Exploring the Challenges of Developing and Operating Consortium Blockchains: A Case Study

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ABSTRACT

Blockchain and smart contracts are being embraced by more and more industrial practitioners in multiple domains including agriculture, manufacturing, and healthcare. As a distributed, immutable, and partly public ledger, the consortium blockchain demonstrates its potential to enable trustworthy interoperability and collaboration between organizations. However, the mismatch between the unruled software engineering practices and the increased interest of the consortium blockchain technology may pose threats to the quality of systems implemented. To mitigate the possible threats, this study takes the angle of software engineering to systematically understand the challenges and possible solutions in terms of developing and operating a consortium blockchain-based system. For this purpose, we conducted a case study on a typical consortium blockchain-based system and exhaustively collected the data by two rounds in-depth interviews on practitioners of different roles in the case project. Based on the data analysis, eight pairs of challenges and potential solutions were identified, which cover the phases of the development and operation of consortium blockchains. Moreover, we also captured two implications after further analysis of the findings, which worth the special attention of researchers in the near future, i.e. DevOps and microservices for blockchain or smart contracts.

CCS CONCEPTS

• **Software and its engineering** → **Software development techniques**; **Software development methods**.

KEYWORDS

Consortium blockchain, smart contracts, DevOps, microservices

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1 INTRODUCTION

The concept of blockchain was first proposed by Nakamoto [1] as the underlying technology of the Bitcoin system. As a decentralized and shared ledger combining transaction data blocks into a specific data structure through cryptographic and encrypted technologies, blockchain ensures the benefits of immutability and non-repudiation of transaction records among different parties. Generally, blockchain technology can be classified into three types, namely public, private and consortium blockchain [2]. During the evolution of the blockchain technology from 1.0 to 2.0 and 3.0, the consortium blockchain is increasingly being adopted by enterprises due to its three main advantages in comparison with the public blockchain: 1) Fewer nodes and higher transaction speed; 2) Better data privacy among specific parties; 3) Higher flexibility to recover from faults as long as the participated institutions reach a consensus.

With such increased interest in the consortium blockchain, software engineering practices related to this technology should grow at a matching rate, on the one hand, to minimize the possible attacks to applications [3], e.g., the MtGox attack and the Dao attack; and on the other hand, to improve specific SLAs of applications, for example, lead time, delivery frequency or mean time to recovery (MTTR). However, the new context of blockchain brings many challenges to the applications developed using this technology from the aspect of software engineering [4]. If not well emphasized and addressed, the quality of the blockchain applications may be threatened.

Inspired by the research of Porru et al. [3], this study aims to understand the current challenges of developing and operating consortium blockchain-based applications with the angle of software engineering. It is also to further explore possible solution directions for addressing the challenges identified. For this purpose, we conducted a case study in industry, collected the data by in-depth interviews on experienced practitioners. This study highlighted multiple challenges and possible solution directions related to the development and the operation of consortium blockchain-based system. Furthermore, we also refined the findings into two underlying directions worthy of special attention in academia, i.e. DevOps for blockchain and microservices for blockchain.

The rest of this paper is organized as follows: Section 2 introduces the methodology of this study, including research questions, case selection, data collection, and data analysis. Section 3 summarizes the findings related to the challenges and possible solutions of developing and operating consortium blockchain-based systems. Section 4 discusses some possible implications based on the results and findings in section 3. Section 4 also lists the threats to the validity of this study. Section 5 presents the research work associated with the focus of our study and section 6 draws a conclusion.

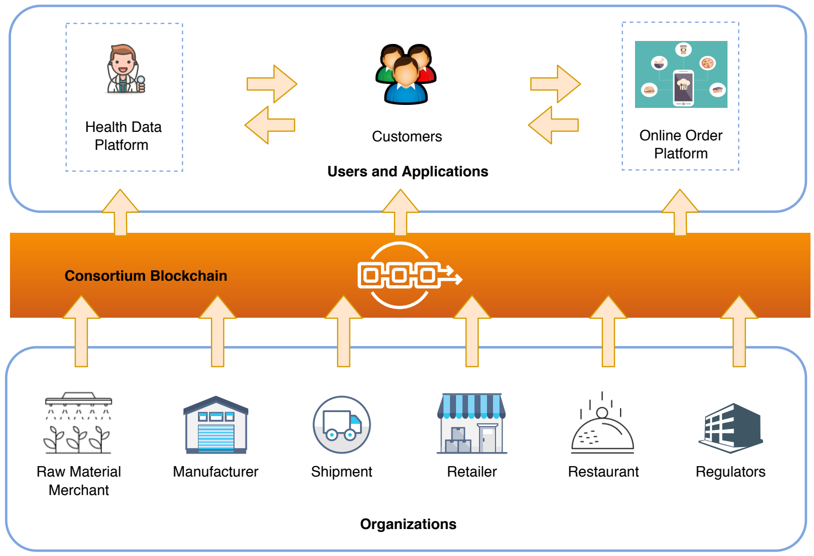

Figure 1: Overview of the consortium blockchain-based supply chain system for agricultural foods.

2 METHODOLOGY

We conducted an exploratory case study to understand the challenges of and possible solutions for consortium blockchain-based systems from the perspective of software engineering, seek new insights, and generate ideas and hypotheses for academic research in the near future. The case study followed the guideline of Runeson et. al. [5], in which we collected the data through in-depth interviews.

2.1 Research questions

This case study was motivated by the following two research questions:

RQ1: What are the challenges associated with the development and operation of consortium blockchain-based applications? This RQ is to figure out the barriers of practitioners when developing and operating consortium blockchain-based applications in practice.

RQ2: What are the potential directions to address the challenges of developing and operating consortium blockchain-based applications? This RQ aims at exploring possible directions or requirements of solutions, which can inspire further research in academia or help practitioners to overcome the barriers identified in RQ1.

2.2 Case selection

To retrieve systematic and exhaustive evidence for answering our research questions, we carried out an in-depth study on a single case selected from one of the few research institutes in China, which involves addressing the challenges of blockchain technology. Blockchain projects studied and implemented by this institute cover multiple domains, e.g., supply chain, cross-border trade, business management, Internet of Things (IoT), and finance.

The case we selected is the most typical and successful project in the aforementioned institute, a food supply chain system for the traceability of agricultural products based on the consortium blockchain technology. This agricultural food supply chain system is mainly implemented in two languages, i.e. Java and Go. The size of this case project is about one million LOC, whose lead time is four months on average. The proportion of developers to operators in this food supply chain project is five to one. The roles of developers include consensus design, blockchain protocol design, smart contract development, front development, backend development, and supervision of full stacks.

The high-level overview of this system is displayed in Figure 1. The main problem facing the agricultural product quality tracking system and the food safety tracking system is that the process involves multiple individuals, and it is difficult for the relevant parties to establish a multi-trust relationship among them. To ensure the traceability and safety of agricultural food, this institute collaborated with large food production companies and government departments to fully apply the DLT (Distributed Ledger Technology) to address the problem of agricultural product quality tracking. It cooperated with ChainNova [1] to build an enterprise-level IoT and DLT management platform that allows different parties in the process of the food supply chain (especially end-users) to access the trusted product data required. The consortium blockchain technology was used as a partially public distributed ledger among organizations with cooperation, raw material merchants, manufacturers, shipment companies, retailers, restaurants, and regulators, etc. The consortium blockchain creates an immutable tracking channel on all links by recording data from those relevant organizations, which simultaneously maintain a single data source and consistency of data records. Food manufacturers label the goods of the Internet of things to ensure that each shipment has a unique identification number. These labels can track many kinds of information concerned about common customers or other applications, e.g., raw material, source, shipment, information of retailers and restaurants,

[1] https://github.com/ChainNova

and health data. a health data platform or an online order platform. The information can be queried by common customers or some upper applications, for example, a health data system of a food and nutrition institution or an online order platform.

2.3 Data collection

The data were collected through exhaustive group interviews with practitioners who participated in the work of the food supply chain project. We conducted two rounds interviews for comprehensive data collection from different groups. The first interview group includes one project manager and one senior architect, both of whom have more than 10 years of software development experience and no less than 4 years of experience in the blockchain field. Interviewees of the second group are two developers who have at least two and a half years of experience in the blockchain domain. One of them is the technical leader of the security department and participates in the development of the identity authentication and key management modules.

Table 1: Data collection

#	Data	Interview questions	RQs
F1	Demography	Q1-Q4	–
F2	Challenges	Q5-Q9,Q10-Q12,Q14-Q16	RQ1
F3	Solutions	Q5-Q9,Q13,Q17	RQ2
F4	Comments	–	–

We designed a set of semi-structured interview questions (cf. Appendix. A) to guide the dialogue between the researchers and the interviewees, which are: 1) Opening questions (Q1-Q4) related to the background of interviewees and their organizations, for example, development experience, team size, and individual roles; 2) General questions (Q5-Q9) related to the background and the brief introduction of the food supply chain system, e.g., functional requirements and technologies used; 3) specific questions (Q10-Q17) related to the challenges, practices, and possible solution directions of the food supply chain system in the phases of development and operation. The relationship between the data collected by these interview questions and the research questions are shown in Table 1. Dialogues of the two-round interviews were driven by three student researchers with the process of asking the questions, taking notes and recording the conversation after getting the interviewees' permission.

2.4 Data analysis

The two-round group interviews last for about three hours, whose audio materials were then transcribed to textual documents with about 20,000 Chinese words. Three student researchers analyzed the transcripts through the widely-used qualitative method, coding [6]. Furthermore, the coding process was assisted by NVivo, a prevalent tool for the qualitative analysis of data with high efficiency and less complexity. The thematic analysis [7] was also used to manually analyze the challenges and possible solutions associated with developing and operating the consortium blockchain-based food supply chain system. To prevent the bias of the researchers, the aforementioned processes of data analysis were independently carried out, and then the results obtained were double-checked. Any disagreements were addressed through regular meetings and discussions with their supervisors.

3 FINDINGS

The analysis of the data that were exhaustively collected through in-depth interviews generates many interesting findings. This section elaborates those findings associated with our two research questions. The answers to RQ1 (Challenges) and RQ2 (Solution directions) are organized in pairs to facilitate the understanding of our audience.

3.1 Development

3.1.1 *Requirement analysis and coordination.*

- **Challenges.** Blockchain projects especially the consortium blockchains pose higher demands for requirement analysts, the employees who are responsible for the work of requirement analysis. For traditional applications, requirement analysts can just master the knowledge of one specific field. By contrast, consortium blockchains require requirement analysts from involved parties to have the background knowledge across multiple fields, since they need to collectively complete the analysis of requirements for consortium blockchain-based systems. Coordination now is manually conducted among multiple parties to confirm many aspects for a unified design or modification of specific requirements, e.g., extracting business processes from functional requirements, determining the data interaction, and defining all relevant interfaces. Communication and coordination among different parties are usually time-consuming and may result in the low efficiency of requirements analysis and design.
"This a big problem for consortium blockchains. Whenever a new requirement comes or a modification is needed, it always needs to be jointly discussed and determined by multiple parties from many aspects, for example, what information should be put on the chain or which logics should be implemented with smart contract. "
- **Solution directions.** The practitioners desired an automated tool or a standard process to help them reduce the complexity of requirement analysis and coordination. Since one requirement document may correspond to multiple organizations, the expected tool should automatically support the process of requirement analysis, design, and decision in a collaborative way. Disappointingly, they did not find any suitable tools or methods to achieve their expectation.

3.1.2 *Architecture design.*

- **Challenges.** From the perspective of software architecture, when building a blockchain system, it is necessary to carefully consider the features of blockchains and decide how

to design the architecture to decrease the impact on quality attributes for the overall systems. For the food supply chain system in this study, key quality attributes are: 1) Interoperability: Coordinate information exchange across the many information systems from different parties; 2) Latency: Exchange of physical foods wait upon exchange of digital documentation; 3) Scalability: Many processes in progress at anytime across a large number of parties. However, the interviewees said that:
"The application of blockchain technology is at an early stage in our institution. A systematic support is missing currently to evaluate the possible impact of this technology on quality attributes of systems and guide the design of the software architecture through addressing some important quality attributes."

- **Solution directions.** The interviewees mentioned that systematic evaluation and guide for the architecture design need the contribution of academic researchers and senior architects in this domain. For example, as mentioned by one interviewee, microservice architecture (MSA) may be a potential direction to help address the scalability problem after appropriately decomposing blockchain systems into small and independent services. However, many aspects should be figured out before applying this new architectural style to the design of the supply chain system, among which a critical one relates to the extent of the decomposition. For this aspect, a key consideration of our interviewees is trading-off the granularity and performance based on the requirements of the supply chain system and deciding the suitable extent of decomposition.
"We are studying how to decompose the system into core entities and corresponding operations. Then we need to develop discreet and composable smart contracts for each entity and operation so as to achieve better non-functional requirements. But now we are confusing about how to achieve an appropriate decomposition, evaluate the effectiveness of it, and avoid some negative impacts that may be caused by adopting this architectural style..."

3.1.3 Testing.

- **Challenges.** The natures of a consortium blockchain make it challenging to test the food supply chain system implemented using this technology: 1) It is more difficult to upgrade or modify the system due to the immutability of the blockchain and therefore requires high-quality testing technologies in advance. 2) It is also challenging to to establish an agreement on what to test and how to test it, since different parties of related to a consortium blockchain may have different priorities and criteria for testing. 3) Automated testing technologies are needed to efficiently support different levels of testing, e.g., protocol level, smart contract level, or consortium level.
- **Solution directions.** An emerging trend for the first challenge is to deliver a snapshot (referred to as a "fork") of an existing blockchain for testing. This can often deliver the same result without the complexity of building a system to create synthetic transactions to populate the ledger. Moreover, there is also the scope to utilize formal verification techniques [8, 9] in order to reason about the underlying assumptions to find faults. However, many aspects of these technologies still need to be further studied, e.g., improving the security and avoiding vulnerabilities of the blockchain-based system during the fork process. Automated tools and SaaS implementing a DevOps strategy may be the potential solution for the rest two challenges, which provide an effective testing environment for consortium members for member-specific applications and support the automated testing at different levels. Prevalent tools for this purpose are Truffle Suite [2], Azure Blockchain Service [3], etc.

3.1.4 Integration.

1) Integration with off-chain business modules.

- **Challenges.** Blockchain, located at the bottom layer of an application, can be viewed as a distributed database. The database is a ledger among a set of peer-to-peer nodes with the same copy. The data on the chain needs to be integrated and communicate with other off-chain business modules, e.g., clients, to implement specific requirements. However, developers find it challenging to achieve data communication between on-chain data and off-chain modules.
- **Solution directions.** a) Many companies have developed and provided BaaS (Blockchain as a Service) platforms whose SDKs can help developers easily connect the on-chain and off-chain modules using different programming languages, e.g., Microsoft's Azure Blockchain Service and Alibaba's Blockchain as a Service[4]. b) Microservices can be adopted to bridge the gap between traditional business modules and chain nodes, then the data communication can be completed through RESTful APIs. As mentioned by our interviewees, in the next step they will focus on designing a blockchain application ecosystem that optimizes on-chain and off-chain transactions at scale using microservices.

2) Integration with heterogeneous blockchains.

- **Challenges.** Consortium blockchains of the supply chain system may include multiple heterogeneous chains among different consortia (companies). A blockchain within a company is private to other companies, which is difficult for developers from other consortia to communicate with.
- **Solution directions.** An inter-blockchain connection model may be useful for heterogeneous blockchains to lower the barriers and facilitate blockchains' communication. In this kind of model, a blockchain system is able to establish connections with other blockchain systems. After two systems connected, data and messages are shared. Specifically, directions and requirements of this solution are: a) Heterogeneous blockchains can communicate with each other through standard cross-chain transactions; b) Crossing-chain transactions can be transferred by nodes in router blockchain; c) Transactions can be transferred in a peer-to-peer way without the participation of any third party.

[2] https://www.trufflesuite.com
[3] https://azure.microsoft.com/en-us/services/blockchain-service/
[4] http://url.cn/5MM8XKY

3.1.5 *Deployment.*

- **Challenges.** The complexity of the blockchains burdened the deployment work of our interviewees. The length of the consortium blockchain in the food supply chain system is very long because of the the complex business logic, which is associated with multiple members. Consequently, our interviewees found that it was troublesome for them to deploy the long-chain system, especially when different parties have distinct requirements and restrictions of the production environment for deployment.
"Improving the efficiency of deployment and reducing the lead time of products is highly emphasized in our institution now. We hope that there could be an effective tool or method to help us address this problem."
- **Solution directions.** Designing and deploying smart contracts using microservices and containers may help reduce the burden of deployment in a modularized way. Microservices architecture patterns are gaining increased popularity as organizations migrate critical application workloads to the cloud and deliver more engaging customer experiences across multiple channels. The rapid growth of microservices lies in an architectural style that decomposes applications into small autonomous services modeled in a single business domain, allowing each microservice to be developed, deployed and scaled independently by a team. The benefits of implementing smart contracts as microservices may include delivering digital products and services to market much faster, simpler application maintenance and improved business agility. Deployability and scalability of microservices-based smart contracts can be achieved easily by automated tooling like Kubernetes [5], Docker [6], OpenWhisk [7], and a wide range of open source technologies.

3.2 Operation

3.2.1 *Monitoring.*

- **Challenges.** Consortium blockchain applications, with the characteristics of decentralization, place higher demands on motoring and visualization in terms of many aspects like performance, availability, and security. As complained by our interviewees, they lacked a standard approach covering different levels to monitor the consortium blockchain-based supply chain system and also a set of widely accepted criteria to evaluate relevant monitoring metrics.
"Consensus is not reached yet in terms of monitoring blockchain especially consortium blockchain systems. In our case, what to monitor and how to monitor are waiting for an unified and effective solution..."
- **Solution directions.** Effective monitoring and management of a consortium blockchain application require a standard and customized framework, which can integrate the data, assimilate the events generated and provide an effective visualization of the blockchain-based systems considering their specific characteristics and constraints. This framework should be modular and should support deployment topologies, which can enable monitoring at different levels of the system. Apart from the common levels for monitoring traditional software such as the infrastructure and the application, some other aspects particularly in the blockchain-based system should be given special attention, e.g., individual nodes, and the entire blockchain network.

[5]https://kubernetes.io
[6]https://www.docker.com
[7]https://github.com/apache/openwhisk

3.2.2 *Fault detection and recovery.*

- **Challenges.** For the consortium blockchain-based supply chain system in this paper, fault detection was mainly performed through logs. However, once the deployment is completed, interference cannot be performed due to the immutability of blockchains. Therefore, fault recovering of consortium blockchains cannot be easily addressed by traditional program debugging methods such as printing bugs. Our interviewees mentioned that they have encountered the problem of data inconsistency among different consortia. The inconsistent data made them painful when deciding whether updating the data and which version of the data criteria from different consortia can be used for consistent updating. These make the practitioners very difficult to solve the fault recovering problems in consortium blockchain.
- **Solution directions.** Our interviewees mentioned that a "healing node" can be designed when developing the blockchain to detect and feedback error information to specific modules. Specifically, if the error is very simple, the system may complete the repair and recovery by itself. Otherwise, customers and the relevant maintenance engineers will be notified. After that, access permissions will be applied to make changes, which may be costly. Unlike traditional software, the blockchains especially the heterogeneous blockchains involve multiple nodes and cannot perform simple operations such as shutdown and restart. Instead, different versions of chains may be provided according to different problems, and improvements are made step by step rather than being changed all at once. "Healing node" may be a potential solution for addressing the aforementioned challenges, while it still needs efforts and contributions in academia to identify a more effective and efficient solution to support detecting and recovering from faults combing logging analysis or some other automatic technologies.

4 DISCUSSION

This section discusses some underlying implications refined from the findings in section 3 and strategies used to mitigate the threats to the validity of this study.

4.1 Implications

1) DevOps for blockchain. The challenges of developing and operating the consortium blockchain-based supply chain system identified in this study may call for a unified and automated solution to support continuous collaboration of various organizations (cf. section 3.1.1), continuous testing (cf. section 3.1.3), continuous integration with off-chain business modules or heterogeneous blockchains (cf. section 3.1.4), continuous deployment and delivery cf. section 3.1.5, and continuous monitoring (cf. section 3.2.1). We noticed that DevOps has drawn a lot of attention of practitioners and become the mainstream in industry thanks to the features required by the aforementioned solution. DevOps, as a culture, enables the collaboration among different teams and bridges the gap between the phases of the development and the operation of a software project through the end-to-end automation [10]. As advocated, DevOps could address the requirements in terms of continuous collaboration, continuous testing, continuous integration, continuous deployment and delivery, and continuous monitoring. Therefore, it may be high potential to apply the DevOps culture and its practices to address the aforementioned challenges of systems with the context of blockchain, especially the consortium blockchain.

As mentioned by our interviewees, the core concepts and activities of DevOps in the blockchain domain may not differ much from traditional software, e.g., SCM, build & configuration, testing, integration, deployment, and operation. However, some features of blockchain may cause specific constraints that need to be considered when adopting the DevOps solution, e.g., the immutability of the ledger. These considerations and differences may also be worthy of further research to contribute to a customized DevOps approach for blockchain systems.

2) Microservices for blockchain. Microservices are gaining more and more popularity as a new architectural style for traditional software for many advantages [11], e.g., supporting continuous delivery and DevOps, scalability, and extensibility by separating the monolithic application into a set of small and independent services. Decomposing the blockchain system into microservices may also have its potential value and has been initially studied in academia [12, 12]. Nevertheless, many challenges need to be solved when considering this new architectural style, for example, how to decompose the blockchain-based system into microservice with suitable granularity considering the possible impacts on specific non-functional requirements, how to implement the microservices-based smart contracts, and how to address the interoperability of smart contract microservices.

4.2 Threats to validity

We took an extremely cautious attitude to mitigate threats to the validity of this study. Specifically, to reduce the possible impacts of other factors on the results as much as possible, we limited the scope to the consortium blockchain domain and carefully selected the typical and successful case from the enterprise. Then, to mitigate the threat of the inconsistency between what the researchers have in mind and what is investigated according to the research questions, we confirmed the meaning of specific answers given by the interviewees for corresponding questions. Moreover, during the process of data analysis, we also emailed to the interviewees to make sure the constructs discussed in the interview questions were interpreted in the same way between us. Although only one case was studied in this paper, we tried to minimize its threats to the external validity and enable the generalization of the results through conducting two rounds in-depth interviews on different groups of people associated with the case project.

5 RELATED WORK

The popularity of blockchain attracts more and more attention of researchers to ask the research questions similar to ours. Macrinici et al. [13] compiled the 64 papers identified in their mapping study, and concluded the most commonly discussed problems and solutions in the literature, e.g., the process of development and operation in blockchain and the challenges. Zheng et al. [14] introduced the creation, deployment, execution, and completion of smart contracts separately, and then concluded the challenges and advances of smart contracts. Chakraborty et al. [15] sent an online survey to 1,604 active BCS developers and identified some challenges and practices related to the testing and security of blockchain systems. Zou et al. [4] performed an exploratory study to understand the current state and potential challenges developers are facing in developing smart contracts on blockchains, with a focus on Ethereum by semi-structured interviews and survey. Their work revealed several major challenges that developers may face and proposed the potential directions as reference. Their study, however, cannot summarize the current station systematically and the analysis of challenges and research questions is not detailed enough in each step of blockchains development. Hamida et al. [16] focused on enterprise blockchains and provided the analysis on its core components, technologies, and applications, and also discussed research challenges and opportunities about the field. Koul et al. [17] highlighted the challenges currently faced in testing blockchain-based applications and Porru et al. [3] revealed the current issues and new directions for blockchain-oriented software engineering, and investigated the need for novel specialized software engineering practices for the blockchain sector. Dib et al. [18] analyzed the consortium blockchains in terms of architectures, technological components, applications, challenges, and opportunities. In order to deal with the problem that people know little about the active community of smart contract developers, Ayman et al. [19] studied the online community on Stack Overflow and found that while the community is active and growing rapidly, a lot of smart contracts related questions remain unanswered.

Different from the above studies, we focused on the challenges and potential solutions associated with the development and the operation of consortium blockchain-based systems through an in-depth case study. To improve the generality of the results, we exhaustively collected the data through two round of interviews on different groups of people associated with the case project.

6 CONCLUSION

Blockchain, especially the consortium blockchain technology, is gaining rapidly growing popularity in the enterprise environment. However, the lack of sound practice support for the consortium blockchain projects from the perspective of software engineering may cause a potential threat to the security of systems. For this purpose, this study is to identify the challenges and possible solutions of developing and operating consortium blockchain-based systems from the perspective of software engineering. To achieve this aim, we selected a successful and typical case from industry and conducted two-round group interviews to exhaustively collect data from practitioners with different roles in this case. This study identified eight pairs of challenges and solutions in different phases of developing and operating the consortium blockchain-based systems. Based on the findings, two valuable implications were extracted and provided for practitioners and researchers, e.g., DevOps and microservices for blockchain.

The future work of this study is threefold: 1) Expanding the sample of the case study and comparing the findings of different cases to improve the representativeness of the findings; 2) Complementing the evidence from other sources, for example, academic and grey literature; 3) Conducting primary studies to practically address the two implications identified by this study, i.e. an unified and automated DevOps solution for blockchain or a systematic method to guide the design and the implementation of blockchains (smart contracts) as microservices.

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A INTERVIEW QUESTIONS

Part A: Demographic questions.

- **Q1.** How many years of software relevant experiences do you have? [Less than a year, between one to five years, between six to ten years, more than ten years]
- **Q2.** How many years have you been in the domain of blockchain? [Less than a year, between one to two years, between three to five years, more than five years]
- **Q3.** What are your roles in your blockchain project? [Developer, Maintainer, requirement analysis, Testing, User support, Documentation, Social marketing]
- **Q4.** What is the percentage of developers, testers, and maintainers in your team?

Part B: General questions.

- **Q5.** Please give a brief introduction about the consortium blockchain-based system, e.g., functional and non-functional requirements and blockchain-oriented technologies.
- **Q6.** What is the size of the blockchain system?
- **Q7.** What is the lead time and the delivery frequency of the blockchain system?
- **Q8.** Did you use or consider to use DevOps for your blockchain system? Why?
- **Q9.** Did you use or consider to use Microservices for your blockchain system? Why?

Part C: Specific questions.

- **Q10.** Can you please describe the processes of developing the blockchain system?
- **Q11.** What tools did you use in the processes of developing the blockchain system?
- **Q12.** What are the main challenges in the processes of developing the blockchain system?
- **Q13.** What are your solutions to address the challenges of developing the blockchain system?
- **Q14.** Can you please describe the processes of operating the blockchain system?
- **Q15.** What tools did you use in the processes of operating the blockchain system?
- **Q16.** What are the main challenges in the processes of operating the blockchain system?
- **Q17.** What are your solutions to address the challenges of operating the blockchain system?