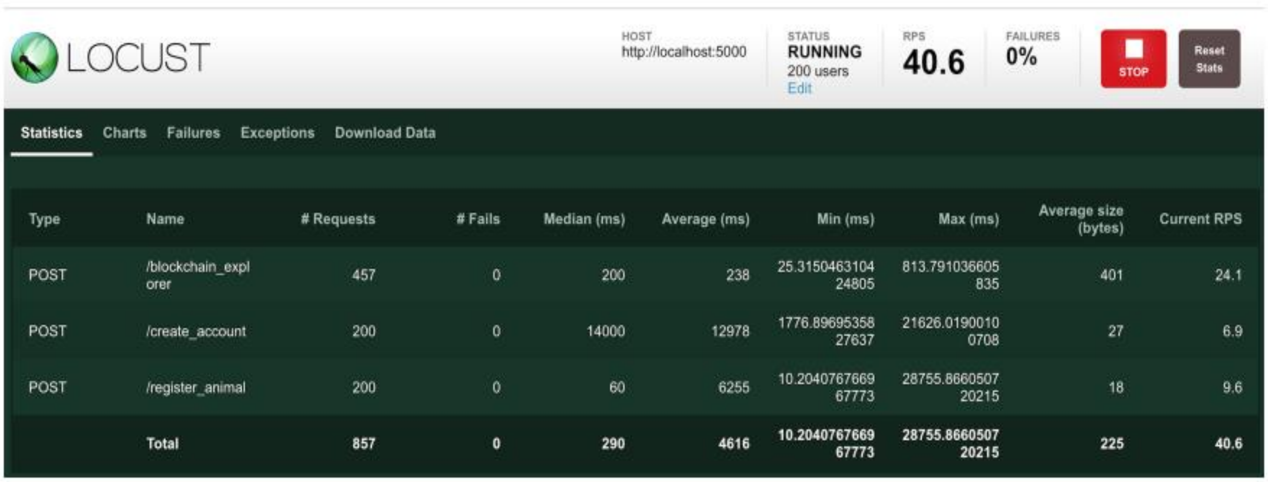

Fig. 3. Requests per second (RPS) supported by Iroha for 1. Generating a farmer or processor account; 2. Registering an animal to a farmer's account; and 3. Querying and retrieving the account information from the Blockchain

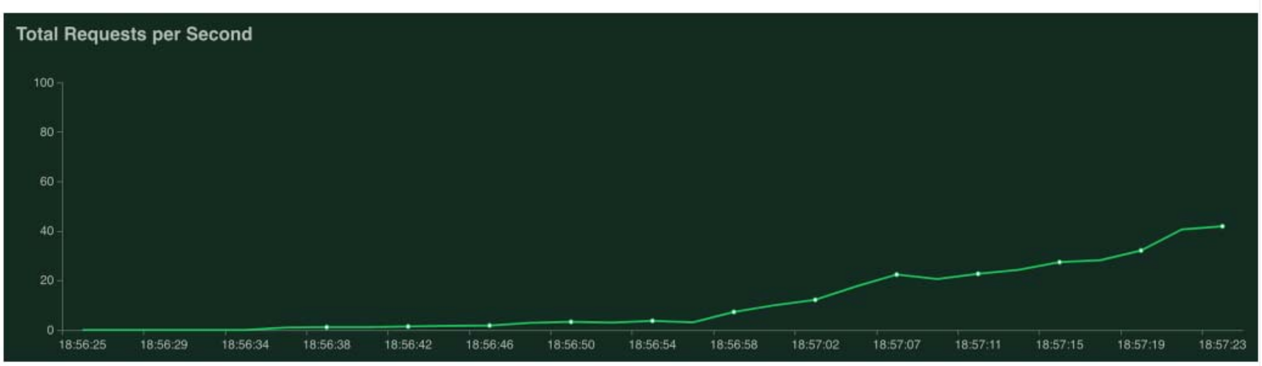

Fig. 4. Total requests per seconds over time

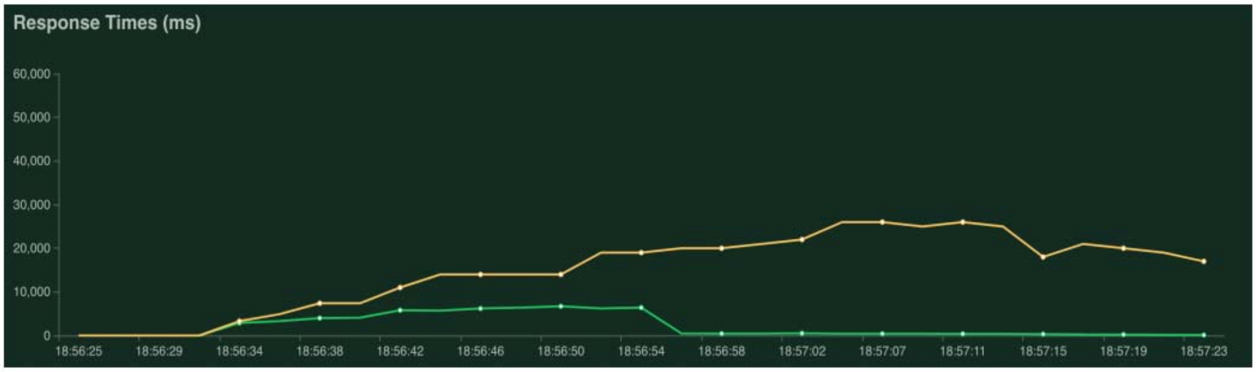

Fig. 5. Response times in milliseconds over time

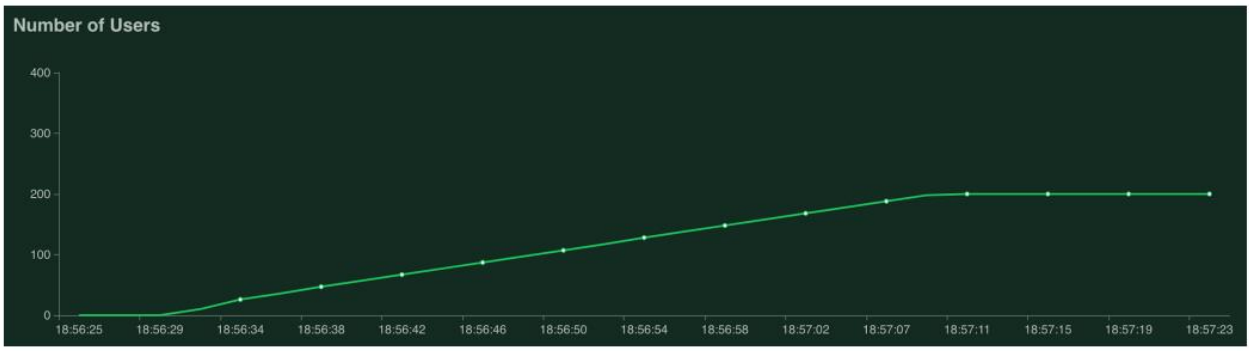

Fig. 6. Number of users in the network over time

TABLE I. A GENERAL EVALUATION OF THE HYPERLEDGER IROHA FRAMEWORK INTEGRATED WITH BREEDR PLATFORM

Parameter	**Hyperledger Iroha**
Requests Per Second (RPS)	40.6
Response time	A fraction of a second
Scalability	Good (Our implementation scaled up to 200 users with 5 users spawned per second) + reconfigurable
Robustness	Good (our implementation scaled up to 200 users with 5 users spawned per second with 0 failures) + YAC (Yet Another Consensus) Byzantine fault tolerant algorithm
Industrial Use	Medium (e.g. Soramitsu, Cambodian Payment System, xor crypto)
Data Security	Advanced – 2 Layers of Access Control (our implementation)
Costs	Nodes running + Labour
Integration	Advanced
Labour Force	Potentially less (+Much bigger after integration with Burrow and smart contracts written in Solidity)
Business Perspective	Innovative, faster development (at least in the beginning)
Technical Maturity	Medium
Issues reported	9 Open – 35 Closed

V. Conclusions, Limitations, Furtur Work

This research seeks to investigate the performance analysis and full potentials of Hyperledger Iroha and add to the current academic literature and industrial work. This technology offers a high performance, novel BFT algorithm and guarantees low response times and finality of transactions. It provides a secure and easy-to-use API to interact with the Blockchain. Furthermore, developers can take advantage of a collaborative and active community and are encouraged to contribute themselves to make the community develop and prosper. Iroha makes the relatively simple utilization and maintenance of the network possible, while encouraging the development of mobile applications. Additionally, it offers a completely operational mechanism for multi-signature transactions, which are extensively utilized in our application. However, it is important to bear in mind that Iroha is a novel and, thus, not fully-fledged technology. There are not many resources available and even though the community is active and collaborative, it is not as large as that of other Blockchain technologies that have been around much longer in the market. Lastly, Iroha v.1 does not yet offer a facility for the generation and deployment of smart contracts. However, Hyperledger Iroha v.2 provides such a facility [18].

As limitations of this project, it should be noted that these results are contingent upon software design and implementation as well as the API calls produced. They are specific to our use case and implementation and also represent the time complexity of our software. Furthermore, it should be stressed that each request does not correspond to one transaction only, but rather to multiple transactions organized in an atomic batch and signed by different network users. This fact should be taken into consideration when comparing the software performance with other Blockchains or other implementations in Iroha. It should also be noted that these results are subject to hardware restrictions of the devices used. For future work, we have a plan to assess newer versions of Hyperledger Iroha, and we are interested in comparing the performance results of Hyperledger Iroha with more common Blockchain frameworks such as Hyperledger Fabric and Ethereum. Moreover, given that we only have a single node at the moment for each environment, we can potentially deploy more nodes then compare and contrast the performance with our current setting.

Acknowledgment

The authors would like to acknowledge the financial support and funding of the UK Research and Innovation (UKRI), Imperial College London, Breedr Ltd and the Northumbria University.

References

[1] Singh, S., Kumar, R., Panchal, R., & Tiwari, M. K. (2021). Impact of COVID-19 on logistics systems and disruptions in food supply chain. International Journal of Production Research, 59(7), 1993-2008

[2] Kouhizadeh, M., Saberi, S., & Sarkis, J. (2021). Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. *International Journal of Production Economics*, *231*, 107831.

[3] G. Perboli, S. Musso, and M. Rosano, "Blockchain in Logistics and Supply Chain: A Lean Approach for Designing Real-World Use Cases," IEEE Access, vol. 6, pp. 62018–62028, 2018, doi: 10.1109/ACCESS.2018.2875782.

[4] N. Alzahrani, N., & Bulusu, "Towards true decentralization: A blockchain consensus protocol based on game theory and randomness," Int. Conf. Decis. Game Theory Secur., pp. 465–485, 2018, doi: 10.1007/978-3-030-01554-1.

[5] S. Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," 2008, doi: 10.1162/ARTL_a_00247.

[6] S. Kumar, V. Mookerjee, and A. Shubham, "Research in Operations Management and Information Systems Interface," Prod. Oper. Manag., vol. 27, no. 11, pp. 1893–1905, 2018, doi: 10.1111/poms.12961.

[7] Y. Chang, E. Iakovou, and W. Shi, "Blockchain in global supply chains and cross border trade: a critical synthesis of the state-of-the-art, challenges and opportunities," Int. J. Prod. Res., vol. 58, no. 7, pp. 2082–2099, 2020, doi: 10.1080/00207543.2019.1651946.

[8] Hyperledger Iroha (2019). Python library for Hyperledger Iroha. Retrieved from https://github.com/hyperledger/iroha-python. Accessed: 2019-09-05.

[9] Flask (2019). Flask web development, one drop at a time. Retrieved from https: //flask.palletsprojects.com/en/1.1.x/. Accessed: 2019-09-05.

[10] Django (2019). The web framework for perfectionists with deadlines. Retrieved from https://docs.djangoproject.com/en/2.2/. Accessed: 2019-09-05.

[11] PostgreSQL (2019). PostgreSQL: The World's Most Advanced Open Source Relational Database. Retrieved from https://www.postgresql.org/. Accessed: 2019-09-05.

[12] Saraf, C. and Sabadra, S. (2018). Blockchain platforms: A compendium. In 2018 IEEE International Conference on Innovative Research and Development (ICIRD), pages 1–6. IEEE.

[13] Cachin, C. and Vukoli´c, M. (2017). Blockchain consensus protocols in the wild. arXiv preprint arXiv:1707.01873.

[14] Brinckman, A., Luc, D., Nabrzyski, J., Neidig, G. L., Neidig, J., Puckett, T. A., Radha, S. K., and Taylor, I. J. (2017). A comparative evaluation of blockchain systems for application sharing using containers. In 2017 IEEE 13th International Conference on e-Science (e-Science), pages 490–497. IEEE.

[15] Garifullina, S. (2019). Weekly iroha newsletter - performance tests. Retrieved from https://lists.hyperledger.org/g/iroha/message/106. Accessed: 2019-09-05.

[16] Dimant, B. (2019). Stockchain: A blockchain-based stock exchange. BEng Individual Project. Imperial College London.

[17] Locust (2019). An open source load testing tool. Retrieved from https://locust.io/. Accessed: 2019-09-05.

[18] Hyperledger Iroha (2021). Hyperledger Iroha v2.0 – Hyperledger Iroha Documentation. Retrieved from https://iroha.readthedocs.io/en/iroha2-dev/iroha_2_whitepaper.html. Accessed: 2021-07-10.