Software Engineering Approaches Adopted By Blockchain Developers

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Software Engineering Approaches Adopted By Blockchain Developers

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***Abstract*—The adoption of blockchain technology has witnessed a rapid surge in recent years, revolutionizing various industries. As blockchain-based solutions continue to gain momentum, understanding the software development approaches employed by blockchain developers becomes crucial. This research paper examines the experiences of blockchain developers with software engineering (SE) approaches in blockchain development. We deployed an online survey focused on topics such as the importance of SE approaches, preferred methodologies, and the significance of different stages within the Software Development Life Cycle (SDLC) for blockchain projects. Our findings reveal a consensus among participants regarding the importance of utilizing SE approaches in blockchain development to ensure secure, reliable, and scalable solutions. Agile methodologies, such as Scrum, were prominently favored for their adaptability and iterative nature. Furthermore, design emerged as the stage of primary importance within the SDLC for blockchain-based solutions. These insights provide valuable guidance for researchers, practitioners, and organizations involved in blockchain development, contributing to the advancement of SE practices in the context of blockchain technology.**

***Index Terms*—Blockchain-oriented software engineering, SE methodologies, Agile**

I. Introduction

Blockchain technology has emerged as a transformative force with the potential to revolutionize various industries, ranging from finance and supply chain management to healthcare and governance [2]. Its decentralized, immutable, and transparent nature offers new possibilities for secure and efficient data management and transaction processing. As the adoption of blockchain-based solutions continues to grow, there is an increasing need to understand the software development approaches employed by developers. The development of blockchain applications requires a deep understanding of both the underlying blockchain technology and the principles of software engineering (SE) [5].

Blockchain developers face unique challenges in designing, implementing, and deploying decentralized applications (DApps) while ensuring security, privacy, and resilience against attacks. The distributed nature of blockchain networks presents challenges, such as the mitigation of attacks and vulnerabilities in smart contracts [7]. Therefore, understanding SE approaches employed by blockchain developers and the integration of SE principles and methodologies in blockchain development plays a pivotal role in ensuring the reliability, security, and efficiency of blockchain-based applications.

This research paper aims to address the aforementioned gaps by conducting a study of blockchain developers regarding SE approaches. The objective of this research is to explore the approaches adopted by blockchain developers, highlighting their importance in facilitating the successful implementation of blockchain technology. By examining the methods and techniques employed in the software development lifecycle (SDLC) of blockchain applications, we aim to shed light on the key considerations, strategies, and tools employed by developers to address the inherent complexities of blockchain systems. In this paper, we seek to answer the following research questions.

RQ1 How do blockchain developers perceive the importance of software engineering in blockchain development?

RQ2 Which software development approaches and methodologies are preferred by blockchain developers?

RQ3 Which stages of the SDLC are considered most important in blockchain-based solutions?

RQ4 What is the experience of blockchain developers with different software engineering processes and methodologies?

To answer these research questions, we surveyed practitioners in the field to gain an understanding of the methodologies, tools, and practices that are effective in supporting blockchain development projects. This investigation contributes to the existing body of knowledge in SE and provides valuable insights for both researchers and industry professionals in the blockchain space. By identifying the prevalent SE approaches in blockchain development, we can evaluate their strengths and weaknesses, assess their compatibility with traditional SE practices, and identify areas where further research and innovation are needed. The findings from this research paper offer valuable insights for researchers, practitioners, and organizations involved in blockchain development. The insights will help shape best practices and facilitate the adoption of efficient SE approaches within the blockchain domain.

II. Background

A. Blockchain and Software Engineering Methodologies

Blockchain technology, initially introduced in the context of cryptocurrencies such as Bitcoin, has evolved into a versatile technology with applications extending beyond digital currencies [14]. At its core, blockchain is a distributed ledger technology that enables secure, transparent, and tamper-resistant recording and verification of transactions across mul-

tiple participants in a network. The decentralized nature of blockchain eliminates the need for intermediaries, fostering trust and enabling efficient peer-to-peer interactions. However, the design, development, and deployment of blockchain-based systems pose unique challenges that necessitate the application of sound software engineering principles [6].

Blockchain developers must navigate complexities related to scalability, performance, interoperability, security, and privacy. The immutable nature of blockchain introduces complexities in ensuring data consistency, consensus mechanisms, and the prevention of malicious attacks [9]. Therefore, adopting rigorous SE practices is crucial to overcome these challenges and deliver robust and reliable blockchain solutions. Moreover, blockchain technology itself is evolving rapidly, with new protocols, platforms, and frameworks constantly emerging. This dynamic nature requires developers to remain Agile and adaptable in their SE practices. As blockchain technology evolves and becomes more prevalent in various industries, understanding how developers perceive SE approaches such as requirements gathering, design, testing, and maintenance can shed light on the adoption and implementation of best practices, the identification of potential challenges, and the overall quality of blockchain-based software solutions.

B. Evaluation of Software Engineering Techniques

Research efforts have been devoted to blockchain-based SE, focusing on addressing key challenges to enhance the development and deployment of blockchain applications. Researchers have explored the adoption of Agile methodologies in blockchain projects, emphasizing iterative development, rapid prototyping, and close collaboration with stakeholders [11]. Additionally, the design and implementation of smart contracts, self-executing digital agreements stored on the blockchain, has received attention with regard to the importance of secure coding practices, formal verification, and testing techniques to ensure their integrity and reliability [3].

Typical SDLC consist of requirements gathering, design, implementation, testing, and maintenance phases [10]. Traditional software development methodologies, such as the waterfall model, follow a sequential and linear approach to software development, with distinct phases [13]. However, the rigid nature of the waterfall model may not be suitable for the dynamic nature of blockchain development. On the other hand, Agile methodologies, including Scrum, Kanban, and Extreme Programming (XP), are iterative in nature and prioritize flexibility, collaboration, and incremental development [1].

While existing research has made notable contributions to the field of blockchain-based SE, there remains a need for understanding of the preferences and experiences of blockchain developers regarding SE approaches. This research paper fills this gap by investigating the experiences of blockchain developers, shedding light on the importance of SE practices, preferred methodologies, and the stages within the software development life cycle specific to blockchain development. By examining the intersection of SE and blockchain technology, this research paper contributes to the existing knowledge, bridging the gap between theory and practice and paving the way for enhanced SE methodologies in the blockchain domain.

III. Research Methodology

To achieve the research objectives, a mixed-methods approach was adopted, utilizing a survey to gather data from a diverse sample of blockchain developers. The online survey consisted of both closed-ended questions with predefined response options and open-ended questions that allowed participants to provide detailed insights and opinions. This approach allows exploration of the topic, leveraging both statistical analysis and in-depth insights from developers. The survey was designed to collect information on the SE methodologies, tools, and practices employed in blockchain development.

The survey was distributed to participants recruited through various channels of blockchain developer communities. After the survey data collection, a thorough coding process was conducted to analyze the responses. It involved systematically categorizing and organizing the survey data to identify common themes and patterns. These insights were used to enrich the findings and provide additional depth to the quantitative analysis. By utilizing a mixed-methods approach, including open-ended questions and a rigorous survey coding process, this study was able to capture a holistic view of the SE approaches employed by blockchain developers.

A. Data Collection

Our research methodology has undergone a thorough review and received approval from the Virginia Tech Institutional Review Board (IRB). Our data collection process involved the careful design of survey questions that addressed the research objectives and captured relevant information from the participants. These questions were formulated to gather insights into blockchain developers opinions, experiences, and preferences related to the SE methods. We received a total of 54 responses. A thoughtfully crafted recruitment email was used to invite potential participants, providing a clear explanation of the research, ensuring participant confidentiality and anonymity, and providing detailed instructions on how to access and complete the survey.

To delve deeper into the subject matter and gather more insights, participants were also given the opportunity to participate in an optional interview. However, only four participants agreed to take part in the interview process. While the interviews provided valuable qualitative data, the limited number of participants involved in the interviews prevents their inclusion in the final results. As a result, the findings from these interviews were not included in our analysis.

B. Data Analysis

Our data collection process allowed us to gather both quantitative and qualitative insights from participants. For the open-ended survey questions, an open coding process was employed. The process involved extracting and categorizing key themes and insights from the open-ended responses provided by participants in the survey. Two researchers independently reviewed and analyzed the open-ended responses

to identify the common themes from respondents. We began with identifying general themes from a subset of responses. Through discussions the researchers developed an agreed-upon coding scheme for each open-ended question. This provided a framework for categorizing responses and identifying relevant themes. The coders also had the flexibility to add new codes as necessary, ensuring that the analysis captured the breadth of the participants perspectives. Throughout the coding process, the researchers engaged in discussions to address any discrepancies in coding and resolve conflicts. This iterative process helped ensure the accuracy and consistency of analysis.

C. Participants

We received responses from 54 blockchain developers. Participants had a variety of expertise and experience in blockchain development, consisting of graduate students ($n = 41$) and professionals ($n = 13$) with experience working in the blockchain industry. The professionals in the study represented various roles within the blockchain development domain, including developers, project managers, and researchers. The graduate students, on the other hand, brought fresh perspectives and knowledge gained from their academic pursuits in blockchain technology. Most participants had 3-5 (41%, $n = 21$) or 1-2 (37%, $n = 19$) years of professional SE experience. In terms of blockchain-based development, most participants (58%, $n = 29$) had less than one year of experience while 25% ($n = 12$) had 1-2 years and 16% ($n = 8$) had 3-5 years.

Participants reported working on a wide variety of blockchain projects such as Ethereum, Bitcoin, a blockchain-based medical record share, electronic voting systems, a pharmaceutical supply chain company, Metaverse gaming, digital currency wallets, decentralized finance applications, and more. The survey responses also provide insights into the extent to which developers use blockchain technology. Among the participants, the majority ($n = 18$) indicated that they are currently in the experimental phase, actively exploring and testing the technology. This group represents 33% of the participants, highlighting number of developers who are in the stages of understanding and familiarizing themselves with blockchain solutions. 17% of participants ($n = 9$) reported that they are in the process of developing prototype applications, indicating interest and investment in exploring the potential of blockchain for various use cases.

IV. Results

Our findings provide insights into the perspectives, preferences, and experiences of blockchain developers regarding SE methodologies and SDLC stages.

A. RQ1: Insights on SE Practices

The majority of participants (59%, $n = 32$) expressed a preference for using SE approaches in blockchain development. They emphasized the benefits of adopting structured methodologies, such as ensuring systematic and modular design, code reuse, and managing maintenance activities effectively. In particular P51 responded, *"Yes I believe, using SE approaches for blockchain development can help ensure that the resulting software is reliable, scalable, maintainable, and secure, and can help developers to better understand the requirements and constraints of the project, design a system that meets those requirements, implement the system in a modular and extensible way, test the system thoroughly, and maintain the system over time"*. These participants recognized the value of SE practices in improving the reliability, scalability, and security of blockchain solutions.

The second theme that emerged was the importance of secure coding practices in blockchain development. Respondents (14%, $n = 8$) recognized the need to handle valuable assets and sensitive data securely, emphasizing the benefits of SE processes for implementing secure coding techniques and following best practices to ensure the integrity and confidentiality of blockchain-based systems. For instance, P1 responded *"SE approaches help in adopting secure coding practices, conducting thorough security audits, and implementing encryption and authentication mechanisms"*.

Another theme was the focus on delivering high-quality solutions. Respondents (7%, $n = 4$) recognized that SE approaches play a crucial role in ensuring the delivery of high-quality blockchain applications that meet customer expectations and adhere to industry standards. For instance, P21 mentioned *"applying software engineering approaches to the development will enhance the quality"*. By incorporating SE practices, such as rigorous testing, modular design, and adherence to industry standards, developers can enhance the overall quality and performance of blockchain solutions.

Another theme was requirements gathering. Participants (9%, $n = 5$) emphasized the importance of understanding and fulfilling project requirements in blockchain development. They recognized that SE approaches facilitate thorough requirement analysis, effective design, and the development of solutions that address specific project needs and constraints. This aligns with the core principles of SE, which emphasize the importance of requirements analysis and design in developing successful software systems [8]. Participants ($n = 3$) also expressed the belief that SE approaches are applicable to blockchain development. However, those who indicated SE processes were not important ($n = 5$) mentioned they didn't fit their particular use case, it depends on the project, and that these approaches are outdated.

B. RQ2: Preferred SE Approaches in Blockchain

The survey results revealed diverse preferences among the participants regarding their preferred SE approaches. Agile emerged as the most popular choice (57%, $n = 31$), with respondents expressing a preference for its iterative and adaptive methodologies. Agile's ability to respond to changing project requirements and deliver incremental value was highly appreciated by developers. Interestingly, a portion of respondents (33%, $n = 18$) indicated that their choice of SE approach varied depending on the specific project requirements. This highlights the flexibility and adaptability of developers in

tailoring their methodologies to suit the unique needs and complexities of each project.

The remaining participants expressed varied preferences, with (7%, $n = 5$) favoring the Waterfall approach, (6%, $n = 4$) opting for Prototyping, and smaller percentages for Spiral (1%, $n = 1$) , Incremental (1%, $n = 1$) , and other (4%, $n = 3$) approaches.

In terms of qualitative feedback, one respondent explicitly mentioned a preference for Scrum, a well-known Agile framework, showcasing its popularity among developers. Conversely, another respondent expressed a more independent approach, stating a willingness to follow their own methodologies rather than strictly adhering to predefined frameworks.

Furthermore, the analysis of the open-ended responses to the survey question "What is your opinion on which software development approach is suitable for blockchain-based projects and why?" revealed several key themes. While there were individual variations in opinions, many participants ($n = 24, 60\%$) expressed a strong preference for Agile development approaches. The participants highlighted the benefits of flexibility, iterative development, and adaptability that Agile methodologies offer. Participants believed that Agile methodologies enable them to effectively respond to changing requirements, deliver high-quality solutions, and track issues throughout the development process. In particular, P42 stated, *"I believe that an Agile approach is often a good fit for blockchain development, as it provides a flexible, iterative, and adaptive framework that can help manage the complexity and uncertainty of blockchain development."* Consequently, Agile was perceived as well-suited to meet the dynamic and evolving nature of blockchain projects.

Another theme that emerged was project-dependent approaches. Some participants (($n = 7, 17\%$) expressed the view that the choice of software development approach should be project-dependent, highlighting the need to consider factors such as complexity, requirements, and goals, when determining the most suitable approach. They acknowledged that different projects may require different methodologies based on their unique characteristics. Another theme was the preference for Waterfall and Plan-Driven Approaches as a small number of participants ($n = 3, 7\%$) expressed a preference for waterfall, spiral or plan-driven approaches. These participants emphasized the advantages of advance planning, risk identification, and the potential to address complex requirements in a systematic manner. Some participants ($n = 6, 15\%$) mentioned specific approaches like Continuous integration and Continuous delivery/Continuous deployment (CI/CD) and Test Driven Development (TDD). These findings shed light on the wide range of SE approaches embraced by blockchain developers.

C. RQ3: SDLC Stages for Blockchain-based Solutions

The survey responses indicate that the majority of participants (84%, $n = 39$) prefer SDLC processes for their blockchain-based projects that aim to produce software with the highest quality, lowest cost, and in the shortest possible time. Respondents favoring SDLC acknowledge the benefits and value of following a structured and systematic approach in their blockchain development endeavors. By adhering to SDLC principles, developers can ensure proper planning, requirements gathering, design, development, testing, and maintenance throughout the software development process. This approach enables them to deliver high-quality blockchain solutions that meet client expectations, adhere to industry standards, and achieve project objectives efficiently. It reflects the understanding that implementing established practices and methodologies can contribute to the successful development and deployment of blockchain solutions.

Our survey responses also highlight the preferences and perspectives of the participants regarding the importance of each SDLC stage. Among the surveyed blockchain developers, a majority (43%, $n = 21$) expressed that the design stage is the most crucial in the SDLC for blockchain-based solutions. Design encompasses the planning and conceptualization of the architecture, data structures, and overall system design for blockchain applications. This emphasizes the importance of a well-thought-out and robust design as the foundation for secure, efficient, and scalable blockchain solutions. While design received the highest percentage of responses, other stages of the SDLC also garnered attention. Implementation, the process of translating the design into functional code, was second emphasized by 20% ($n = 10$) of participants. Requirements gathering was noted by 12% ($n = 6$) of respondents as a critical stage for ensuring a clear understanding of project objectives and stakeholder needs. Deployment, the stage where the solution becomes available to users, was identified as important by 12% ($n = 6$) of respondents Testing, to ensure the functionality and reliability of solutions, received responses from three participants (6%). Finally Maintenance, involving ongoing support and updates, was acknowledged by two participants (4%). These perspectives on the SDLC stages reflect the multifaceted nature of blockchain development.

D. RQ4: Experiences and Productivity in SE Methodologies

The survey responses provide valuable insights into the SE processes preferred by blockchain developers and their perceived productivity. Kanban and Scrum emerged as the most popular choices (63%, $n = 38$), with respondents indicating higher productivity with these Agile methodologies for their emphasis on iterative development, continuous improvement, and effective team collaboration align well with the dynamic and evolving nature of blockchain [4]. Adaptive software development was preferred by 18% ($n = 11$) of respondents. Meanwhile, 15% ($n = 9$) of participants expressed a preference for Extreme Programming. One respondent each (1%) reported being most productive using the Unified Process and Lean software development methodologies.

Furthermore, the analysis of open-ended responses to the research question "What is your experience being part of an Agile software development process as a team or with different other processes, if any?", lead to the identification of key insights. A common theme that emerged was the positive ex-

perience of participants in Agile software development. Most participants (70%, $n = 28$) highlighted the benefits of Agile methodologies, such as flexibility, collaboration, iterative nature, and efficient communication. One participant responded, *"My experience so far has been quite good. Following Agile processes increases developer productivity and issues are also resolved quite quickly" (P36).* Participants emphasized that being part of an Agile process enabled them to deliver working software in incremental stages, prioritize early and frequent delivery, and respond effectively to changing requirements.

Another theme that emerged was the diversity of experiences with Agile processes. Participants $(n = 5, 12\%)$ mentioned their involvement in various roles within Agile teams, including scrum masters, project managers, and team members. They shared their experiences of working in scrum teams, participating in sprints, and following Agile principles. For example, one participant mentioned, *"I really enjoyed being part of an Agile software development process as a team, as I felt we made strong continuous progress each day without significant conflicts" (P14).*

V. Discussion

Our paper addresses the software development approaches adopted by blockchain developers. It delves into the preferences, experiences, and perspectives of blockchain developers regarding the SE processes and methodologies they employ. By exploring the preferred development approaches, the paper sheds light on the development languages and tools commonly utilized within the blockchain development community. The research also highlights the importance of incorporating SE approaches to ensure secure coding practices to enhance the security and privacy of blockchain solutions while addressing potential attacks and vulnerabilities. Based on our results, we provide implications for blockchain-based software practitioners, organizations, and researchers.

A. Practitioners

The findings from our research shed light on how SE processes can intersect with blockchain-oriented software development. The survey results highlighted the importance of addressing security and privacy within blockchain development processes. One of our interview participants also emphasized the importance of adopting a *security-first approach* when developing blockchain applications. Given the sensitive nature of blockchain systems and the potential for financial transactions and sensitive data, security considerations are paramount. Integrating these security-focused SE processes into blockchain-oriented software development is essential for building robust and secure applications. One essential aspect is the adoption of secure coding guidelines. These guidelines provide developers with best practices for writing secure code and help mitigate common vulnerabilities, such as injection attacks, improper input validation, and cryptographic weaknesses. By adhering to these guidelines, blockchain developers can minimize the risk of exploitable vulnerabilities and strengthen the overall security posture of their applications.

B. Organizations

For organizations, the findings of this study provide valuable insights into optimizing their software development processes. By adopting established SE practices, such as Agile methodologies, organizations can enhance the quality, efficiency, and reliability of their blockchain solutions. It is recommended that organizations invest in training and skill development programs to empower their teams with the necessary SE knowledge and expertise [12].

Furthermore, organizations can prioritize collaboration and effective communication among team members, leveraging SE methodologies and tools to foster transparency, adaptability, and responsiveness. For instance, one participant noted *"As agile methodologies emphasize collaboration among team members and stakeholders. so for blockchain projects, which often involve multiple parties and decentralized networks, effective communication and collaboration are [important]. My [experience] with agile practices, such as daily stand-up meetings and frequent interactions have been helpful since it promote transparent and efficient communication, towards understanding of project goals and progress"* (P1). This can lead to improved project outcomes, streamlined development cycles, and accelerated innovation.

C. Researchers

Additionally, blockchain researchers can investigate the integration of security and privacy considerations into SE practices for blockchain. Given the sensitive nature of blockchain data and the potential risks associated with smart contracts and decentralized networks, researchers can delve deeper into designing and implementing robust security measures, conducting rigorous testing and auditing, and exploring novel approaches for ensuring privacy and data protection. Blockchain researchers can further contribute to the field by exploring tailored SE practices addressing security and privacy challenges. By aligning research and practice, the blockchain community can drive the growth and maturation of the technology while delivering secure and reliable blockchain-based applications.

VI. Limitations and Future work

A threat to the validity of these findings is that our participants may not represent all blockchain developers. To ensure a better understanding of the subject matter, participants were selected from different geographic regions and backgrounds to capture a broader perspective and account for any regional variations in software development practices. Additionally, efforts were made to include participants with varying levels of experience in software development and contributions to diverse blockchain-based projects.

Moreover, exploring the integration of security and privacy within SE approaches for blockchain development would be an important area of future investigation. This could involve investigating advanced cryptographic techniques, privacy-enhancing mechanisms, and security measures to ensure the resilience and protection of blockchain-based systems. Additionally, participants noted design was the most challenging

SDLC phase for blockchain-based development. Future work can explore novel tools and approaches to support the design of complex blockchain applications.

Finally, exploring how SE approaches for blockchain developers compare with software engineers in other domains can provide valuable insights into the unique practices and methodologies employed by blockchain developers. This can help understand the similarities and differences between the groups and shed light on the specific challenges and requirements faced by blockchain developers. It can also uncover practices to address characteristics specific to blockchain technology, such as decentralization, consensus mechanisms, and smart contracts. Furthermore, this comparison can provide insights into the transferability and applicability of SE practices across different domains–highlighting areas where blockchain developers can benefit from leveraging existing SE approaches and identifying areas of improvement for blockchain development.

VII. Conclusion

This study highlights the importance of software engineering in blockchain development and provides insights into the preferred methodologies and stages of the Software Development Life Cycle (SDLC) through conducting a survey of blockchain developers. The findings underscore the value of structured and systematic development processes in the blockchain domain. Agile methodologies, particularly Scrum, are favored for their adaptability and iterative nature, aligning well with the dynamic nature of blockchain projects. Design emerges as a critical stage, emphasizing thoughtful planning and system architecture are necessary for robust and scalable blockchain solutions. We provide valuable insights into the perspectives and experiences of blockchain developers, offering practical guidance for practitioners, organizations, and researchers in the field to help developers actively contribute to the growth and adoption of blockchain technology while ensuring the development of secure and efficient digital ecosystems.

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