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Permissioned blockchain frameworks in the industry: A comparison

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Abstract

Permissioned and private blockchain platforms are increasingly used in today's industry. This paper provides a comprehensive and comparative study of the 5 major frameworks (Fabric, Ethereum, Quorum, MultiChain and R3 Corda) with regard to the community activities, performance, scalability, privacy and adoption criteria. Based on a literature review, this study shows that even if Fabric is promising, the final selection of a framework for a specific case-study is always a trade-off. Finally, lessons learnt are given for industrial practitioners and researchers.

Keywords: Blockchain; Industry; Permissioned platforms; Comparison

1. Introduction

Originally introduced with Bitcoin by Satoshi Nakamoto in 2008 [1], blockchain is a distributed ledger technology, where participants maintain a replica of the shared ledger. The ledger updates and the replicas' synchronisation are maintained through a consensus protocol executed by the participants. The ledger contains cryptographically signed transactions which are put together in blocks. Using such cryptographic techniques makes the ledger immutable, which is one of its main characteristic.

Even though blockchain was first invented for building a public and open trustless network without any central authority, it is evolving towards permissioned and private platforms for enterprises. Private blockchains are similar to public blockchains, they also are immutable, nodes share the same ledger, but the access to the network is permissioned. This means that permission and role for each node have to be granted.

In this paper, the features of the major private blockchain frameworks are presented. Hyperledger, Ethereum, Quorum, MultiChain and R3 Corda are considered as the main technologies [2]. We compare them in terms of community activities, performance, scalability, privacy and adoption based on a literature review.

The paper is organised as follows: Section 2 describes the main features of the selected frameworks. The comparison analysis is presented in Section 3. Section 4 discusses our key findings. Section 5 concludes the paper.

2. Major features: Hyperledger Fabric, Ethereum Geth, Quorum, MultiChain and R3 Corda

Even though these 5 platforms share the common property of being permissioned platforms, they all have their own features detailed in the following. Also, all the main features are summarised in Table 1.

Hyperledger Fabric is one of the Hyperledger projects hosted by the Linux Foundation. It is a decentralised operating system for permissioned blockchains that can execute distributed applications (Dapps) written in general-purpose programming languages such as Go, Java or Node.js [3]. A Fabric network is composed by nodes whose identities are given by a membership service provider. These nodes can be: (i) *Clients* that propose transactions to execute and broadcast them for ordering; (ii) *Peers* that maintain the ledger and the state of the latter; or (iii) *Ordering service nodes* that establish the order of all the transactions. Note that the latter do not participate in the execution nor the validation processes. Additionally, Fabric uses smart contracts, called *chaincodes*, for implementing the application logic. The platform natively

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Table 1
Major permissioned frameworks' features.

	Industry focus	Consensus	Smart contracts	Open source	Support/Governance	Cryptocurrency
Hyperledger Fabric	①	Voting-based (Solo) or pluggable consensus	✓	✓	Linux Foundation	✗
Ethereum	①	PoW or Clique PoA	✓	✓	Ethereum developers	✓
Quorum	②	Clique PoA or RAFT-based or Istanbul BFT	✓	✓	Ethereum developers & JPMorgan Chase	✗
MultiChain	①	Round Robin validation	✗(v1) ✓(v2)	✓ / Com.	Coin Sciences	✗
R3 Corda	②	Voting-based / RAFT	✓	✓	R3 Consortium	✗

① Cross-Industry ② Financial Industry / Com.: or Commercial

implements Solo, a voting-based consensus protocol consisting of the *endorsing nodes* (a subset of peers) executing the transactions and validating them in compliance with the *endorsement policy*. However, other consensus protocols such as Practical Byzantine Fault Tolerance (PBFT), Raft or Kafka (to be able to use several ordering nodes) can be plugged in. Fabric has no underlying cryptocurrency.

Ethereum, launched in 2015, is an open source, public, blockchain-based, distributed platform for developing decentralised applications [4]. Originally, Ethereum is a public permissionless blockchain-based platform implementing a Proof-of-Work (PoW) based consensus protocol called Ethash. Ethereum is also used as a private platform (configurable feature). As PoW is not secure enough and requires a lot of computational power, some of the Ethereum testnets are currently implementing the new Clique Proof-of-Authority (PoA) consensus protocol. All blocks are then sealed by approved signers, which is computationally lighter than Etash's mining process. The list of signers is dynamic in Clique: signers can propose to add or remove another signer and the proposal that gets the majority of votes is applied. Additionally, Ethereum supports smarts contracts written in the Solidity object-oriented language for running Dapps. Ethereum also introduces the Ethereum Virtual Machine (EVM) enables any node to run any program regardless of the programming language. Ethereum has a native cryptocurrency called Ether.

Quorum has been developed by J.P. Morgan for financial use-cases, but can be used for any type of industry. Quorum is a permissioned blockchain based on the Ethereum blockchain [5]. More precisely, it is a fork of go-ethereum. It brings several enhancements: (i) *Privacy*: it is possible to create private contracts and transactions whose payload is only visible to participants that are specified in a parameter of the transaction. Public transactions are still possible (i.e. visible by all the participants of the permissioned network, not by the public Ethereum blockchain); (ii) *Alternative consensus protocols*: other protocols for consortium blockchains such as a Raft-based consensus protocol and Istanbul BFT are also available; (iii) *Permissioning*: only known and authorised peers, defined in smart contracts, can join the network; and (iv) *Higher performance*.

MultiChain, developed by Coin Sciences, is an open source platform which is a fork of the Bitcoin blockchain [6]. However, unlike Bitcoin, MultiChain allow users to configure several parameters such as, e.g. the permissions to access the network, the privacy of the chain, the maximum block size, the mining incentive. The mining is done by a set of identified block validators. There is a single validator per block, working in a round-robin type of scheduling. In MultiChain 1.0, it is not possible to build complex logic on the blockchain because of the lack of support of smart contracts, but the new MultiChain 2.0, which is in Beta version at the time of writing, introduces *Smart Filters*, a functionality that enables custom rule coding for validating transactions. Finally, MultiChain supports a variety of programming languages such as Python, C#, PHP, Ruby or JavaScript.

R3 Corda is an open source permissioned platform developed by R3 [7]. Corda follows the "Know Your Customer" principle, each node has to prove its identity to be authorised to join the network. The *Doorman* is the node in charge of validating the identities and distributing the certificates. The network is also composed by one or many *Notary* nodes, their role is to validate the uniqueness and the sequencing of the transactions without global broadcasting. Two types of consensus have to be reached in Corda: validity and uniqueness. Validity is checked by each signer before signing the transaction, and uniqueness is checked by the *Notaries*. Smart contracts written in JVM languages are supported, and Corda supports the development of decentralised applications (CorDapps) written in Kotlin.

3. Comparison

When selecting a private framework for a specific use-case, it is important to know several factors such as community activity, the technology adoption or even the intrinsic performance. In the following, the methodology for assessing each criteria and a comparison of the frameworks are presented. Note that our framework's performance analysis considers only their original/initial features (such as the intrinsic consensus) from a high-level perspective, i.e. without considering and reviewing every single detail that can be used or plugged-in. This is particularly true at consensus level where other consensus (e.g. BFT-like consensus, RAFT, etc.) could be implemented.

3.1. Methodology

Community activity: To assess it, we mainly look at (i) the Github repository of the frameworks in terms of number

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of contributors (denoted u) and commits (c) and (ii) Twitter in terms of number of followers (f) and tweets (t) on the main account. We determine a final grade (gca) between 0 and 5 for each technology i such as defined by Eq. (1).

$$gca_i = \left[\frac{\frac{c_i}{\max c} + \frac{u_i}{\max u} + \frac{f_i}{\max f} + \frac{t_i}{\max t}}{4} * 5 \right] \quad (1)$$

Adoption: Can be measured by looking at industrial use-cases. We rely on (i) the recent Forbes Blockchain 50 report [2], presenting the underlying technologies embraced by big companies of different sectors (such as Amazon, Facebook, Google, BMW, Daimler, etc.) — *the number of groups embracing a framework is denoted n* — and (ii) the scientific interest for each or these frameworks. This latter is measured by reporting the number of results to the search of the platform's name on Google Scholar (denoted h). Our searches are the following: ethereum, hyperledger fabric, quorum blockchain, R3 corda, "multichain" blockchain, and all of them do not count patents and citations. A final grade denoted ga is therefore determined by using Eq. (2).

$$ga_i = \left[\frac{\frac{n_i}{\max n} + \frac{h_i}{\max h}}{2} * 5 \right] \quad (2)$$

Privacy/Confidentiality: When looking at the platforms' privacy, we mainly concern ourselves with the transactions privacy and data exposure/confidentiality, which is more concerning since privacy is more related to participants, and we must know participants in permissioned frameworks. We determine a grade based on the privacy-preserving mechanisms implemented in the different frameworks (e.g. possibility to create private transactions/contracts, the way the transactions are going through the network and so forth). The mechanisms were found in the white papers or reference papers for each framework [3–7]. In private blockchains, data and transactions can be seen either by all the participants (0-grade) or only a part of them. The more restrictive the framework can be, the better the grade is. Also, 0 does not mean no privacy at all.

Scalability, Throughput & Latency: Those criteria levels are computed thanks to our literature review (16 papers). Fig. 1 depicts our three-step methodology. Our corpus consists of 1303 papers collected in five main library databases: IEEE Xplore, ACM Digital Library, Springer, ScienceDirect, MDPI. These papers assess the performance of private/permissioned blockchain platforms. As a first step, we filtered only the papers dealing with one or more of the five frameworks under study. Then, only the papers evaluating our three metrics of interest are kept. Finally, titles and abstracts are analysed in order to exclude papers which (i) claim results that are not obtained through an experiment, (ii) implement a modified/improved version of the original framework, (iii) evaluate on a domain-specific scenario (e.g. healthcare with non-comparable workloads/benchmarks) and (iv) obtain results through analytical models (including simulated models). This final step significantly decreases the final number of papers to be analysed as listed in Table 2. Since no work compared all the frameworks in the same settings, we used

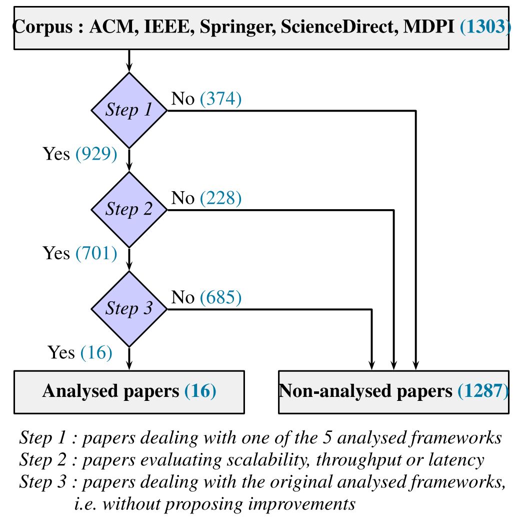

Fig. 1. Methodology for gathering papers evaluating performance.

Table 2
Analysed papers for the scalability, throughput and latency assessment.

Framework	References
Hyperledger fabric	[3,8–19]
Ethereum	[8,9,13,15,20,21]
Quorum	[22]*
MultiChain	[23]
R3 Corda	[11]

**Note that since no paper evaluated the performance of the Quorum framework, the following paper [22] was a posteriori added.*

the best results for each framework. Even if it constitutes a limitation of our comparison, it enables nonetheless to show to what extent the performance is reachable (already known and tested on a real set-up). To assign these grades, for each criterion, we look for the best framework and assign the best grade to it (5), then the other grades are assigned relatively to the best framework. For the latency metric, the 5 grade means the framework has the lowest latency.

3.2. Analysis

Fig. 2 sums up the frameworks' behaviour with regard to the different criteria. Note that, as no paper dealt with the scalability criterion for Quorum and Multichain, the 0 grade is assigned. Looking at the average grade for each platform in order to compare them on one general grade (considering the same weight for each criterion). Fabric, Ethereum, Quorum, Multichain and Corda have respectively an average grade of 4.2, 3.3, 2.2, 2 and 2.2. Even if Fabric is, here, showing better results, it is important to keep in mind that choosing a platform is mainly a trade-off. Indeed, none of these framework is flawless.

Our relative comparison is realistic, but we are aware of the following limitations: (i) some experimental results in the literature are still missing regarding some criteria for several frameworks or conducted in different test environments; (ii) the grades regarding these metrics might not reflect exactly the

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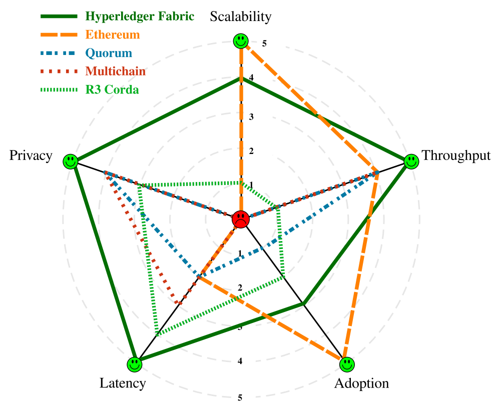

Fig. 2. Overall analysis.

real behaviour of each platform (since only based on a limited number of scenarios experimented in the literature).

4. Discussions/lessons learnt

Based on our literature review and the comparison analysis presented in the previous sections, we highlighted several key findings that can be interesting for both practitioners and researchers:

For industrial practitioners: The provided analysis can be used as a starting point for selecting 2 (or 3 at maximum) frameworks for testing in their own settings/environment without (re-)developing a complete analysis. This comparison gives them important criteria to consider when implementing such blockchain frameworks. It is important to implement the latest version of the framework, since it is usually more secure, scalable and performant as pointed out by [11,14], that shows that Hyperledger Fabric v1.0 performs better than the v0.6. However, Fabric still suffers from scalability issues [9,11]. The performance of a DApp will also depend on the type of transactions (read and/or write) as demonstrated by [12,17] for Fabric. This study also highlights that practitioners have to be careful when configuring the queue size in such a way that it limits the increase of the latency when there are too many simultaneous transactions. Additionally, practitioners willing to implement a Fabric platform need to be aware that the orderer's settings have an impact on the throughput such as demonstrated in [17], and the throughput is also affected by the choice of the database [16,21]. On the other hand, when implementing an Ethereum platform, practitioners also need to consider the overhead in terms of memory and disk usage it implies [9,20,21], and their vulnerability to attacks forking the blockchain, as denoted in [9].

For researchers: Our literature review highlights that: (i) no work compares the major permissioned blockchain frameworks in a same environment, that could be very interesting for analysing deeper where improvements could be done; (ii) no work presents a methodology for sizing the transactions queue, which has an impact on the latency as shown in [12], (iii) there is still room for improvements regarding the consensus protocols used in the private platforms, since they often are the bottlenecks [11]; (iv) there are plenty of optimisations that could be done/found for enhancing the performance of private platforms as shown and experimented in [10,16] and (v) there are still experimental studies to be conducted regarding privacy and scalability, particularly in Ethereum, Quorum and Multichain.

5. Conclusion

Private blockchains are quickly becoming a concern for both the academic and the enterprise worlds. And they are more and more used in the enterprises [2]. However, there are a lot of frameworks, and all of them are slightly different in terms of consensus protocols or underlying currency. We described the main features of five of the major platforms – Hyperledger Fabric, Quorum, Ethereum (geth), MultiChain and R3 Corda – so as to gather and highlight the differences between them in one paper. We analysed the frameworks with regard to several criteria using results obtained from experimental research papers and proposed a comparison based on grades assigned to the platforms for each criterion. We could notice that most papers use old versions of the frameworks and some of the comparisons are debatable, whether it is because the hardware is different or because the features of the platforms are such that it cannot be compared. For future work, we will implement the latest versions of these platforms and experimentally compare them using different benchmark tools.

CRediT authorship contribution statement

Julien Polge: Conceptualization, Investigation, Writing - original draft. **Jérémy Robert:** Conceptualization, Supervision, Writing - review & editing, Funding acquisition. **Yves Le Traon:** Supervision, Writing - review & editing, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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