Towards a Framework for Understanding the Performance of Blockchains

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2021 3rd Conference on Blockchain Research & Applications for Innovative Networks and Services (BRAINS) | 978-1-6654-3924-4/21/$31.00 ©2021 IEEE | DOI: 10.1109/BRAINS52497.2021.9569810

Abstract— **Blockchain and Distributed Ledger Technology (DLT) appears to be at a worldwide threshold of acceptance and adoption. Since their inception, several innovative projects have been proposing solutions to the blockchain trilemma, improving blockchain features and its technical limitations. However, the adoption of blockchain as a technology or a software component, requires a comprehensive understanding and characterization of their technical principles and characteristics. The latter introduces an uncertainty for an organization to decide which blockchain protocol best meets its needs and demands. In general, there is a lack of proper testing and software engineering practices for assessing the usage of blockchains usage and understanding their performance. Towards that direction, this paper presents an architecture for a blockchain benchmarking framework which aims at the deployment and evaluation of different blockchain protocols, focusing on different aspects such as security and scalability. A set of modules is introduced for testing and evaluating the behaviour of blockchain protocols under different test scenarios.**

Keywords— ***blockchain, benchmarking framework, testing, reproducibility, XRP ledger, consensus, protocols***

I. Introduction

A distributed ledger is often described as a shared distributed database which is accessed and maintained by a set of independent, possibly untrusted participants (i.e., nodes). Each participant owns an identical copy of the database of transactions (i.e., the ledger) maintained over a peer-to-peer (p2p) network. All modifications or additions to the ledger are expressed immediately and agreed among the participants using a consensus algorithm. Blockchain, which is considered as a type of a Distributed Ledger Technology (DLT), was first introduced within the concept of a cryptocurrency (i.e., Bitcoin), while by then has received a lot of attention due to the unique characteristics it offers, i.e. security, anonymity, transparency, and decentralization [1]. The decentralized nature of a blockchain, lacks of a central authority to synchronize the state of the processes. For this reason, such systems implement consensus algorithms, which are responsible for (i) the coordination of the distributed nodes, and (b) the validation of the state of transactions propagated in the network. Moreover, consensus algorithms provide reliability and liveness to the network and defend it against malicious *(aka byzantine)* attacks.

Nowadays, blockchain technology has been introduced as a software component in many domains such as healthcare, supply chain, finance, and energy [2], while many enterprises and academic institutions are conducting research on how blockchains can be used for solving real-world challenges (e.g., identity theft, mismanagement in healthcare, digital copyright & piracy issues etc.). Still though, the wide adoption of the technology still remains an ongoing task. On the technical side, choosing which blockchain protocol to deploy, and which type (public, private or consortium) is challenging.

Before deciding which blockchain protocol to deploy several questions need to be explored such as: Why a blockchain infrastructure is required? How is the blockchain infrastructure improving current processes? Which blockchain protocol is suitable based on the requirements at hand? and to what extend does the selected blockchain protocol handles security and scalability concerns?

In an attempt to answer the aforementioned questions, this paper introduces an architecture for a proposed blockchain benchmarking framework that aims to be: (a) generic, in terms of the deployment of different blockchain protocols, (b) reliable in terms of achieving close-to-real data, and (c) scalable. The proposed benchmarking framework aims to serve as a staged environment for supporting blockchain researchers and developers to test and validate the performance of a blockchain protocol under various settings and synthetic scenarios. In brief, the aim of this work is to provide a benchmarking environment for monitoring and comparing the behavior of each blockchain protocol in the presence of faults. In addition, the proposed modules enable the user to monitor different metrics and to identify potential performance bottlenecks within the network.

II. Related Work

Currently, there are multiple studies regarding measuring the performance of blockchain protocols. Some of these studies are targeting public blockchains while others private ones. BlockBench [3] is a framework for analyzing private blockchain protocols. It is considered adaptable in terms of integrating any private blockchain while it can measure throughput, latency, scalability, and fault tolerance against different workloads. Additionally, the authors in [4] have considered the scalability of blockchain protocols as an urgent concern. Thus, they have studied how different bottlenecks in the Bitcoin network can affect the overall throughput of the network. In the work conducted in [5], the authors have studied the propagation time of blocks and transactions in the network concluding to the fact that the latter is the primary cause for blockchain forks. They have also demonstrated what can be achieved while pushing the network to its limit, by introducing unilateral changes to the client's behavior. Furthermore, the authors in [6], have introduced a framework for analyzing existing Proof of Work (PoW) based deployments and PoW blockchain variants, in an attempt to compare the trade-offs between their performance and security provisions.

III. Blockckhain Becnhmarking Framework Proposition

Blockchain-based protocols are complex systems that comprise of many components ranging from the underlying communication network, cryptographic libraries, gossip protocols, consensus, virtual machines, and game theoretical aspects. In most cases, bootstrapping a private blockchain

978-1-6654-3924-4/21/$31.00 ©2021 IEEE

network on a local deployment and use it for testing is a challenging task. It is even more challenging to compare various private blockchain implementations in terms of transactions throughput, latency, fault-tolerance, and scalability. Moreover, having an isolated environment where you can introduce changes to the source code, test and debug the system without affecting the implementation of the production blockchain, is essential. Implementing a blockchain infrastructure considers several design choices such as network performance, network anomalies, node's misbehavior, etc. However, the latter introduces several challenges, while a blockchain network usually consists of several nodes running in different machines around the world (i.e., high level of distribution and decentralization).

The proposed implementation of our benchmarking framework is open-source, and it is published under our GitHub repository [7]. Currently, it is capable of deploying a full-mesh XRP ledger network with a given number of nodes/validators. Moreover, different scripts are developed for generating traffic in the network (e.g., in the form of payment transactions), a monitoring framework for capturing and visualizing data produced by the network, as well as, a connectivity manager, aiming for the adaptation of the network rules at different nodes during runtime. We note that the current deployment is generic, and it could be adapted to support the deployment of any blockchain protocol.

A. Architecture Overview

As depicted in Figure 1, the proposed architecture is comprised of four main building blocks. These are: (a) the Control & Configuration components, (b) the Validators Network, (c) the Accounts Management and Traffic Generator, and (d) the Monitoring Services.

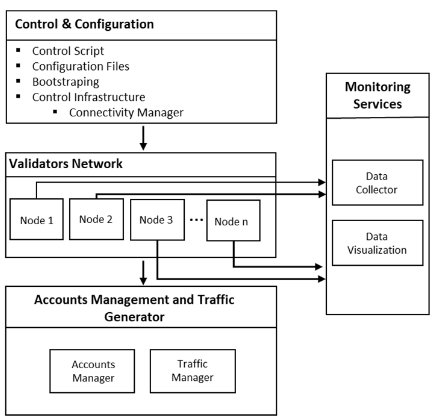

Figure 1: Blockchain Benchmarking Framework Architecture

Control and Configuration: This module considers the deployment process of the network (e.g., generation of configurations files, bootstrapping the network, adapting the connectivity between the nodes/validators etc.)
Validators Network: This module enables the dynamic spawn of a blockchain network of *n* number of nodes that act as validators.
Accounts Management and Traffic Generator: This module is responsible for creating new accounts and for injecting traffic (in form of transactions) towards the network participants.

Monitoring Services: This module enables several monitoring services. In brief this module gathers data and enables different data visualizations by looking at the transactions performed in the network. Furthermore, the module reads data regarding the health of the nodes that participates within then network.

CONCLUSIONS

This paper introduces the architecture of a blockchain benchmarking framework with the aim of monitoring and measuring the performance of various blockchain deployments in the presence of faults. An implementation of the architecture is provided under [9] to showcase an instantiation of the framework with the deployment of the *rippled* daemon. A comprehensive evaluation of the deployment is set as a future work. Currently, we are working towards extending the framework with providing support to other blockchain protocols (e.g., Stellar, Ethereum). The aim of this work is ultimately to act as a common ground for performing benchmarks while stress testing the behavior of different blockchain protocols against different scenarios that simulate close to real environments.

ACKNOWLEDGMENT

This work has been partially supported by the University Blockchain Research Initiative (UBRI) project, funded by the Ripple's Impact Fund, an advised fund of Silicon Valley Community Foundation (Grant id: 2018-188546)

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