Blockchain Governance using Reference Architectures

Luis Florez[1]

[1]Departamento de Ingeniería de Sistemas y Computación - Universidad de los Andes
Cra 1 Nº 18A - 12, Bogotá, Colombia

le.florez602@uniandes.edu.co

Abstract. *Although Blockchain has grown in importance, great barriers still remain, including high failure rates, governance concerns and issues with quality attributes. These barriers have complex interactions and many trade-offs which suggests the need for design tools such as reference governance models and reference architectures. However, these tools are scarce and research in this area, especially governance, is sparse. The object of this research is thus to propose and then validate a new reference governance model and reference architecture to better design systems with desired attributes. The research will be conducted using the design science methodology and validated through case studies.*

1. Introduction

Blockchain has become one of the top 5 priorities for many organizations [Deloitte Insights 2020] which are already investing considerable amounts of money on the technology. This interest has been driven by the technology's perceived potential to remove intermediaries and make processes between multiple organizations more trustworthy and cheaper. Unlike other systems, blockchain has a decentralized architecture designed to operate in adversarial environments. That is, environments where there are malicious actors [Rauchs et al. 2019]. Of the several types of blockchains that exist, consortium blockchains are some of the most popular for the enterprise because unlike others they provide granular access controls, identity management and configurable security settings. However, the failure rate of blockchain projects is considerably high [Rauchs et al. 2019]. The reasons for such high failure rates are complex and involve multidisciplinary factors including laws, regulations, governance, the market, change management, technology and cultural factors [Deloitte Insights 2020, Rauchs et al. 2019]. Of these barriers there are some that stand out because they appear frequently in the literature as significant barriers [Frizzo-Barker et al. 2019, Helliar et al. 2020] and they are highly related to design. These are barriers related to governance and quality attributes.

Blockchain governance relates to how stakeholders exercise bargaining power, who chooses and how choices are made [Allen and Berg 2020]. At a basic level this power can be divided in two. Endogenous power, which comes from the consensus algorithm used and gives certain users abilities such as adding transactions, upgrading nodes and collecting fees. And, exogenous power, which are other mechanisms not related to the consensus algorithms which include forum discussions, voting and change proposals. Governance can also be subdivided by the state of the project, design, operation, evolution/crisis; by level, infrastructure, application, individual, and institutional [Rauchs et al. 2019]; by dimensions like roles, incentives, membership, communication, decision making, formation and context [van Pelt et al. 2021]; by how explicit vs implicit agreements are; or by level of automation [Rikken et al. 2019]. These considerations show how entangled governance and architecture are. The architecture distributes power between stakeholders and may enable some governance processes to take place. At the same time, many governance conflicts have centered on modifying some aspect of the architecture, such as violating immutability, the property that stored data cannot be altered, to recover stolen or lost funds [Zachariadis et al. 2019], seeking to increase performance at the cost of more centralization [Rikken et al. 2019], or the inclusion of features that might impact security. All of these suggest that a reference model for governance would be helpful to navigate concerns, particularly if it includes architectural considerations.

As noted in some works [Tan et al. 2021, Rikken et al. 2019] there are few studies of blockchain governance. Of these, most focus on the blockchain platform and do not consider the governance of other architecturally important elements such as applications and data [Liu et al. 2021]. In addition, the question of how can a system be designed to enable governance is still open [Liu et al. 2021]. The purpose of this research is thus to seek an answer to this question while still achieving the required quality attributes using the reference architecture and reference governance model that will be developed. Unlike existing reference architectures and governance models they will be developed in unison and they will be technology agnostic.

2. Existing Solutions

2.1. Reference Government

In [Alketbi et al. 2020] they present a reference model for blockchain governance based in part on the architecture and processes of the Hyperledger Fabric blockchain. It describes roles, participants, the architecture and model lifecycle. The governance model has two layers, one for the blockchain platform and one for distributed applications dApps. At the platform layer, there is a committee for governance decisions with key stakeholders or regulators and an entity that issues policies and procedures, promotes standards and resolves disputes. To join the network all members must first accept certain terms and conditions. At the dApp layer each dApp is the responsibility of a single member, this member is responsible for the dApp's development, its technical and legal correctness and negotiating with other members the roles and responsibilities required by the dApp.

In [Dursun and Üstünda2021] they propose a framework based on Policy Based Management (PBM) and Decentralized Identity Management (DIM). The framework allows some governance decisions to be described as policies. Decisions like protocol parameters, fees, rewards, access control and voting threshold. These decisions can be proposed on the blockchain, users can vote on them and if approved they can be automatically enforced on nodes. One of the advantages over other approaches is the transparency of the process and that it can be easier to understand, which promotes participation.

2.2. Reference Architectures

In [Viswanathan et al. 2019] they present the Blockchain Solution Reference Architecture that works on solutions built with the Hyperledger Fabric Blockchain. It's a layered architecture that defines several connectors, including blockchain to blockchain connectors. The architecture also includes the Blockchain Member Onboarding Reference Architecture, with different ways a member can participate on the network: as a major member with their own blockchain nodes and infrastructure; as a minor member with blockchain nodes but that uses the same application provided by other members; and as a minor member without blockchain nodes and who connects through the infrastructure of other members.

[Bodkhe et al. 2020] presents a general reference architecture with three networks: a public network that includes mobile devices, web browsers and command line applications; a cloud network that includes blockchain nodes, gateways, security and monitoring services; and the enterprise network with enterprise systems and databases. To add security to the blockchain network they use a VPN to connect nodes, and an Enterprise User directory for authentication and authorization. For integrating different systems, they use event subscription and an enterprise service bus.

In [Xu et al. 2019] they present a layered architecture for blockchain applications. There are 3 main storage zones: the blockchain, with the ledger, smart contracts and tokens; key management, to store keys; and auxiliary databases to store big or private data. Applications communicate with these storage zones through an API. Though not part of the architecture, they also present a comprehensive list of design patterns for blockchains applications that are broadly useful.

In [Ramachandran and Krishnamachari 2019] they present an architecture for IoT with a payment channel, a marketplace, identity management and ratings. It includes a blockchain and DLT platform layer for storing important transactions, an IoT Blockchain interface, and an IoT layer. In [Gong et al. 2021] they present a reference architecture for crowdsourcing platforms with a business rule editor, business rule engine and smart contracts.

In [Yalcinkaya et al. 2020] they present a reference architecture for ISA95 compliant traditional and smart manufacturing systems for distributed smart manufacturing (SMMS) units. It considers scalability, performance, interoperability, data quality and security requirements. In addition it includes six tiers: a device tier with sensors, robots, actuators; the edge tier with programmable logic controllers, manufacturing execution systems and human machine interfaces; cloud tier, with cloud services like AI; Integration tier with Message Queuing Telemetry Transport (MQTT) protocol; the enterprise tier with the ERP, enterprise applications, certificate authorities, off-chain data stores including IPFS, and the enterprise directory service, LDAP; and the ledger tier with the blockchain and smart contracts.

3. Research Question and Objectives

Research question:

Is governance of blockchain systems improved by the use of reference architectures and reference governance models as measured by the ability to implement governance decisions that impact quality attributes of decentralization and performance?

Objectives:

- Propose a reference governance model for consortium blockchain systems.
- Propose a reference architecture for consortium blockchain systems.

- In real world projects, measure the impact of using the proposed artifacts on governance and the system's quality attributes.
- Validate that the proposed artifacts are considered useful by members of the system's government and architects.

4. Research Methodology

This research will follow the design science methodology whose purpose is to make research contributions by building new artifacts that are both useful to practitioners and based on rigorous research [Hevner et al. 2004]. The artifacts that will be built are a reference governance model and a reference architecture for blockchain solutions. Because blockchain is a nascent technology and production networks are scarce these artifacts will be validated only in two scenarios.

The first scenario will act as a baseline in which no reference architecture or reference governance model will be used. While the second scenario will use the proposed artifacts. In these scenarios governance decisions will be documented, their intent, problems encountered, the result of their implementation, and their effect on decentralization and performance. Decentralization will be measured using the Gini coefficient of the distribution of blocks by block producer [Gochhayat et al. 2020]; and the Nakamoto coefficient [Gochhayat et al. 2020], the minimum number of entities required to compromise the system. Performance will be measured using load tests. In addition, interviews and surveys will be carried out to quantify the perceived usefulness of the artifacts in the governance process.

5. Proposed Solution

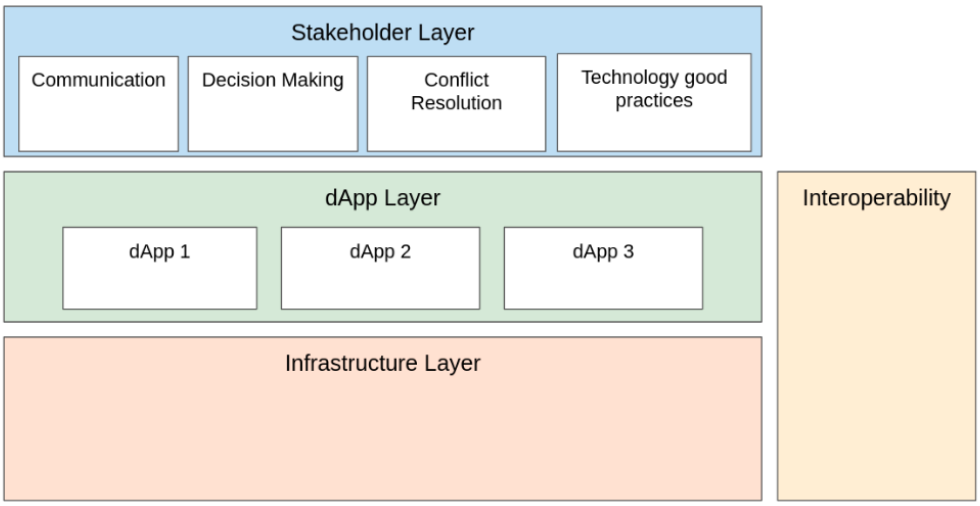

Figure 1. Reference government showing distribution of roles.

Figure 1 shows the main structure of the proposed reference governance model. The infrastructure layer will contain most of the endogenous governance determined by the consensus algorithm, it will also define infrastructure related roles such as admins, infrastructure providers and the like. In the dApp layer there would be one committee for each dApp as they can be developed independently. The interoperability layer contains committees for interoperating with other blockchain networks or external systems. Finally, the stakeholder layer would contain elements of the governance that are mostly outside the network, including communication channels, conflict resolution between members and committees to promote technology standards and good practices.

One of the proposed reference governance model's purposes is to make visible key governance decisions on a blockchain solution. Namely stakeholders, roles, decision process and distribution of power. Unlike other reference governance models, it will explicitly deal with these concerns as well as technological decisions.

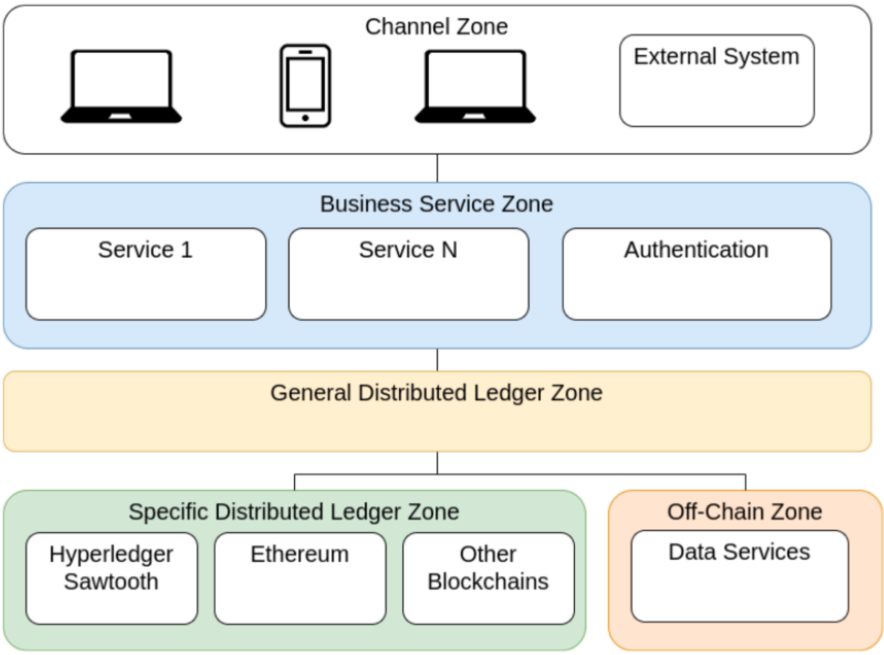

Figure 2. Reference architecture simplified functional view

The proposed reference architecture is divided into three views. A functional view defining services and zones. An integration view with connectors that services can use to communicate between them. And a technology view with deployment diagrams. The proposal has a layered architecture. At the bottom there are two zones, one contains the specific blockchains being used and the other the off-chain storage services. These bottom zones are accessed through a middle zone, the general distributed ledger zone, that hides the zones below. Above these there is the business service zone with domain specific services. Finally, there is the channel zone where clients reside such as web applications, mobile applications and external services. The integration view includes synchronous connectors between zones as well as asynchronous connectors using a message queue. It also details how smart contracts are called.

Unlike other reference architectures, the proposed architecture is designed to be useful in a broad range of domains and not tied to a specific blockchain technology. The reference architecture has been used in several projects at the university's blockchain lab [Blockchain Group Uniandes] with companies, researchers and students prototyping blockchain solutions for diverse domains such as healthcare, additive manufacturing, supply chains and finance. The reference architecture has been used to design these solutions, it's been used as a common language to talk about decisions and to organize development activities. It's also been used in conjunction with model driven engineering tools to deploy these solutions quickly, thus substantially reducing times.

6. Outstanding Issues and Future Work

The proposed governance model requires refinement and the definition of separate views to describe different aspects of the governance model. In particular, work has to be done to better describe roles, responsibilities, power distribution and relationships with the architecture. In addition, validation of the reference governance model has yet to be done. The reference architecture still requires some refining to include services that permit interoperability with other blockchains and it would also benefit from more validation, especially in live networks. Preparing for the validations to come, relations have been established with a bank and a hospital where these validations are planned. Several previous projects have already been made with them, giving more confidence that the validations will go smoothly. The estimated time for the research is 18 additional months, 6 months for the aforementioned refinements on the governance model and architecture, 6 to 8 months for validation and 6 months for writing.

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