Journal of Advanced Research Design 127, Issue 1 (2025) 150-172

Journal of Advanced Research Design

Journal homepage:
https://akademiabaru.com/submit/index.php/ard
ISSN: 2289-7984

An Evaluation of EVM-Compatible Blockchain Platforms for Trade Finance

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ARTICLE INFO

Article history:
Received 23 July 2024
Received in revised form 18 December 2024
Accepted 11 April 2025
Available online 25 April 2025

Keywords:
Blockchain; transaction; variance

ABSTRACT

Blockchain, such as Bitcoin and Ethereum, has received significant attention and widespread usage in recent years. However, blockchain scalability has emerged as a challenging issue. This article explores the existing scalability options for blockchain, which can be categorized into two groups: first layer solutions and second layer solutions. First layer solutions involve network modifications like altering block size, while second layer solutions encompass techniques applied outside of the blockchain. Ethereum, the second largest blockchain, utilizes the Ethereum Virtual Machine (EVM) for executing smart contracts on the blockchain. Currently, there are several EVM-compatible blockchains with noticeable differences. In this study, we evaluated multiple platforms for conducting business processes in trade finance. We considered both Layer 1 and Layer 2 blockchain solutions and examined variations in cost and performance (speed). Based on the evidence gathered in this study, we provide recommendations for system designers to consider when selecting a blockchain platform.

1. Introduction

Scalability is critical to the success of public blockchains. Many institutions and organizations involved in improving public blockchains want to provide strategies capable of handling a wide variety of nodes and a high volume of transactions per second. Though shared systems such as peer-to-peer networks may expand well enough in many aspects, blockchain technologies have historically been challenging. The challenge arises from the conflicting requirements inherent in blockchain construction. Vitalik Buterin, the Ethereum project's creator, succinctly articulated his knowledge of this issue by establishing the blockchain's scalability trilemma [1]. This trilemma asserts that an advancement in one of these three areas—scalability, security or decentralization—has a detrimental effect on at least one of the other two.

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https://doi.org/10.37934/ard.127.1.150172

Therefore, there is always an argument over which blockchain platform will be most suitable for implementing a business I.T. solution. One of the earliest use cases for blockchain in business is trade finance due to its enduring trust issues among trading partners [2].

Our goal in this paper is to evaluate several platforms with different categories of solutions to execute a whole business process in trade finance. Scalability solutions provided by blockchain can be classified as either Layer 1 solutions or Layer 2. A Layer 1 solution will directly change the rules and mechanisms of the original blockchain. In contrast, a Layer 2 solution will use an external, parallel network to facilitate transactions away from the mainchain.

In our paper, we considered both Layer 1 and Layer 2 blockchain solutions and observed the differences between speed, cost and variations in performance. Based on the evidence gathered from this study, we provide some recommendations for system designers to consider. The fundamental contribution of the study is an examination of several public scalability choices in terms of performance, volatility and cost.

2. Research Background

2.1 Scalability Trilemma

The Scalability Trilemma, defined by Vitalik Buterin, co-founder of Ethereum, refers to the Scalability Trilemma as a trade-off mechanism that crypto-based projects should face while determining how to maximize the underlying architecture of the blockchain [3]. In layman's terms, this is synonymous with the adage, "You cannot have everything." Vitalik is referring to the trilemma, which is shown in Figure 1. It consists of three components: decentralization, security and scalability. This is a handy paradigm for comparing blockchains. Although it sometimes occurs, it is not typical for the infrastructure to be deficient. Below, we discuss some use cases and characteristics of crypto-based projects.

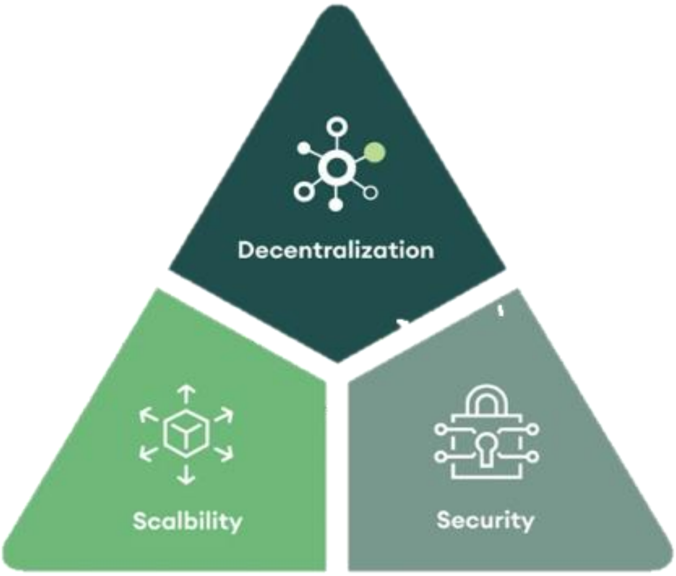

Fig. 1. Scalability trilemma: Scalability, decentralization and security

1.1 Security

Security refers to a blockchain's ability to withstand assaults from external sources. Internally or inside the blockchain, it's a metric for how impervious the system is to modify. Several security vulnerabilities are associated with most blockchains, e.g., Re-entrancy Vulnerability, Transaction Malleability Vulnerability, Timestamp Dependence Vulnerability and Cross Function Race Condition Vulnerability [4].

Decentralization and security, from our perspective, go side by side. In many circumstances, the more nodes in a network, the less dependent it is on a centralized entity and therefore the lower the chance of a single point of failure. However, there are a variety of other attack vectors that pose threats to decentralized networks, including the following:

i. 50% Attack: A single entity (or group of companies) that holds more than 50% of all tokens in circulation essentially owns the network.
ii. Sybil Attack: A single organization (or group of entities) might create several identities on a system to effectively hold a sizable part in the network ownership as well as decision-making.
iii. Penny spends Attack: a single entity (or a collection of entities) that floods the network, especially when it comes to low-value transactions in attempt to cause the network to fail to operate.
iv. Distributed Denial of Service Attack (DDoS): happens when rogue transactions are used to attempt to interrupt network traffic by flooding the network traffic using malicious requests.
v. Collusion Attack: may involve more than one node or entities and conspire to carry out harmful operations on the network.

2.1.2 Scalability

Scalability is critical since it determines the ultimate capacity of any network [5]. In other words, it establishes the maximum size of a network. By size, we mean how much data storage is needed to save the entire blockchain starting from the Genesis block. The most critical factor to consider when analysing a network is how many users the network can support. Bitcoin has between 2.9 and 5.8 million wallet owners; Facebook has 4 billion users and Eos has a few thousand. Nano has the highest throughput of all DAG (Directed Acyclic Graph) systems, including Bitcoin N.G. IoTA, Nano, Ouroborous, Algorand and Conflux, with 7000 TPS (transactions per second). Along with high throughput, Nano, Logos and Rapid chain solutions provide the lowest latency [6]. Nano is one of the most expandable systems available for several reasons:

i. It compresses transactions into tiny UDP packets (like a zip file), allowing transactions to be processed on even the most minimal computer hardware.
ii. Each user contributes by providing their power to compute their transactions on their blockchain, i.e., there is no centralized blockchain that other users must support; and
iii. Individual blockchains contain just the user's most recent balance. It does not include the whole transaction history for the user. However, the past is backed up separately and can be available upon request.

Nevertheless, there are trade-offs associated with reaching unlimited scalability. While scalability and decentralization are compatible, security threats increase. Developers will choose the platform that best meets their requirements and consumers will select the forum that performs the best for them. Specific consumers may be prepared to forego security in favour of scalability, whereas others may choose scalability above security. We examine the system's fundamental characteristics in light of its overall mission.

2.1.3 Decentralization

Decentralization refers to the degree to which ownership, influence and value are distributed over the blockchain. Ethereum, for example, is a highly decentralized platform; Eos is a partly decentralized platform and Twitter is entirely decentralized. A widespread misperception is that networks may be classified as decentralized or not. Another is that all blockchains are equally decentralized.

Let us begin with the most centralized organizational structures. Typically, these businesses do not operate on a blockchain. A small number of persons at the top, i.e., the management team, controls the company. They often own most of the firm and act as decision-makers with a board of advisers. This is the nature of most businesses today, whether they are partnerships, C-Corporations or non-profit organizations.

On the other hand, in a decentralized network, users control the majority of decentralized networks. Users may pool their stakes to vote, access platform features and profit financially. While users may stake their tokens to vote in all blockchains, their power varies. In proof-of-stake systems, each individual's vote has the same weight as their token holdings. Individuals' stakes are only used to elect a third party to vote on their behalf under delegated proof-of-stake procedures. However, since most of the governance structure is embedded directly in the code, these "decisions" are primarily concerned with resolving disagreements. This is in contrast to the choices made by a management team about strategy, operations and shareholder rights.

Another critical aspect of decentralization is that the community retains the most value. No "management team" and hence no centralized entity takes a cut before shareholders get compensation. In practice, most cryptocurrency projects are owned entirely by their shareholders or users rather than the creators. This is a more tempting proposal for individuals who were not founders. Consider today's music business. Apple (iTunes) retains 30% of the sales money for hosting and distribution, with 70% going to content authors. If music streaming were to be managed on a blockchain, the content producers would likely get $90 percent or more of the value. A small amount would go to the organizations responsible for the network's operation, but most of the deal would flow to the value creator rather than an intermediary.

2.2 Scaling Overview

Recently, due to NFT (Non-Fungible Tokens) becoming popular, the number of Ethereum users increased and thus, the second largest blockchain in Market Capital encountered certain capacity limits. This has increased the cost of network use, necessitating the development of "scaling solutions." Numerous solutions are being explored, evaluated and deployed, each of which takes a unique method to accomplish identical aims [7]. For blockchains to compete with legacy payment processors, they need to be able to process high volumes of transactions quickly at a low cost.

There are several ways to scale a blockchain. Layer-1 scaling solutions improve the underlying layer-1 protocol, whereas layer-2 solutions take computations off-chain to reduce congestion.

Scalability's primary objective is to enhance transaction speed (faster finality) and throughput (number of transactions per second) without jeopardizing decentralization or security. On Ethereum's layer one blockchain, increased demand results in slower transactions and unviable gas costs. Accelerating the network's speed and throughput is critical to the meaningful and widespread adoption of Ethereum.

While speed and throughput are critical, scaling solutions that enable these objectives to remain decentralized and safe. Maintaining a low entry barrier for node operators is crucial for avoiding a trend toward centralized and unsecured computing power. The following section describes the scaling solutions that are currently being explored.

2.2.1 Scaling categories

2.2.1.1 On-chain scaling

Sharding is horizontally dividing a database to distribute the load [8]. In the context of Ethereum, sharding reduces network congestion and increases transactions per second by creating separate chains dubbed "shards." This also alleviates the burden on validators since they will no longer be needed to process the totality of all network transactions.

Another way to describe it is to consider typical committee-based blockchains (e.g., Algorand [9] or EOS). All transactions to be included in the next block are being processed by a single committee (and each member of that committee). The block is then broadcast and all nodes must execute all approved transactions (somewhat, they must store them).

Several scientific papers [10-15] have attempted to give better trade-offs by some type of sharding. In the studies mentioned earlier, the blockchain network (blocks, nodes, transaction history and consensus) is divided into multiple smaller networks (shards) with some degree of connectivity between them. One of the most critical challenges to overcome in these systems is inter-shard transactions, which degrade scalability when there are many of them and the limited number of shards, which affects security.

2.2.1.2 Off-chain scaling

Off-chain solutions are developed independently of the layer 1 Mainnet and do not need modifications to the Ethereum protocol. Specific solutions, dubbed "layer 2" keys, draw their security directly from Ethereum's layer 1 consensus mechanisms, such as rollups [16] or state channels [17]. Other possibilities include constructing new chains in various configurations that are not connected to the Mainnet, such as sidechains or plasma chains. The sidechain concept is basically to run another blockchain alongside some other "main" blockchain. These two blockchains could then talk to each other uniquely, making it possible for assets to move between the two chains. Plasma chains are like sidechains, except they trade off some utility for extra security. These systems connect with Mainnet but use a range of different security mechanisms to accomplish a variety of aims.

2.2.1.3 Layer 2 scaling

Off-chain solutions in this category draw their security from Mainnet Ethereum. Most layer 2 answers are based on a cluster of servers or a single server referred to as a validator, node, operator, block producer or sequencer. The people may administer these layer 2 nodes, businesses and organizations that utilize them by many people (e.g. Mainnet) or by a third-party operator, depending on the implementation. Rather than sending transactions straight to layer 1, they are routed through these layer 2 nodes (Mainnet). For certain implementations, the layer 2 instance groups them before anchoring them to layer 1, where they are permanently secured by layer 1. The specifics of how it was done differ substantially between implementations and layer 2 technologies. Furthermore, a layer 2 instance can be opened and shared by many applications or deployed by a single project dedicated to servicing only that project's app.

i. RollUps*:* Rollups execute transactions outside Layer 1 and then upload the data to Layer 1, where consensus is achieved [16]. Figure 2 shows that transaction data in layer 1 blocks enables rollups to be safeguarded using native Ethereum security. All rollups execute transactions off-chain, which means they do it using their infrastructure. Rollups act as decongestants for Ethereum in this sense. They alleviate Ethereum by conveniently supporting Ethereum-based activities that would have competed for "L1" Ethereum block space without their assistance. What distinguishes rollups stylistically is how they manage data.

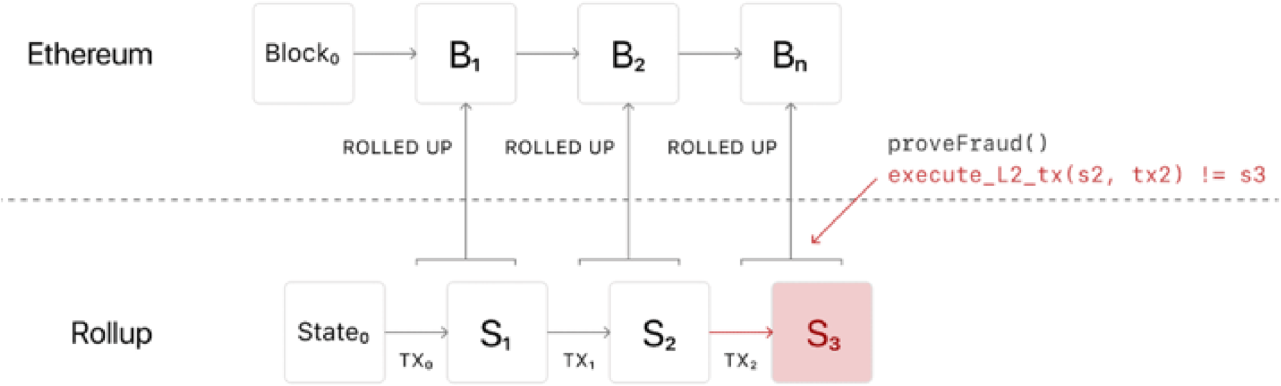

Fig. 2. Roll Ups of transactions affecting states for rollup in Mainnet [16]

ii. ZK-Rollups: Hundreds of off-chain transactions are bundled (or "rolled up") into a cryptographic proof known as a SNARK using zero-knowledge rollups (ZK-rollups). This is known as viability evidence, depicted on layer one [18]. The ZK-rollup smart contract monitors the status of all Layer 2 transactions, which can only be changed with valid evidence of ownership [19]. The above indicates that ZK-rollups require validity proof and not the entire transaction data. Validating a block is faster and less expensive with a ZK-rollup since less data is provided. When funds are moved from layer 2 to layer 1 *via* a ZK-rollup contract, there have been no delays because the funds have already been confirmed by a validity proof recognized by the ZK-rollup contract. Because of its position on layer 2, ZK-rollups may be changed to reduce transaction size even more. An account, for example, is represented by an index rather than an address, reducing the transaction size from 32 to 4 bytes. Furthermore, the transactions are written as calldata in Ethereum, reducing gas usage.

iii. Optimistic Rollups: On layer 2, optimistic rollups run concurrently with the main Ethereum chain [20]. They might provide scalability benefits since they do not do any computation by default. Rather than that, they "notarize" the transaction after it has occurred or propose the new state to Mainnet. Transactions are written as calldata by Optimistic rollups to the main Ethereum chain, further improving them by lowering the gas cost. Because processing is the most time-consuming and expensive aspect of using Ethereum, optimistic rollups may boost scalability by up to $10-100x$, depending on the transactions. The figure will grow much greater once shard chains are implemented because more data will be available in the case of a transaction dispute. Because optimistic rollups do not calculate the transaction, a mechanism is necessary to ensure that transactions are not fraudulent [21]. And that is when proof of fraud comes into play. If a rollup identifies a fraudulent transaction, it will perform a fraud-proof computation and calculate the transaction using the available state data. Because the transaction may be challenged, you may have to wait longer for transaction confirmation than you would with a ZK-rollup. Even the gas used to execute the fraud-proof computation is repaid. Participants are punished for fraud and compensated for establishing fraud.

iv. State Channels: State channels use multi-sig contracts to allow parties to trade swiftly and freely off-chain and finalize their transactions on Mainnet [17]. This helps to keep network congestion, costs and delays to a minimum. Currently, there are two sorts of channels: payment and state.
v. Sidechains: A sidechain is a self-contained EVM-compatible blockchain that operates concurrently with Mainnet. These are interoperable with Ethereum through two-way bridges and act according to their consensus rules and block parameters [22].
vi. Plasma: A plasma chain is a separate blockchain connected to the Ethereum main chain that uses fraud evidence (such as Optimistic rollups) to settle disputes [23].

3. Methodology

3.1 Purpose of the Study

This research aimed to assess the performance and cost of several kinds of blockchain-based solutions. Additionally, get a broad picture of how currency variations affect the price of smart contract implementation and invocation.

3.2 Research Data

To ensure that the trade finance processes functioned correctly, we created test cases for the smart contract's methods. For this research, the code written for the smart contracts to generate our data is archived in GitHub [24]. The code and smart contracts written in solidity to run the experiments were uploaded to GitHub [25] for future researchers to verify, expand and improve. To conduct testing, these tests required the registration of users with various roles, including buyer, seller, issuing bank, corresponding bank, shipping company, company inspection, buyer's country customs and seller's country customs. These user identities were then utilized to evaluate the various techniques for changing the status of the contract. It was confirmed that if the user calling methods did not have the required role or authorization, his transaction would be rejected by the blockchain network. Following that, view type functions (which read state variables but do not modify them or execute transactions) were used to get information from the blockchain system, as shown in Table 1 and verify that the smart contract's state was altered in the desired manner. Running a single trade finance transaction test against a particular blockchain network would produce a smart contract and all the 21 transactions on that network, which are then exported as a sample CSV file. The sample file includes the information we needed for the experiment, such as Transaction Hash, From, To, Method Name, status, Transaction Fee, Gas Price, etc. The sample size was 154 CSV (Comma Separated Value) files, each containing 21 transactions, as shown in Table 1, including the smart contract deployment. The statistics were gathered by exporting CSV files from the respective network's block explorer website daily between 22 November and 29 November. Aggregate and average approaches were used to examine the data.

Table 1
Transactions and calls invoked by each participant in a trade finance transaction

Participants	Transactions	Calls
Buyer	setSalesContract() addOrder() confirmInvoice() cancelOrder() setFinancialAgreementParties() confirmShipment()	orderExists() viewInvoices() viewOrders() checkOrder()
Seller	createInvoice() confirmOrder() cancelOrder() setShippingAgreement() paymentReceived()	orderExists() viewInvoices() viewOrders() checkOrder()
Issuing/Import Bank	confirmFinancialAgreement() setLCAgreement() addDocument() setPaymentAgreement() initiatePayment()	getNumberOfDocuments() getDocumentID() IsDocumentValid()
Corresponding Bank	validateDocument() processpayment()	getNumberOfDocuments() getDocumentID() IsDocumentValid()
Shipping Company	initiateShipment()	
Inspection Company	verifyGoods()	
Buyer's Country Customs	verifyGoods()	
Seller's Country Customs	verifyGoods()	

Additionally, to these procedures, the standard deviation was employed to quantify the variance of these estimating methods about the final aggregate result. Three primary kinds of data were analysed: cost, performance and variability. The charges in Ether and USD were pre-calculated at the time of the transaction by the relevant platforms based on market and gas prices.

3.3 Experiment Design

We used Hevner [26] three-cycle perspective to construct the smart contracts, as seen in Figure 3. It details the development process and underlines the need to evaluate the artifact's value and contribution to the knowledge base and environment. It will assess the present design throughout each iteration of the design cycle [27].

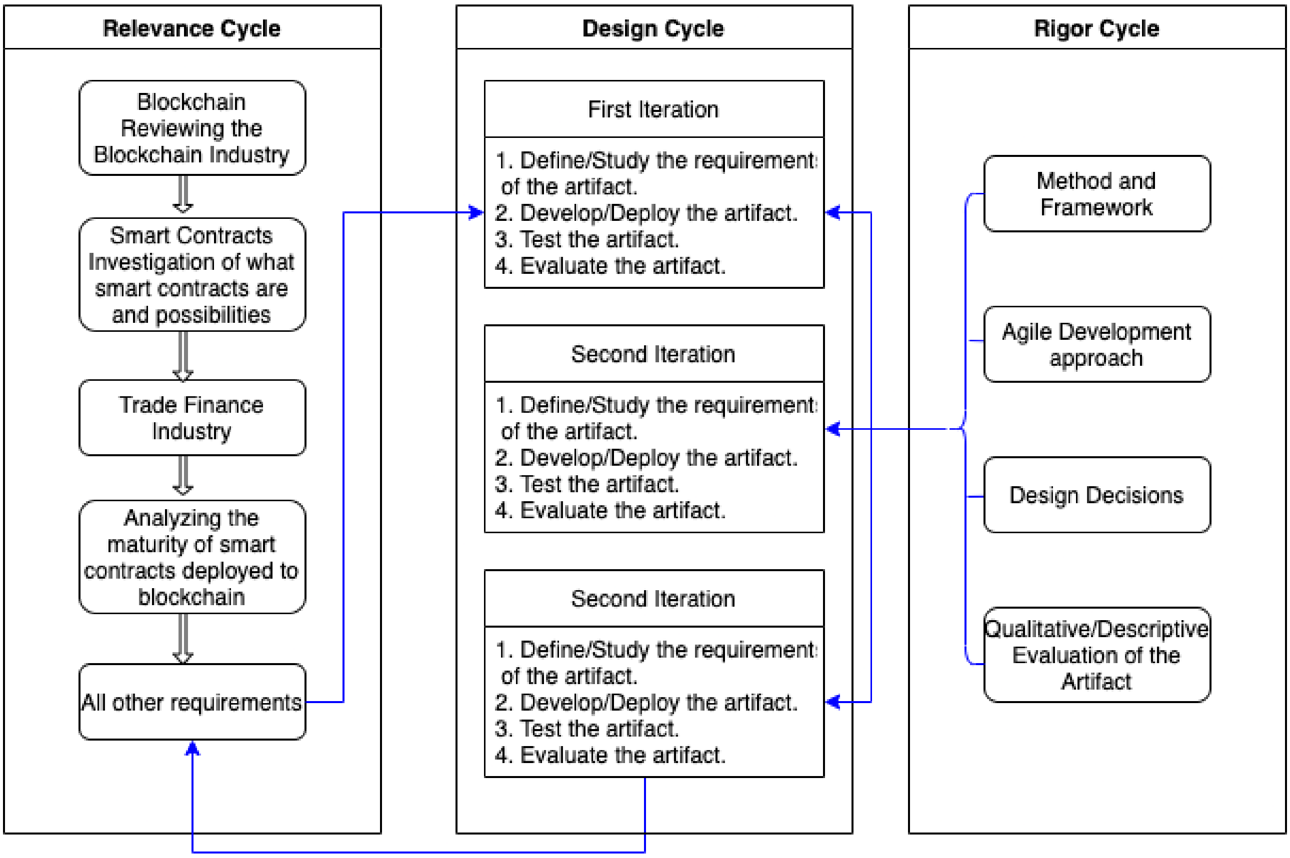

Fig. 3. Overview of the 3 cycles applied in this study

Additionally, emphasize this as a critical and fundamental component of design science study. We used agile development ideas to create the artifact. The agile philosophy will provide flexibility and allow us to adapt quickly to change [28]. The agile methodology assisted us in meeting the criteria outlined in our relevance and rigor cycles. At the same time, it will work well in conjunction with our iterative design cycles. Each iteration provided new needs, which were included in our artifact.

As our smart contracts were developed in solidity, which is a statically typed programming language and operates on the Ethereum Virtual Machine (EVM), we picked some well-known EVM-based blockchain networks from ChainList as below:

i. Scalability Solutions

- <u>Arbitrum:</u> Arbitrum is an L2 scaling solution for Ethereum (optimistic rollup) that provides a unique set of benefits:
  a. Trustless security: security based on Ethereum, with any one party capable of ensuring that Layer 2 outcomes are valid.
  b. Compatibility with Ethereum: the ability to execute unmodified EVM contracts and Ethereum transactions.
  c. Scalability: by offloading the processing and storage of contracts of the main Ethereum chain, significantly increased throughput is enabled
  d. Cost-effective: built and developed to decrease the system's L1 gas footprint, lowering per-transaction costs.
- <u>Avalanche:</u> Avalanche is an Ava Labs platform that enables anybody to create multi-functional blockchains quickly and simply and decentralized apps. It is intended to overcome some of the shortcomings of existing blockchain systems, including poor transaction rates, centralization

and scalability—and it does this via deploying various technologies. This includes its Avalanche consensus system, which guarantees low latency, high throughput and resilience to 51% assaults.

  a. Avalanche is based on three interoperable blockchains: the Exchange Chain (X-Chain), the Contract Chain (C-Chain) and the Platform Chain (P-Chain). To summarize, the X-Chain is used to create new digital assets, the C-Chain is Avalanche's implementation of the Ethereum Virtual Machine (EVM) and the P-Chain is used to coordinate validators and create subnets.
  b. Two blockchains (the P-Chain and the C-Chain) are secured using the chain-optimized 'Snowman' consensus, which enables high-throughput secure smart contracts. In contrast, the X-Chain is secured using the DAG-optimized 'Avalanche' agreement—a fast and scalable protocol capable of achieving transaction finality in seconds.
  c. By dividing its design across three distinct blockchains, Avalanche can optimize for flexibility, performance and security without compromising on any of these characteristics. As a result, it is a powerful platform for both public and business use cases, as developers have a great degree of freedom in terms of the sorts of apps they may design.
  d. The platform is built on the AVAX utility token, used to pay network fees, staking and as a "base unit of account" across Avalanche subnets.
  e. According to Ava Labs, the platform can process over 4,500 transactions per second—compared to approximately 7 transactions per second for Bitcoin and $14 transactions per second for Ethereum. Additionally, it can complete transactions in less than three seconds. This potentially makes it more suitable for massively scale decentralized applications—something that would be a bottleneck on several rival platforms.
  f. Apart from being extremely scalable, Avalanche is designed to address another significant issue confronting blockchain-based systems today: interoperability. This is accomplished by enabling blockchains inside and across subnets to interact, allowing them to complement and facilitate cross-chain value transfers.

- <u>Fantom:</u> Fantom is a scalable, high-performance smart-contract platform. It is intended to address the shortcomings of earlier generations of blockchain systems.
  a. Fantom is a permissionless, decentralized and open-source network management system. Fantom's unique aBFT [29] consensus process, Lachesis [15], enables it to be far quicker and cheaper than prior technologies while being exceptionally safe. Lachesis's high-speed consensus process allows digital assets to function at previously unheard-of speeds and significantly outperforms existing systems. In contrast to previous approaches, Fantom does not compromise on security or decentralization for the sake of scale.
  b. Indeed, Fantom's benefits go beyond sheer efficiency; its modular design enables complete customization of blockchains for digital assets, with unique properties customized to each asset's use case.
  c. Additionally, Fantom provides unprecedented security by using a leaderless Proof-of-Stake protocol to safeguard the network. Lachesis, Fantom's aBFT consensus protocol, can scale to many nodes worldwide in a permissionless, open environment, achieving a high degree of decentralization. It does not use Delegated Proof of Stake or recognize the idea of "Primary nodes."
- <u>Optimism:</u> Optimistic Ethereum is a rollup scaling method that enables users to submit transactions to the Ethereum network and complete them more quickly and at a much-reduced gas cost. From the users' and developers' views, there is a "parallel world" referred to as Layer 2 [30] or L2, in which users generally have the same addresses as on the Ethereum blockchain

(also called Layer 1 or L1). Some gateways enable the transmission of communications and assets across universes.

   a. On L1 Ethereum, your transaction is validated by hundreds of nodes to ensure that the proposed block that contains it is legitimate. This procedure is costly and must be compensated for. Unlike on L1 Ethereum, optimistic rollups enable users to complete most of their work off-chain through a "layer 2" protocol. On Optimistic Ethereum, the smart contract is solely responsible for depositing/withdrawing funds and verifying transaction proofs on the blockchain. This results in a more efficient and cost-effective approach.
   b. The wonderful thing about decentralization is that you can trust that transactions will be done accurately since thousands of machines will execute them. Honest miners would reject such a trade. Rollups lack that amount of redundancy.

- Binance Smart Chain: Binance Smart Chain is a revolutionary technology that enables Binance Chain to be programmable and interoperable. Binance Smart Chain is based on a network of 21 validators using a Proof of Staked Authority (PoSA) consensus algorithm that enables fast block times and minimal fees. Staking's most strongly bonded validator candidates will become validators and generate blocks. Double-sign detection and other cutting logic ensure security, stability and chain finality. Additionally, the Binance Smart Chain enables smart contracts and protocols that are compatible with the EVM. Due to the natural support for interoperability, cross-chain transfer and other communication are feasible. Binance DEX remains a liquid market for asset exchanges on both networks. This dual-chain design will let users benefit from brisk trade on one side while developing decentralized applications on the other. The Binance Smart Chain will consist of the following:
   a. A self-sovereign blockchain ensures security and privacy *via* the use of chosen validators.
   b. EVM-compatible: Supports all current Ethereum tools with quicker completion time and lower transaction costs.
   c. Interoperable: Comes with efficient native dual chain connectivity; Optimized for scaling high-performance decentralized applications (dApps) that demand a quick and fluid user experience.
   d. Distributed governance with on-chain participation: Proof of Staked Authority encourages decentralization and community participation. As the native token, BNB will work as both the execution gas for smart contracts and the staking tokens.
- Polygon: Polygon is a public blockchain scaling solution. Polygon is built on an updated version of the Plasma framework (Plasma MoreVP) - with an account-based implementation. It supports all the current Ethereum tools while enabling quicker and cheaper transactions. Polygon Network is a decentralized platform for blockchain applications that enables hybrid Proof-of-Stake and Plasma-enabled sidechains.
   a. The elegance of Polygon's architecture stems from its simple design, which separates a general validation layer from various execution contexts, including Plasma-enabled chains, full-blown EVM sidechains and, in the future, alternative Layer 2 techniques such as Optimistic Rollups.
   b. To support the PoS mechanism on our platform, we've deployed a set of Ethereum-based staking management contracts and a collection of incentive-based validators running Heimdall and Bor nodes. Although Polygon initially supported Ethereum, the company wants to keep multiple base chains depending on community proposals and consensus to build an interoperable decentralized Layer 2 blockchain platform.
   c. We have a fast finality layer that periodically utilizes checkpoints to finalize the sidechain state. The rapid finality aids in the establishment of a sidechain state. The EVM-compliant

chain features a small number of validators and a quick block time, resulting in high throughput. Scalability is prioritized above a high degree of decentralization. Heimdall assures that the final state commit is error-free and travels through a vast validator set, resulting in a high degree of decentralization.

4. Experiment

The experiment was done on various EVM networks that have been suggested to evaluate how the Scalability Trilemma affects them.

4.1 Setup

4.1.1 Hardhat

Hardhat is a software development environment for compiling, deploying, testing and debugging Ethereum applications. It enables developers to organize and automate the repeating processes inherent in the process of developing smart contracts and decentralized applications, as well as simply add more features to this workflow.

4.1.2 Solidity

Solidity is a high-level object-oriented language for implementing smart contracts.

4.1.3 MetaMask

MetaMask was intended to address the security and usability concerns associated with Ethereum-based web applications. It manages user accounts and connects the user to the blockchain.

4.1.4 ChainList

This section is a list of EVM networks. The information may link users' wallets and Web3 middleware providers to the proper Chain ID and Network ID to connect to the correct chain.

4.1.5 Tableau desktop

Tableau is a visual analytics tool created based on scientific research to accelerate, simplify and intuitively perform analysis. From 22nd to 29th November, the script was executed through hardhat every 4-6 hours. After completing the transactions, CSV files were collected and analysed using Tableau from the network block explorer sites (Etherscan). Three distinct categories of data are analysed:

i. Performance: It denotes the period between the deployment of a smart contract and the final transaction.
ii. Cost: This column indicates the cost of each transaction in U.S. dollars.
iii. Variability: This term refers to the degree to which costs vary from their average value.

5. Results

As discussed in the methodology section, we collected results for various blockchain platforms that are EVM-compatible. This allowed us to deploy the same smart contract developed to evaluate trade finance standard smart contracts and analyse the behaviour for performance, cost and variability of each transaction.

We also separated the analysis based on 2 categories, layer 1 and layer 2 blockchain implementations and observed the related data metrics for each type.

5.1 Layer 1: Blockchain Solutions

In a decentralized ecosystem, a Layer-1 network is a blockchain, while a Layer-2 protocol is a third component that may be used in conjunction with a Layer-1 blockchain. Bitcoin, Litecoin and Ethereum are all examples of layer-1 blockchains. Scalability is improved through layer-1 scaling solutions that augment the blockchain protocol's foundation layer. Numerous approaches are being developed [31] – and used – to improve blockchain networks' scalability.

Layer-1 solutions directly modify the protocol's rules to boost transaction capacity and speed while simultaneously accommodating additional users and data. Scaling at the layer-1 level may include raising the quantity of data contained in each block or increasing the pace at which blocks are validated to improve overall network throughput.

5.1.1 Transactional cost

As can be seen in Figure 4, we ran and simulated transactions in trade finance smart contracts using Ethereum (Rinkeby Network), Binance Smart Chain, Avalanche and Fantom blockchain networks for the Layer 1 category. Except for the Fantom network, it can be seen that the price for deployments and invocations of trade finance smart contracts can range from USD 20 to USD 100, with Ethereum being more expensive on average and Avalanche being the cheapest averaging around USD 20. The smart contract's most affordable deployment and invocation are on the Fantom network, averaging much more reasonably, around USD 0.02.

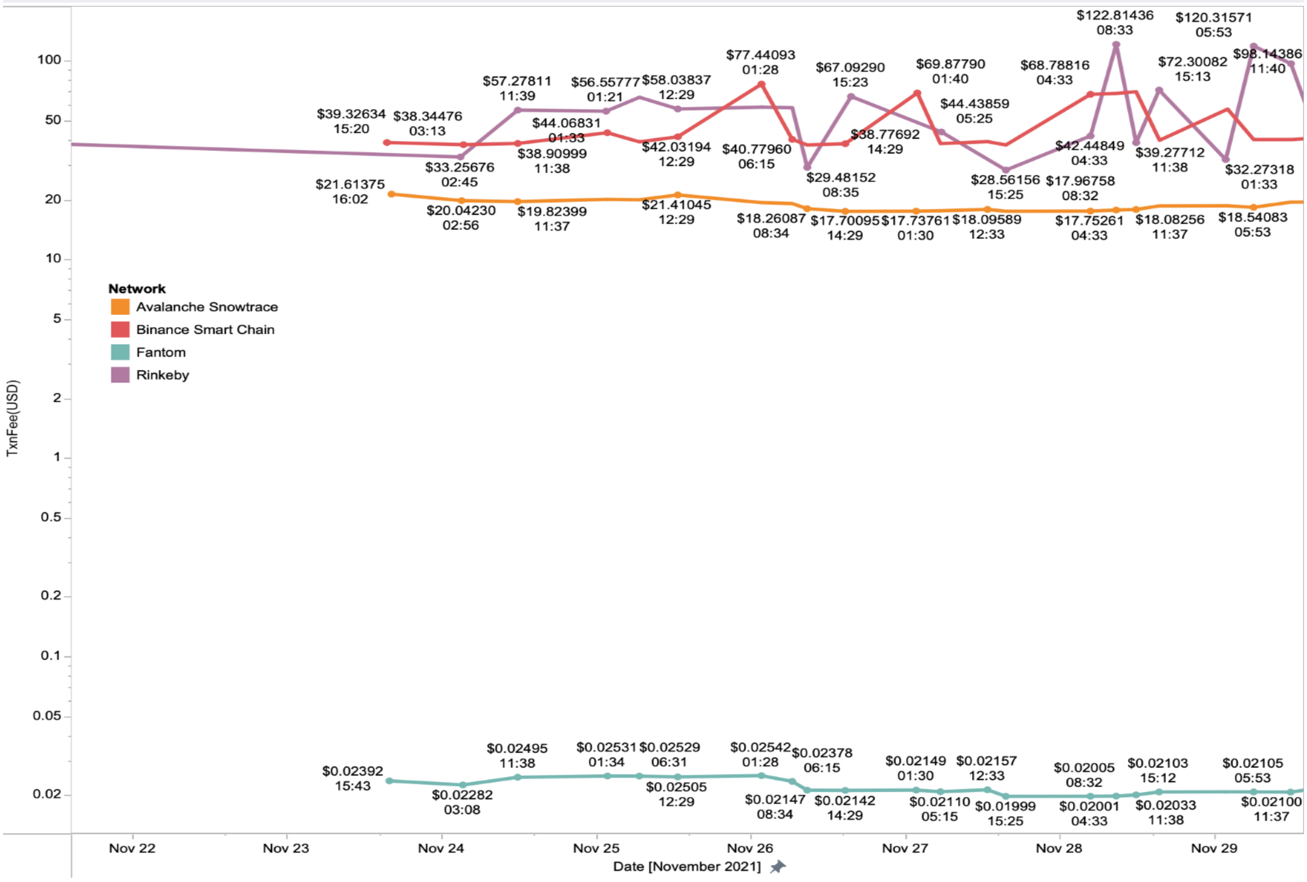

Fig. 4. Cost for overall transactional cost of smart contract deployment and invocations on Layer 1 Blockchain Solutions

5.1.2 Transactional speed

As can be seen in Figure 5, we ran and simulated transactions in trade finance smart contracts using Ethereum (Rinkeby Network), Binance Smart Chain, Avalanche and Fantom blockchain networks for the Layer 1 category. It can be seen performance-wise; they are reasonably good between the range of 3 to 6 seconds to complete the trade finance smart contract deployment and invocation. Despite being the cheapest, the Fantom blockchain seems to have lower performance when compared to Avalanche. Ethereum appears to have the most deficient performance, which can be attributed to the fact that it is a more popular blockchain with the most significant number of users second to bitcoin. Hence, the network may react slower in the delta queue.

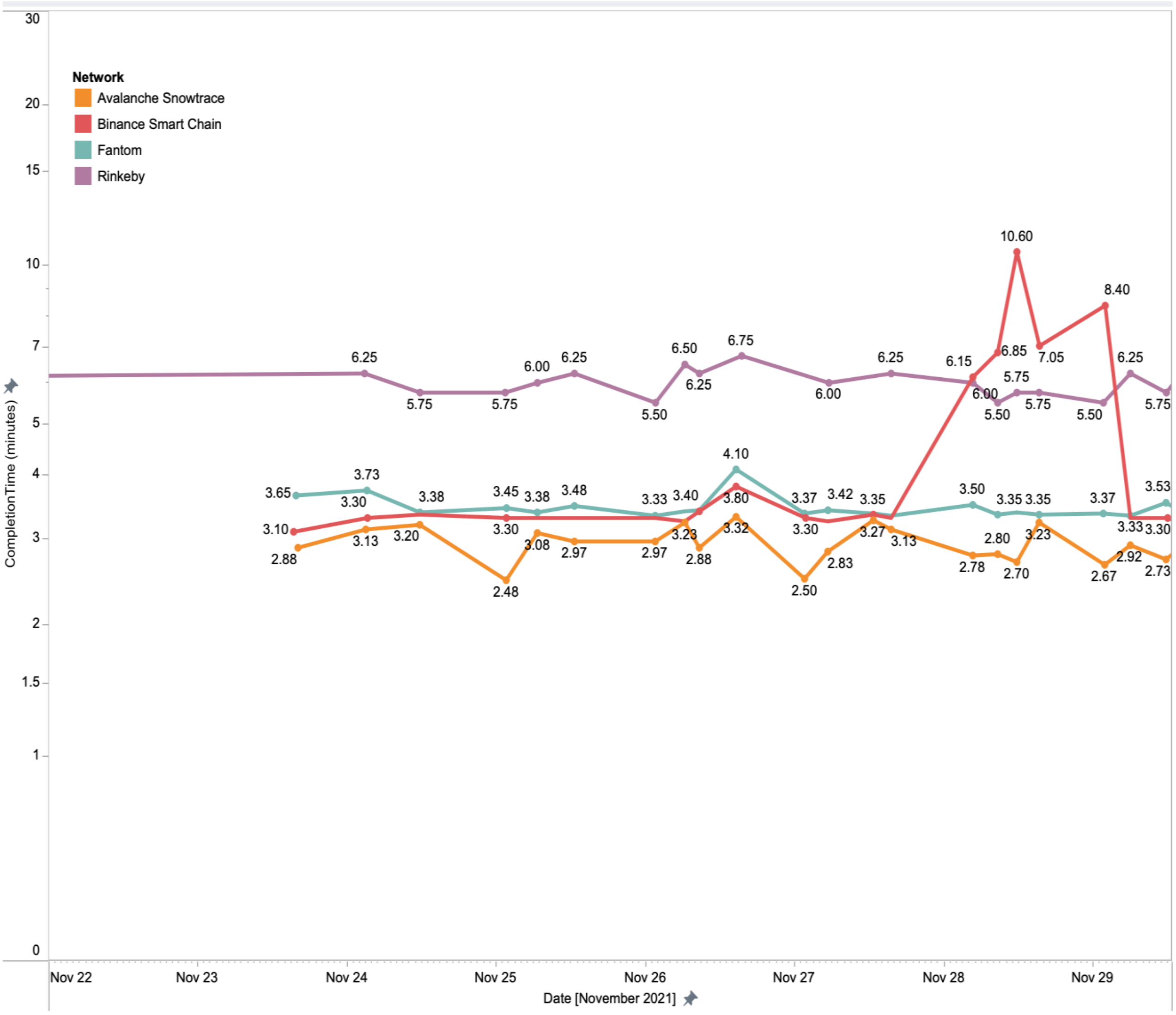

Fig. 5. Speed performance for overall transactions of smart contract deployment and invocations on Layer 1 Blockchain solutions

5.2 Layer 2: Blockchain Solutions

Layer 2 blockchains operate on the native layer to maximize efficiency. By offloading a part of the Level 1 blockchain's transactional burden to another system design, Layer 2 effectively offloads transactions. The processing burden is subsequently carried by the Layer 2 blockchain, which communicates with Layer 1 to finalize the outcome. Since this nearby auxiliary architecture handles the bulk of the data processing load, network congestion is reduced: the Layer 1 blockchain is less crowded and more scalable.

5.2.1 Transactional cost

As can be seen in Figure 6, we ran and simulated transactions in trade finance smart contracts using Optimistic Ethereum, Arbitrum and Polygon blockchain networks for the Layer 2 category. The price for deployments and invocations of trade finance smart contracts can range from USD 0.00029 to USD 2.8, with Arbitrum being more expensive on average, followed by Polygon and Optimistic Ethereum being the cheapest, averaging around USD 0.00029.

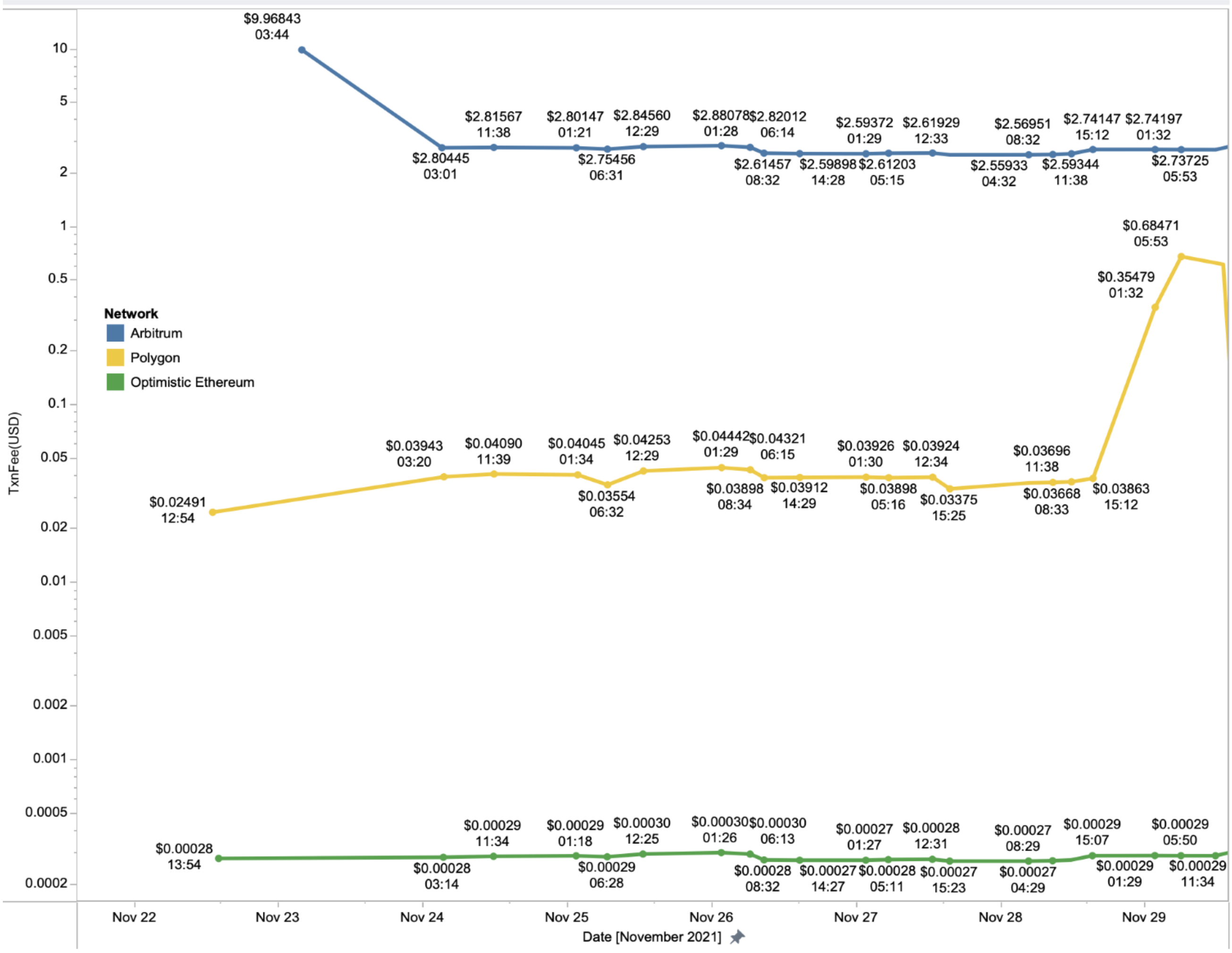

Fig. 6. Cost for overall transactional cost of smart contract deployment and invocations on Layer 2 Blockchain Solutions

5.2.2 Transactional speed

As can be seen in Figure 7, we ran and simulated transactions in trade finance smart contracts using Optimistic Ethereum, Arbitrum and Polygon blockchain networks for the Layer 2 category. It is expected that Layer 2 transactions will be much faster because it was created to reduce the load on the leading network. Except for Optimistic Ethereum, deployments and invocations of trade finance smart contracts for Arbitrum and Polygon can take about 3 to 4 seconds on average, which is impressive. Performance for Optimistic Ethereum is off the charts. However, it is inconsistent and seems to have high swings in performance variations.

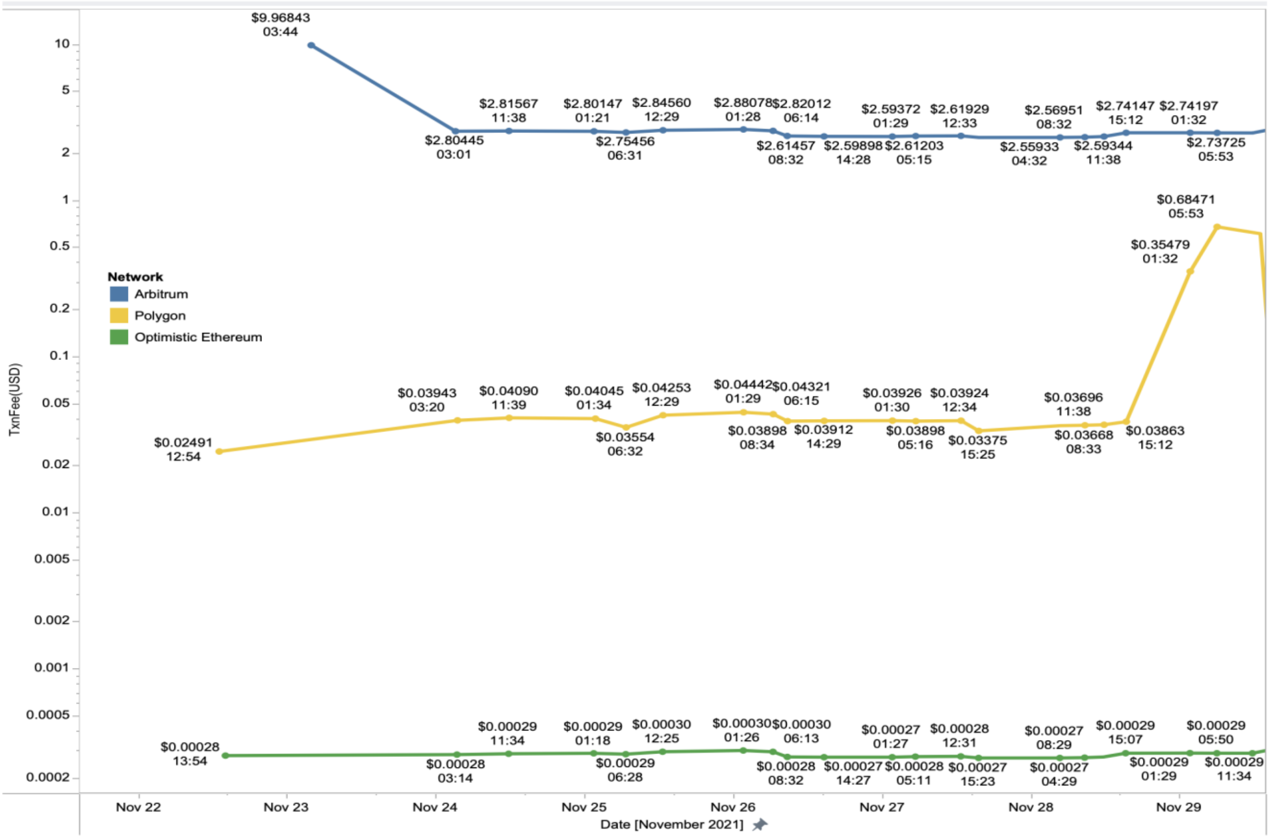

Fig. 7. Speed for overall transactions of smart contract deployment and invocations on Layer 2 Blockchain Solutions

5.2.3 Cost and speed variability

5.2.3.1 Cost variations

All blockchain requires fees for deployment and invocations of smart contracts. While the cost can be justified through business operations, the variations may affect the price of a large volume of trade finance contracts. It can be seen in Figure 8 that among all the blockchains tested, Optimistic Ethereum, Avalanche and Fathom are the most consistent when it comes to transaction fees. Both Polygon and Arbitrum had occasional fluctuations but a giant swing of differences. While Binance Smart Chain and Ethereum seem to have many variances tend to involve much smaller swings in prices.

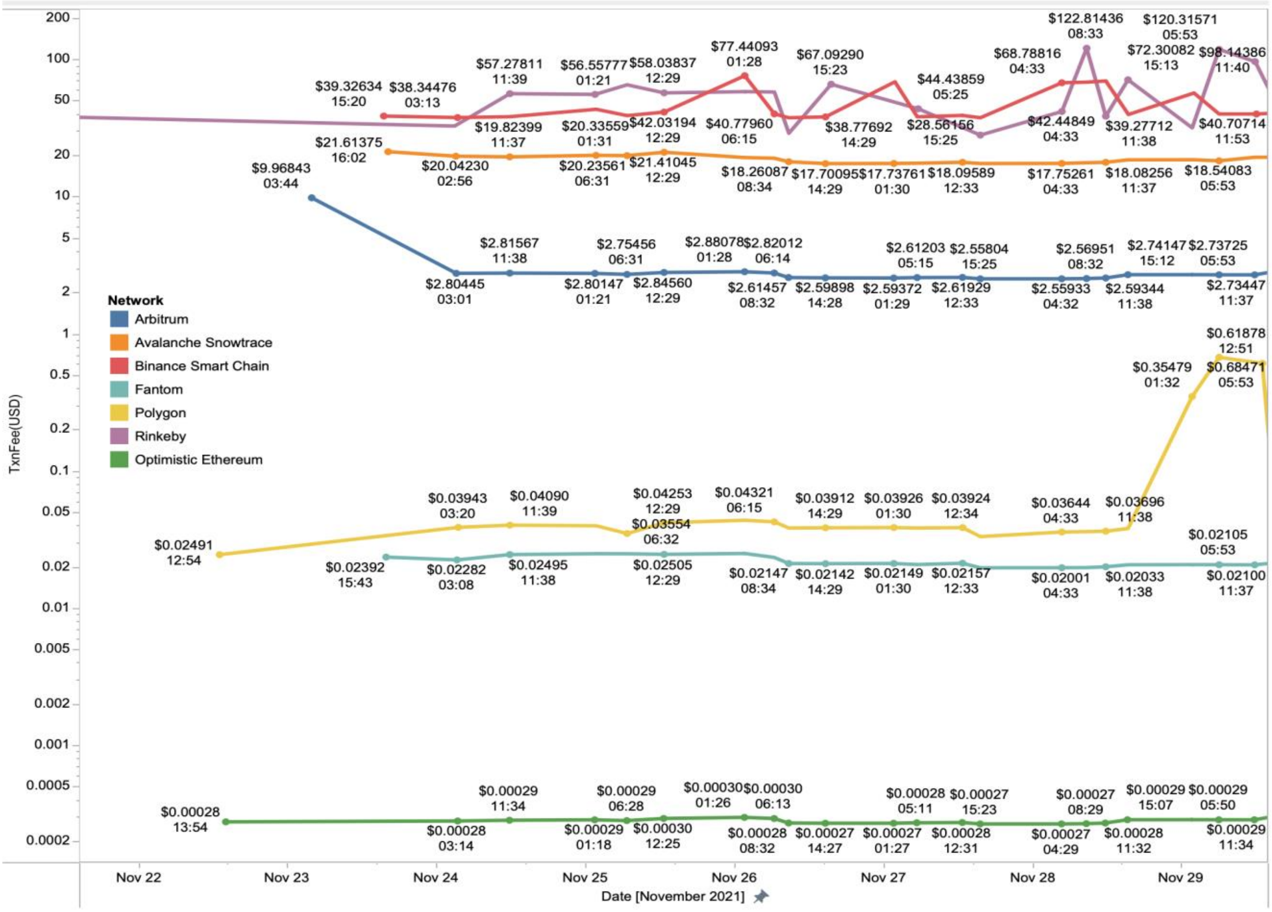

Fig. 8. Overall transactional cost of smart contract deployment and invocations

5.2.3.2 Speed variations

The speed performance for smart contract deployment and invocations may not affect cost but may affect business operations and user expectations. Predictable behaviour is preferred despite network conditions [32]. As seen in Figure 9, although Ethereum is the lowest in performance, it behaves much more reliably and consistently with very low variance. Compared to Optimistic Ethereum and Binance Smart Chain, speed performance can vary with a massive conflict.

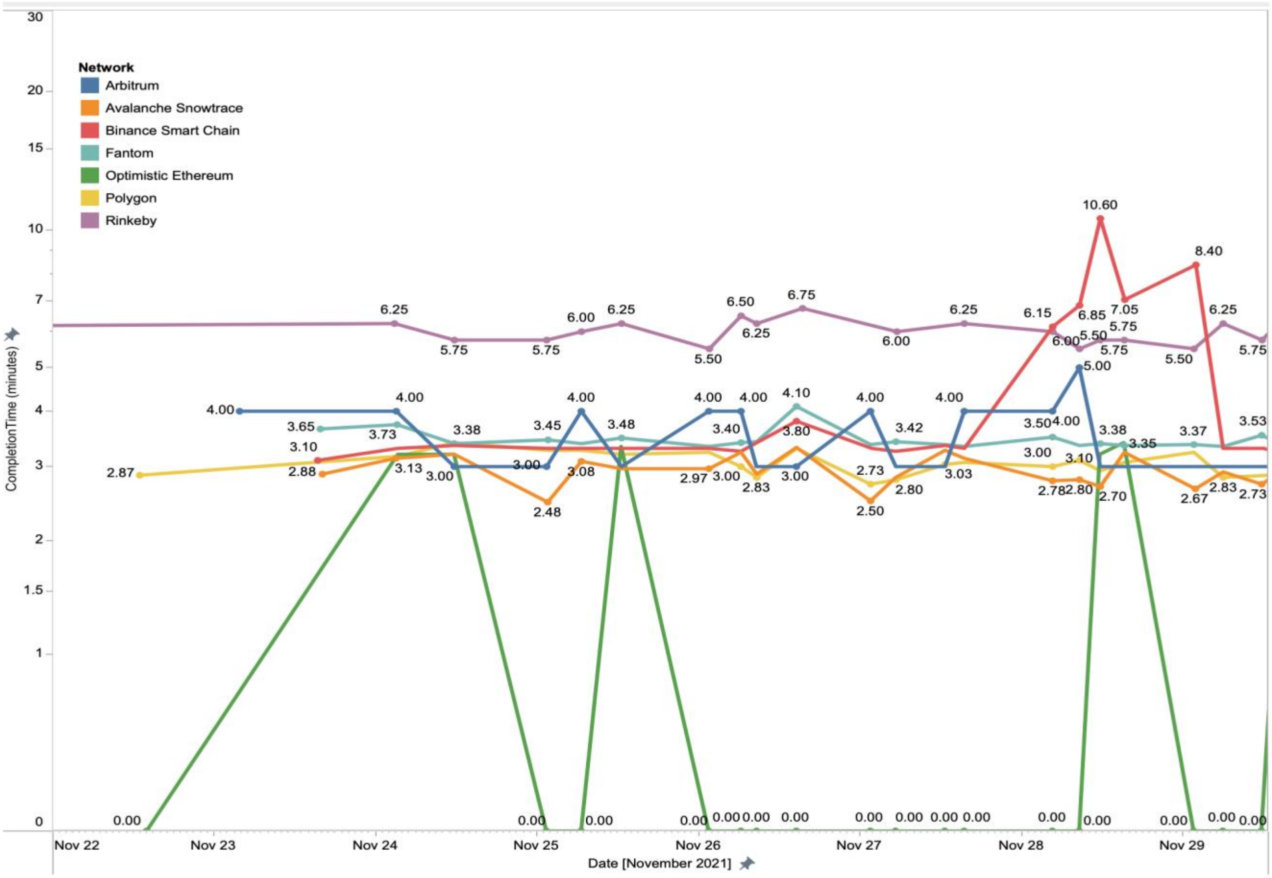

Fig. 9. Overall performance of smart contract deployment and invocations

6. Cost Benefit Analysis

As organizations explore the adoption of blockchain platforms, it becomes crucial to evaluate their cost and benefits comprehensively. A cost-benefit analysis provides a structured approach to assess the economic feasibility of implementing blockchain solutions. By weighing the advantages against the associated expenses, decision-makers can make informed choices regarding the adoption of blockchain platforms. This analysis considers both tangible and intangible factors to provide a holistic understanding of the potential benefits and costs involved. Table 2 outlines the key considerations and evaluates the financial and strategic implications of integrating blockchain technology into organizational operations.

Table 2
Cost benefit analysis of Blockchain platforms

Blockchain Platform	Benefits	Costs
Avalanche	Scalability Low Transaction Fees Interoperability	Learning Curve Ecosystem Maturity
Binance Smart Chain	Decentralization Low Transaction Fees Ecosystem Integration	Centralization Concerns Security Risks
Ropsten	Familiarity (EVM Compatibility) Ethereum Compatibility Familiar Development Environment	Limited Scalability Higher Transaction Fees
Fantom	High Throughput Low Transaction Fees Interoperability	Ecosystem Development
Arbitrum	Scalability Compatibility with Ethereum Lower Transaction Fees	Learning Curve Ecosystem Adoption
Polygon	Security Scalability Interoperability Low Transaction Fees	Centralization Concerns Security Considerations
Optimistic Ethereum	Ecosystem Integration Scalability Compatibility with Ethereum Lower Transaction Fees Security	Latency Limited Smart Contract Support

i. Avalanche: Offers high scalability and low transaction fees, but users might face a learning curve. Its ecosystem is mature and supports interoperability.
ii. Binance Smart Chain: Provides decentralization and low transaction fees, but there are concerns about centralization and security risks. It integrates well with existing ecosystems.
iii. Ropsten: Compatible with Ethereum and provides a familiar development environment. However, it has limited scalability and higher transaction fees.
iv. Fantom: Boasts high throughput and low transaction fees, with a focus on ecosystem development and interoperability.
v. Arbitrum: Offers scalability and compatibility with Ethereum, but users might encounter a learning curve. It aims for wider ecosystem adoption and lower transaction fees.
vi. Polygon: Prioritizes security and scalability, but users should be aware of centralization concerns and security considerations. It also supports interoperability and low transaction fees.
vii. Optimistic Ethereum: Integrates well with existing ecosystems and offers scalability with lower transaction fees. However, there may be latency issues and limited support for smart contracts.

7. Conclusion and Future Work

While one may argue that the duration of our experiment was just a week and may not be sufficient to prove our results, we would like to maintain the focus of our investigation to study the differences in the choice of the underlying blockchain solution and how it affects cost fluctuations—noting that this is constantly changing. Still, some solutions had consistently higher volatility compared to others. This probably needs to be studied further, but our research was limited in time. However, the differences are highly related to how transaction fees work on the type of blockchain used [33]. Layer 2 solutions typically have much lower transaction fees due to how the algorithm and reward system work.

Looking into the data gathered, we would urge developers and system designers to seriously consider the three paradigms in the blockchain trilemma. For systems that put a higher priority on security [34], Layer 2 solutions will have a weaker form of security. This is due to some of the processes involved in achieving better speed and the cost of transactional fees. If the blockchain trilemma proves too constraining for an on-chain, layer 1 solution, we have shown that off-chain, layer 2 solutions may provide a viable alternative.

Despite the persistent blockchain trilemma, developers are actively addressing scalability with innovative solutions. Experimentation is encouraged, especially when tested against real-world transactional conditions. In this paper, we showed a framework that developers could emulate to produce and compare transactional results. As advancements in Layer 1 and Layer 2 solutions continue, the key question remains: will these scaling efforts be temporary or long-term? It's too early to determine, but we hope our paper serves as a foundational resource for researchers and developers evaluating these solutions.

Acknowledgement

This research was not funded by any grant; however, the authors would like to acknowledge the support of Postgraduate Office, Kulliyyah of ICT, IIUM for providing support and guidance.

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