

Critical Analysis and Problem Definition Report

7113ICT - Research For IT Professional - Griffith University

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I. INTRODUCTION

This report aims to analyze three academic papers and critically examine them, focusing on:

a) The context that examines the research community where the paper has gained relevance, categorization of the paper, key researchers, rating of the conference or journal, and authors and institution ratings.

b) The study of the research questions, justification, connections, theories on which it is based, paradigms, methods used by the authors, research design, relevance, and references.

Finally, a research question is developed from a problem emerging from the literature discussed.

This structure of the paper is:

- I. Introduction
- II. Level of conceptual interoperability model for blockchain based systems
- III. Blockchain Cross-Chain Bridge Security: Challenges, Solutions, and Future Outlook
- IV. Cross-Chain Bridges: Attack Taxonomy, Defenses, and Open Problems.
- V. Research Question

II. LEVEL OF CONCEPTUAL INTEROPERABILITY MODEL FOR BLOCKCHAIN BASED SYSTEMS

A. The context

Introduction

The “*Level of conceptual interoperability model for blockchain based systems*” is written by Babu Pillai¹, Kamanashis Biswas², Zhe Hou³, and Villipuram Muthukkumarasamy⁴. This paper was published by IEEE Crosschain Workshop (ICBC-CROSS) and added to IEEE Xplore on 16 June 2022.

Categorization

The main purpose of the paper is to give a deeper perspective on interoperability terms, for these authors, the term expresses the ability of systems to communicate with

each other, so that the information they share is also useful in contextual and conceptual terms. For this, the authors propose the categorization of interoperability within the blockchain. Given the structure of this system, whereby nature intercommunication between several chains is not viable, it is essential to start thinking about an organized structure where it is possible to discern the types of interoperability that each system (Blockchain) can have.

Key Researcher

One of the key researchers in the field as of now is Rafael Belchior⁵ with more than 1000 citations and a hindex of 15, Rafael Belchior is a researcher at INESC-ID, a Fulbright awardee (MIT Connection Science & MIT Media Lab) and holds a Ph.D. from Técnico Lisboa (awarded "Best INESC-ID Ph.D. student"). With mayor fields such as security, blockchain, interoperability, crypto, and Defi.

Key Journal

The ACM Computing Surveys is a highly regarded journal in computer science, with an H-index of 213 and an Impact Factor of 25.699 in 2023. It publishes comprehensive surveys and tutorial papers, offering valuable insights into emerging technologies, including blockchain and distributed systems.

Key conference

ACM Conference on Computer and Communications Security (CCS) is of the top conferences belongs to the paper's field. The ACM CCS is an annual conference with A* ranking according to The Computing Research and Education Association of Australasia (CORE).

Conference rating

The IEEE International Conference on Blockchain and Cryptocurrency (ICBC) is relatively new, with its first edition held in Seoul in 2019. However, it has a CORE "C" classification due to its short development, but with a trend towards improvement. This type of conference is among the strongest within the specific field of blockchain.

¹ <https://scholar.google.com/citations?hl=en&user=WC31KJgAAAAJ>

² https://scholar.google.com/citations?hl=en&user=eNoB_WwAAAAJ

³ <https://scholar.google.com/citations?hl=en&user=sxuQmIIAAAAJ>

⁴ <https://scholar.google.com/citations?hl=en&user=JB7pThEAAAAJ>

⁵ <https://scholar.google.com/citations?hl=en&user=B0O3stQAAAAJ>

Authors and Institution Rating

The authors are affiliated with Griffith University, a prestigious institution ranked within the 201-250th range in the 2025 Times Higher Education (THE) World University Rankings in the Computer Science field⁶. Renowned for its significant contributions to blockchain and cybersecurity research, Griffith University is highly regarded in the academic and technological communities.

B. The content

Research question

The paper aims to propose a new interoperability model within blockchain systems that can be adapted to effectively evaluate and enhance interoperability among blockchain-based systems. The authors consider the concerns and barriers that it presents. The barriers, which are commonly known as the problems that interoperability may have, the technical components (software and hardware) that the systems may have when crossing information; contextual barriers, the representation that the information has. Interoperability concerns on the other hand have various interpretations depending on the level of operability from which they are viewed. The authors analyze and employ a new framework where the organization of different levels of interoperability within the blockchain is linked to a direct relationship between interoperability barriers and interoperability concerns.

Justification

The research is well-founded as, at the time of the investigation, there is no framework that organizes blockchain interoperability. This results in an outcome where different levels of interoperability can be classified according to the communication relationship between networks. Being one of the first, if not the first, research aimed at organizing the levels of interoperability in blockchain, it establishes a framework for a better understanding of the needs or scope of each level of communication. With the help of established models for computer connections like the LCIM, the authors seek to adapt this model to the needs that network connections within the blockchain would require.

Connections

This paper analyzes the problem that blockchain systems have in defining their levels of communication between various networks. Initially, the authors provide a perspective on interoperability in information systems, followed by a technical definition of blockchain technology to analyze the current technology for data

transfer between different chains and then define methods or protocols that facilitate the formalization of interrelations. The authors propose a model where interoperability is organized in blockchain systems based on the LCIM model (The Level of Conceptual Interoperability Model), which simplifies and analyzes the needs of these new technologies. Consequently, the new proposed model has five levels that help to better understand the organization within the blockchain systems.

Theory

The authors adapt the needs of this new technology with an interoperability model widely used in information systems. Therefore, this new proposal includes five levels where most intercommunications between chains can fall.

- Level 1 (Technical), here at a low level of communication, both systems and share a standard and communication protocols.
- Level 2 (Syntactic), at this level the compatibility between systems is higher, however the shared data has no value other than in its own chain.
- Level 3 (Semantic), the information shared between systems is more understandable to each other, here there is a greater understanding of the information to be shared.
- Level 4 (Pragmatic), the functions or communications can be interpreted by multiple systems.
- Level 5 (Dynamic), at this level, the understanding of the communication and knowledge of the functions in both systems is extensive and can be interpreted by other chains in their perfection.

Research Paradigm

The research follows a model-driven approach, combining conceptual analysis, gathering empirical evidence emphasizing in observation, experimentation, and evidence-based conclusions, as well as its systematic approach adapting the LCIM for blockchain and validation through case studies. Finally, it also aims to evaluate and enhance interoperability focusing on measurable outcomes. Such qualities could be translated to a scientific paradigm [3].

Research method

For the most part and according to Walliman [9], the method used by the authors in this paper is qualitative. This is due to the adaptation of the already established model in information systems, deconstructing it to adapt it to the new technological needs (interoperability barriers and

⁶ Griffith University | World University Rankings | THE

concerns) that blockchain systems would require today. Additionally, the demonstration in the cases used by the authors focuses on descriptive and interpretive aspects, detailing them due to their qualities and categorizing them according to their scope within the established definitions.

Research design

The design used by the authors is a detailed framework that tries to explain from generic to specific concepts. With the help of the motivation and study objective, they provide a detailed concept of the key aspects to understand the interoperability of a blockchain system. The authors aim to conduct an exhaustive analysis of the barriers and concerns of this topic, then combine the definitions and synthesize an organizational method to categorize real-life examples within these levels.

Relevance

This paper can be fundamental in providing a clearer idea of the challenges that networks may face due to their structure and connection with others. It also helps to understand the capabilities and scope that can be achieved for interconnectivity between networks. Thus, the research community can have a clear vision of the connection and the types of challenges they face.

Reference

Based on the premise that the authors rely on an already established model within information systems, the references used in the paper are appropriate. Additionally, the authors correctly and extensively reference terms that demonstrate their deep understanding of their research.

III. BLOCKCHAIN CROSS-CHAIN BRIDGE SECURITY: CHALLENGES, SOLUTIONS, AND FUTURE OUTLOOK

A. The context

Introduction

The “Blockchain Cross-Chain Bridge Security: Challenges, Solutions, and Future Outlook” is written by Ningran Li⁷, Zhiyu Xu⁸, Xiaogang Zhu⁹, Wei Zhou¹⁰, Sheng Wen¹¹, Yang Xiang¹², and Minfeng Qi¹³. This paper

was published by ACM, Distributed Ledger Technologies: Research and Practice, Volume 4, Issue 1 2025.

Categorization

The main purpose of this paper is to highlight the different qualities that bridges possess. This type of technology provides the possibility of transferring assets from one chain to another. It analyzes the types of bridges that exist, their mechanisms of operation, their classification, and their vulnerabilities. The paper studies the methods and protocols that these types of cross-chain solutions entail and their risks. Therefore, this paper falls under the classification of Blockchain, interoperability and Cross chain fields.

Key researcher

One of the most influent research in this field is Prof. Dr. Yoesoep Edhie Rachmad¹⁴, PhD, DBA. He is a distinguished academic and researcher with over 411.729 citations, an h-index of 511, and an i10-index of 811, and specializes in blockchain, digital health, and healthcare transformation. He received the Global Influential Scientist Award from 2020 to 2024 for his transformative research across technology, mental health, tourism, and entrepreneurship.

Key Journal

There are highly regarded journals in blockchain and related fields, given the growing importance of these areas in research and industry. To the reviewer’s knowledge, the IEEE Journal on Selected Areas in Communications has a H-index of 263 and an Impact Factor of 14.826 in 2023.

Key conference

ACM Conference on Computer and Communications Security (CCS) is of the top conferences belongs to the paper’s field. The ACM CCS is an annual conference with A* ranking according to The Computing Research and Education Association of Australasia (CORE).

Journal Rating

Distributed Ledger Technologies: Research and Practice (DLT) is a peer-reviewed journal that seeks to publish high-quality, interdisciplinary research on the research and development, real-world deployment, and evaluation of distributed ledger technologies, such as blockchain, cryptocurrency, and smart contract. ACM is top ranged

⁷ (28) Ningran (Icey) Li | LinkedIn

⁸ <https://scholar.google.com/citations?hl=en&user=70n6BWYAAAAJ>

⁹ <https://scholar.google.com/citations?hl=en&user=rav4c-0AAAAJ>

¹⁰ <https://scholar.google.com/citations?user=QRvMXocAAAAJ&hl=en&oi=sra>

¹¹ <https://experts.swinburne.edu.au/3615-sheng-wen>

¹² <https://scholar.google.com/citations?hl=en&user=7ymTWY4AAAAJ>

¹³ https://scholar.google.com/citations?hl=en&user=9KUc_KQAAAAJ

¹⁴ https://scholar.google.com/citations?hl=en&user=M_fGs2YAAAAJ

journals in the field as well, since this is a new journal, there is no ranking yet but based on ACM reputation this could be a Q1 journal in the following years.

Authors and Institution Rating

The authors—Ningran Li, Zhiyu Xu, Xiaogang Zhu, Wei Zhou, Sheng Wen, and Yang Xiang—are affiliated with Swinburne University of Technology, which is ranked within the 151-175 range in the 2025 Times Higher Education (THE) World University Rankings¹⁵ for Computer Science in Melbourne, Australia. While Minfeng Qi is associated with the City University of Macau, which is a recognized institution in China with a strong focus on data science.

Ningran Li actively contributes to blockchain research, while Zhiyu Xu, Xiaogang Zhu, Wei Zhou, Sheng Wen, and Yang Xiang are collectively known for their work in blockchain security, interoperability, and cybersecurity. Yang Xiang is a distinguished professor with extensive contributions to the field. Minfeng Qi, affiliated with the City University of Macau, also focuses on blockchain and data science research with a ranking between 125-150^{th16}.

B. The content

The research questions

The authors emphasize the methodology that bridges have, analyzing their architecture, the protocols they follow, and the functionality of each methodology. Additionally, they address the challenges they face, their vulnerabilities, their level of security, and possible solutions. Finally, they stipulate future questions and trends that these types of bridges will have.

Justification

With the rise of blockchain in recent times, interoperability between various chains has become a very attractive research topic. One of the proposed solutions that has gained traction is bridges that facilitate the transfer of assets between blockchain networks. Due to this, the present research is well justified, and together with the findings and analysis, makes this paper a significant contribution to the industry.

Connections

The authors provide a series of references linked with renowned authors, deep, current, and well-justified research. The existing work mentioned in this paper is relevant to the topic as it addresses significant collaborations such as blockchain, interoperability, cross-

chain, bridges, smart contracts, relays, etc. Additionally, it contrasts and compares the findings with previous research.

Theory

The authors focus on the framework of blockchain technology and its security principles. Although they do not rely on a traditional systematic theory, the authors base their findings on contemporary theories that contemplate concepts such as decentralized consensus mechanisms, cryptographic security, and smart contract vulnerabilities. Several models are analyzed a priori to have a clearer vision of the mechanism or architecture that bridges possess. After this, the authors focus on a deep analysis of the possible weaknesses in the system's structure to conclude and obtain valuable findings for this technology.

Research paradigm

The paradigms that are implicit can be technocratic as they propose technical solutions and good practices when addressing security issues. The authors also implicitly recommend managing these types of solutions by entities with superior knowledge for better handling of the concerns that may arise [3]. On the other hand, during a deep analysis, there are several assumptions that the authors take for granted. They do not analyze the possible insecurities that blockchains may have as a system or the assumption that a more rigid security system is necessary in the cross-chain. This type of reinforcement can be vital for a better understanding, as people who may not have much technical or prior knowledge of the topic might get confused.

Research method

The research method used is an exhaustive and comprehensive literature review where previous works and current technologies are analyzed to begin a deeper analysis. Additionally, the use of case studies. The authors conduct a qualitative analysis [9] of the security levels that these bridges may have, detailing their implications and the possible practical solutions that should be followed to mitigate these types of risks. Furthermore, the authors use real examples to support their recommendations or solutions. Based on this, the authors contemplate a whole plan where security challenges are identified and analyzed, and a series of practical solutions are proposed. Additionally, the authors detail the solutions with ample evidence, trying to exemplify possible scenarios and their solutions.

¹⁵ Swinburne University of Technology | World University Rankings | THE

¹⁶ University of Macau | World University Rankings | THE

Relevance

As a topic that is on the rise but does not have a theory studied for years, this contribution is very relevant in the field as it provides more specific technical knowledge, problems that this type of technology may have, or even a more peripheral vision of the methodologies that are gaining strength in the cross-chain. Additionally, the authors recommend practical solutions and rigorous security implementations. It can also serve as a guide for future research and continuous technological development.

Reference

The paper has high-level references, from academic literature, industry reports, and case studies. It has a broad review of relevant works and uses optimal language for the level of study. However, there are several sources that could be better analyzed and presented for better understanding.

IV. CROSS-CHAIN BRIDGES: ATTACK TAXONOMY, DEFENSES, AND OPEN PROBLEMS.

A. The context

Introduction

The “Cross-Chain Bridges: Attack Taxonomy, Defenses, and Open Problems” is written by Mengya Zhang¹⁷, Zhiqiang Lin¹⁸, Yinqian Zhang¹⁹, and Xiaokuan Zhang²⁰. This paper is published in RAID '24: The 27th International Symposium on Research in Attacks, Intrusions and Defenses in September 2024.

Categorization

The core intention of this paper is to scrutinize the technology used by bridges within the field of interconnectivity between blockchains, their applications, vulnerabilities, possible bugs, and categorize them according to their characteristics to achieve optimized and structured solutions. With a specialized focus on security and its development within this field, this paper can be categorized under Blockchain technologies, Cross-Chain dilemmas, and security challenges.

Key Researcher

Claudio J. Tessone²¹ is a Professor for Blockchain & Distributed Ledger Technologies, at Zurich University. He has more than 6000 citations on google scholar and is actively involved with blockchain, Crypto economics,

DeFi, and complexity. His h-index is 35 with 36 articles published so far.

Key Journal

There are many reputable journals in the field of blockchain research, as it is a rapidly evolving and impactful area. To the reviewer's knowledge, one of the most significant journals is International Journal of Information Management which is indexed in Scopus, has an H-index of 177 and an impact factor of 14.277 in 2023.

Key Conference

Automated Software Engineering Conference (ASE) is of the top conferences belongs to the paper's field. The ASE is an annual conference with A* ranking according to The Computing Research and Education Association of Australasia (CORE).

Conference rating

The International Symposium on Research in Attacks, Intrusions and Defenses (RAID) has an "A" category according to the CORE2023 ranking. It has maintained this ranking for several years, indicating that it is an established conference with high credibility.

Authors and Institutions

Mengya Zhang and Zhiqiang Lin are affiliated with The Ohio State University, USA, which holds the 71st position in the 2025 Times Higher Education (THE) rankings²². The university is acclaimed for its impactful publications in top-tier venues and significant advancements in blockchain research. Xiaokuan Zhang is associated with George Mason University, USA, an institution renowned for its achievements in system security and privacy research, ranked within the 301-350 range in the THE²³. Yinqian Zhang, a professor at the Southern University of Science and Technology, China, represents an institution recognized for its expertise in decentralized systems and blockchain security, also positioned within the 301-350 range in the ranking. These authors are highly regarded for their substantial contributions to blockchain research.

B. The content

Research questions

The authors propose a robust investigation with the main objective of deeply analyzing the most recognized current technologies in the industry, their possible security

¹⁷ <https://scholar.google.com/citations?hl=en&user=UdJX2hAAAAAJ>

¹⁸ <https://scholar.google.com/citations?hl=en&user=6KuqlacAAAAAJ>

¹⁹ <https://scholar.google.com/citations?hl=en&user=C7htwEIAAAAAJ>

²⁰ <https://scholar.google.com/citations?hl=en&user=HbuPL5IAAAAAJ>

²¹ <https://scholar.google.com/citations?hl=en&user=RAGOVXgAAAAAJ>

²² World University Rankings 2025 | Times Higher Education (THE)

²³ George Mason University | World University Rankings | THE

implications, specific characteristics, and methods employed to reflect on each stage of the cross-chain exchange process. They address the main problems that can occur at each stage of the process, potential attack vectors, and vulnerabilities. They aim to reconstruct security in a more organized way to redistribute efforts to combat these weaknesses in exchange systems (Bridges). Additionally, they provide an analysis for future research and a guide for implementing these security measures.

Justification

The authors justify this research by providing a brief introduction explaining the current needs in blockchain technology. Its limitations make the field of Cross-Chain a broader research activity. Therefore, the current research is well justified. One of the most used tools today in this area is bridges, which warrants research focused on organizing their possible vulnerabilities and solutions.

Connections

Through a literature review, the authors reveal the connections this work has with the field, contrasting existing works and methodologies in Cross-Chain. Since this field is still developing, there is no specific methodology to be analyzed. Therefore, its current development is at its peak. Bridges are one of the methodologies being studied, although there are several different protocols that the industry is adopting. The authors also mention the connection these have with bridges. Due to this, the connection with technology and field development is very strong.

Theory

Although there is no specific theory where the authors work since it is an emerging technology, the compilation made by the authors is exhaustive, including the blockchain framework. Therefore, it could be said that it is an implicit theory. However, the authors review the most common terms, explaining and detailing why they are relevant in this type of research and how they relate to Cross-Chain.

Research paradigms

The paradigms seen in the paper are scientific [3] for the analysis of system vulnerabilities, using past case studies to discover possible errors compared to formal verifications to conclude the error. It can also be said that it uses a technocratic paradigm since for possible solutions, they use technical mechanisms, practical implementation, and recommend solutions based on expert knowledge.

Research method

The method used by the authors is qualitative [9] as they conduct a deep analysis of the current theory, comparison with case studies, and question how to improve from that, strengthen security in smart contracts, and analyze possible vulnerabilities to have a framework to work on and constantly improve the system. By focusing on a qualitative system, the authors reinforce security concepts, use structured techniques, and analyze patterns to discern detailed descriptions of events.

Research design

The authors detail the structure of the vulnerabilities of the systems proposed by bridges, from a superficial approach to a code analysis where they verify the possible causes of case studies. Additionally, they structure the types of vulnerabilities according to their characteristics, revealing 12 types of vulnerabilities that can occur and exemplifying them with real cases, verifying and analyzing each one in depth, allowing future research to focus on different aspects or delve deeper into the same ones. The authors' premises are well-founded, and the main objective of the research is well justified. It has enough information to understand the problem statement and resolution concisely.

Relevance

The paper is highly relevant in the field, with an easy-to-understand structure, and the authors try to explain from general to specific. For future work, this research can serve as a precise guide to take the right direction. Additionally, it contributes to the theories proposed in the literature review and promotes specific recommendations for mitigating vulnerabilities in current systems.

Reference

The paper has a solid and well-explained foundation, with well-established references. However, an exhaustive analysis of the references should be conducted to ensure none are overlooked. As a reviewer, it is seen as a rigorous paper, and the level of references is considered optimal for this type of work.

V. RESEARCH QUESTION

From the problem emerging from the literature discussed in the three above papers, I can formulate a question: Due to the existing vulnerabilities inherent in a bridge, is there any way to eliminate the vulnerabilities of this type of

system so that assets do not migrate from one chain to another? For this, a few factors should be analyzed, from the macro blockchain [7] issue to the current emerging technologies that are being projected [6]. Once the macro environment of the problem is stipulated, it can be inferred that the research problem is closely related to new Cross-chain technologies within blockchain systems [2].

It is known that interoperability between two chain systems that operate vertically is impossible to implement due to their protective nature [1]. During their development, it was not anticipated that their expansion would be so extensive, it is for this reason that research into this type of technology (CrossChain) is important as the growth of this industry is expected to double or triple in the coming years [8]. A secure, stable, scalable, atomic and fast asset exchange technology is what can make a difference in the evolution of the digital market.

State-of-the-art Cross-chain research focuses on the security level of existing solutions. Polkadot [11] or Cosmos [4] protocols have gained traction in recent times. However, emerging technologies that intent-based transfers on exchange attempts, auctions, and more interaction from the users themselves are gaining strength.

To overcome this problem, we propose to analyze this new type of technique, highlighting its characteristics and virtues, comparing them with a traditional bridge [5], and conducting an exhaustive analysis to understand more deeply the mechanisms behind intent-based bridges where those involved in the exchange do not have to rely on the transfer between chains but are themselves the liquidity providers in the transaction. Through an auction that benefits both parties and reliably secures that same exchange by the very nature of the exchange. The simplicity of this technique is what makes it more valuable, an intent can be defined as an expression of change by a user who wants the representation of that asset in a different chain, the solvers are nodes that try to meet the demand of the main user, this is the key difference between inconsistent proposed models [10] and this new technique, where the assets are not transferred by a bridge, but are solvers who are responsible for transferring the value from the destination chain avoiding the vulnerabilities that can occur in environments outside the chain.

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