

# zeppelin\_os: An open-source, decentralized platform of tools and services on top of the EVM to develop and manage smart contract applications securely

Manuel Araoz, Demian Brener, Francisco Giordano,  
Santiago Palladino, Teemu Paivinen, Alberto Gozzi,  
Franco Zeoli

<https://zeppelinos.org>

November 2017  
Version 0.1.2

WORKING DRAFT

## Abstract

The blockchain ecosystem has recently seen an explosion in new protocols. These protocols promise to provide everything from traditional transfer of value to decentralized file storage. This is an exciting time as the blockchain industry can redesign and rebuild much of the traditional internet infrastructure. We have an opportunity to make it faster, easier, and safer to deploy complex applications online, in a decentralized environment.

However, the industry has been plagued by security breaches and it is increasingly clear that while the promise of blockchain technology is phenomenal, we need to approach this technology with caution. At the same time, we want to make this technology as accessible as possible, fueling innovation and accelerating the move to a decentralized, open economy.

To address these problems and opportunities, we propose zeppelin\_os, a blockchain operating system for decentralized applications. zeppelin\_os allows developers to easily build secure applications that use and combine existing protocols, while creating incentives for the perpetual development of zeppelin\_os.

zeppelin\_os is made up of three core components: the kernel, the marketplace, and the SDK. We also propose the ZEP token to fuel the zeppelin\_os ecosystem. The token is used to consume and provide services in a protocol marketplace. It also serves as the primary governance mechanism for kernel upgrades, which will be updated as frequently as OpenZeppelin, making it a key piece of our proposal.

# Contents

<b>1</b>	<b>Introduction</b>	<b>3</b>
<b>2</b>	<b>Core systems overview</b>	<b>3</b>
2.1	Vouching . . . . .	3
2.2	Kernel . . . . .	3
2.3	Marketplace . . . . .	4
2.4	Software Development Kit . . . . .	4
<b>3</b>	<b>Security Model</b>	<b>5</b>
<b>4</b>	<b>Incentives and governance</b>	<b>6</b>
4.1	Development Bounties . . . . .	6
4.2	Mechanics . . . . .	7
4.3	Rewards . . . . .	8
<b>5</b>	<b>Kernel</b>	<b>8</b>
5.1	Standard Library . . . . .	8
5.2	Contract Upgradeability . . . . .	8
5.3	Scheduler . . . . .	9
5.4	Messaging Library . . . . .	9
5.5	Trusted Oracles . . . . .	9
<b>6</b>	<b>Marketplace</b>	<b>9</b>
6.1	Exchange . . . . .	10
6.2	Buffer . . . . .	10
6.3	ZEP-based Economy . . . . .	10
	Considerations and Pending Challenges . . . . .	10
6.4	Marketplace Curation . . . . .	11
	Considerations and Pending Challenges . . . . .	11
<b>7</b>	<b>Software Development Kit</b>	<b>11</b>
7.1	Analytics & Monitoring . . . . .	11
7.2	Continuous Integration for Contracts . . . . .	12
7.3	Automated Code Analysis . . . . .	12
7.4	Heroku [7] for Decentralized applications . . . . .	12
	<b>References</b>	<b>13</b>

# 1 Introduction

Anyone can use open networks like Ethereum to run software and formalize contractual relationships through code. These decentralized applications often facilitate some kind of financial exchange for services. However, the development process to build this kind of software is often complex, time-consuming, and prone to error.

Ensuring the security of these financial transactions and the funds held in smart contracts is imperative to the success of the blockchain ecosystem. There is currently little standardization and no easy way to develop highly secure applications. Responding effectively to security emergencies is beyond challenging with current tools.

On the other hand, decentralized networks are not structured to work together, often needing access to each other's native tokens to operate, making it hard to leverage external systems.

To address these issues we propose zeppelin\_os: an open-source, decentralized platform of tools and services on top of the EVM to securely build and manage smart contract applications, free of charge.

## 2 Core systems overview

### 2.1 Vouching

In the context of zeppelin\_os, governance refers to the action of upgrading or patching Kernel code. This is achieved with a vouching mechanism where network participants can lock up ZEP tokens to vouch for a new version of the Kernel. Upgrading to a new version is free, so this vouching mechanism is primarily a way for the network to indicate the latest, most-qualified version of the Kernel while rewarding contributors with a portion of the staked tokens.

### 2.2 Kernel

The Kernel is the foundation layer of zeppelin\_os. Existing as a smart contract library deployed on the blockchain, it provides a set of basic functionality and services for smart contracts that use the operating system. It is supported by a decentralized upgrading mechanism powered by the vouching mechanism governed by ZEP token holders. The upgradeability mechanism of the zeppelin\_os Kernel will be based on the proxy library pattern [1] developed in joint collaboration between Zeppelin and Aragon. Developers will not have to spend ZEP tokens to use the Kernel functionality, it will be available free of charge.

The goal for the zeppelin\_os Kernel is to provide a set of functions for the smart contracts that run on top of it, requesting services from the OS rather than re-implementing them from scratch. This library of reusable contracts and functions will be heavily inspired by OpenZeppelin [2], and held to the same security standards.

Examples of things developers will be able to do with these libraries include:

- Create and customize an ERC20 Token.
- Create a capped, refundable, and/or whitelisted crowdsale contract.
- Create a trustless bug bounty.
- Create pausable, ownable, and balance-limited contracts.
- Set up a token vesting or token locking contract.
- Create trustless token sale or token purchase contracts.

- Create atomic token swap contracts.
- Create a token future contract.

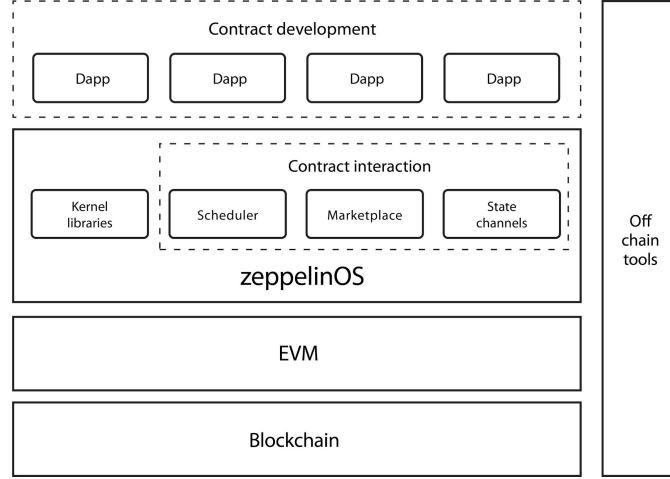


Figure 1: zeppelin\_os in the broader blockchain stack

### 2.3 Marketplace

Much as traditional mobile app marketplaces act as central hubs for mobile users to browse and purchase available services, one of the central features of zeppelin\_os is a marketplace for smart contracts, where services can be purchased and integrated into other applications.

Today the majority of interactions with smart contracts are triggered by people. We believe that for the industry to grow, smart contracts need to start talking to each other. The interaction with such services will be facilitated through different standard execution models powered by the OS, and payments executed with the platform's ZEP tokens, thus enabling an effective in-OS economy between service providers and their client applications. This model would allow, for example, any smart contract to store data both in Filecoin and Storj at the same time, without the need to use either's native token, paying both with ZEP.

Though smart contracts are currently quite limited in their interactions with the off-chain world, the advent of services that provide the bridge to execute off-chain effects can offer true decentralized applications the power to run entirely on zeppelin\_os. Examples of such services are file storage, mail sending, push notifications, off-chain intensive computation, machine-learning services, etc.

### 2.4 Software Development Kit

As an addition to the on-chain services offered by zeppelin\_os, the platform will provide a set of off-chain tools aimed at simplifying the development, debugging, testing, deployment, and monitoring of decentralized applications. We intend to raise the quality and security bar of smart contracts by accelerating the professionalization of the industry. We will lead the creation of the well-known tools that already exist for traditional centralized software such as continuous integration systems, static code analysis, and health monitoring.

### 3 Security Model

Being a layer that smart contract applications interact with on-chain, we open up the possibility of seamlessly delivering upgrades to zeppelin\_os users. This enables rolling out security mitigations and patches as soon as a vulnerability is found, instantly protecting all users of zeppelin\_os.

Users of the Kernel libraries will have the option to enable automatic upgrades. For instance, users may specify that they use version ^1.2, meaning the most-vouched version among 1.2 and above, but below 2.0.

These upgrades are optional for Kernel users, as they may choose to switch manually to 1.3 after reviewing the new version themselves, regardless of the vouching of that version.

The upgrading system will be incentivized for ZEP holders to review patches and vouch for their correctness. A reviewing mechanism is necessary to avoid the possibility of a centralized party upgrading (i.e. changing) all contracts using the optional automatic upgrade system in the OS without any control from the community, while providing a mechanism of fast response in the event of a critical security issue if it is acknowledged by the majority.

Experience has shown that bugs will always be found in a codebase. As smart contracts become more complex, the probability of bugs becomes larger [3], and with it comes a greater possibility of attack.

To prepare, zeppelin\_os will provide users a toolbox for attack response. Triggering an emergency pause, reverting to a previous uncompromised state, or forking a contract are some of the possibilities.

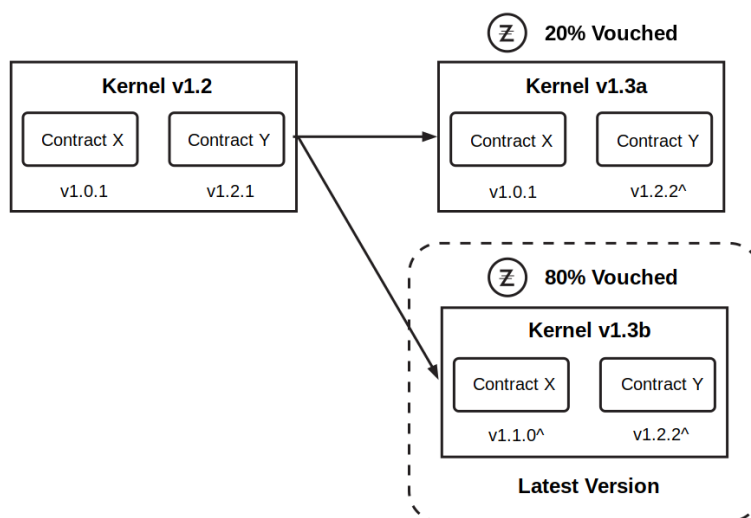


Figure 2: Illustration of automatic upgrade mechanism. Previously, version 1.2 was the “Latest version”, with the highest amount of ZEP vouched. As versions 1.3a and 1.3b are introduced, users move their vouched tokens to them, having 80% vouching version 1.3b and 20% vouch version 1.3a. Version 1.3b becomes then the “Latest version”, as it is the one with the highest vouching.

## 4 Incentives and governance

Crypto-economic protocols create financial incentives to drive a network of rational actors to coordinate their behavior towards a common goal. Often, the alignment of incentives is achieved by introducing a native token. In the case of `zeppelin_os`, the native token is ZEP, and its goal is to align network incentives to establish, grow, and maintain an ecosystem for easy development of secure decentralized applications.

Conceptually, there are two distinct actions a Kernel user can perform with regards to the upgrade mechanism:

- 1) To change their contract's used kernel version from  $V$  to  $V_0$ .
- 2) To signal their approval or willingness to use  $V_0$  over  $V$ .

Given 1) is very hard (or impossible) to tie into token mechanics without forcing developers to hold ZEP tokens to use the Kernel, we will use 2) as a proxy of 1). To do so, we define the following “vouching” mechanic: ZEP token holders can signal their approval for a specific Kernel version  $V$  by locking part of their tokens and specifying which version they vouch for. It is worth noting that the Kernel is upgraded as a monolithic system and individual components are not upgraded in a modular fashion, although this may be subject to change in the future.

Locking tokens simply means the user cannot transfer or vouch other versions with those same tokens. This does not mean tokens are locked for a specific amount of time.

For example, given a Kernel with only versions `v1.0.0` and `v1.0.1`, and 3 token holders with 100 ZEP tokens each, the following situation can occur:

- Holder A vouches for `v1.0.0` with 50 ZEP tokens and `v1.0.1` with 50 ZEP tokens.
- Holder B does not vouch for any version.
- Holder C vouches for `v1.0.1` with 80 ZEP tokens.

In this example, if holders ABC make up a majority of vouching power in the network, the new version `1.0.1` would be considered the latest version accepted by the network, in the context of automatic upgrades. It is important to note that users can manually change the Kernel version their contracts use, making upgrades of the Kernel opt-in. `zeppelin_os` will also provide tools for contracts to automatically upgrade based on a policy set by the developer.

### 4.1 Development Bounties

In order to guide the development of the `zeppelin_os` Kernel and incentivize contributors to begin working on an issue, the OS will provide a platform for development bounties. In it, users can post their desired features and place an upfront bounty for them. The same can be done for bugs that need to be fixed. The aim is for bounties to act as a pushing force for the development of the Kernel and a motivation for developers, in addition to the usual reward that comes with the community vouching an already released version. We aim to implement a delegated review process for development bounty proposals, but initially, this process will be managed in a centralized manner.

As an end-to-end example of this process, think of a developer that is building a project on top of the `zeppelin_os` Kernel who needs a type of smart contract that has not been built yet. Through the platform, they can post a bounty of a given amount of ZEP tokens for its development. Other developers might share the need for the feature, and can add their own

bounty on top. A developer can see this bounty and announce that they're working on the feature. Once it is finished, a network delegate will review the submission. If the feature implementation is acceptable, the bounty will be released to the developer and the feature will be submitted for normal Kernel upgrade vouching. A small cut will be rewarded to the reviewer.

## Considerations and Pending Challenges

- Specifics of the voting process for choosing network delegates are still undecided. Most likely, this will be a staking system, where each token holder has a right to lock up tokens and thus give their vote for a specific delegate/reviewer.
- The incentives of the reviewer are easily misaligned with the network as the reviewer should be rewarded for every review, regardless of if the proposal is accepted or not. This creates an incentive for the reviewers to create large amounts of proposals that will be declined as the reviewer would still receive the reward, depleting the developer bounty pool.

## 4.2 Mechanics

The following mechanics govern the Kernel upgrade mechanism and incentives.

Any developer can propose a new Kernel version upgrade based on a previously existing version. Creating this new version proposal has a cost in ZEP tokens as a way to prevent denial-of-service attacks related to proposal submissions. Compensation to the developer of a Kernel version is a function of the amount of tokens vouching for that version. When a developer proposes a new version of the Kernel building upon a previous version, users can stop vouching for the previous version in favor of the new one. Multiple versions of the Kernel can exist in parallel, creating a sort of tree structure for versions.

Each of these vouching operations will compensate the new version's developer according to a function of tokens vouched.

`change_vouching( $v_1, v_2, n$ )` will trigger a `payout( $v_2, f(n)$ )`, where  $f$  is monotonically increasing over  $n$ , the amount of tokens. Payouts may also include a time-lock or other additional safety measures to ensure incentives are aligned.

Whenever a user vouches for a new version with  $t$  tokens, a fraction of those tokens is sent to the developer as a reward. This causes `change_vouching( $v_1, v_2, n$ )` to take  $n$  tokens from  $v_1$ , give  $f(n)$  to the developer, and lock  $n - f(n)$  for  $v_2$ , where  $f(n) = n * (1/k)$  where  $k$  is a natural number. This definition of  $f$  does not depend on total vouching tokens. This means the payout is a fraction of the moved tokens, coming out of the voucher's balance. Tokens given as reward to the developer have a time lock and are only redeemable after a certain token amount threshold is met. During this lock-in period, vouchers may decide to change their target version.

An example timeline of vouching changes would look like this:

Version	Vouch % over time		
	$t_0$	$t_1$	$t_2$
1.6.3	20	20	20
2.0.1	80	70	0
2.0.2	0	10	80

- At time  $t_0$ , version 2.0.2 is released fixing a vulnerability in version 2.0.1.

- At time  $t_1$ , a user with 10% of the total vouching power moves their tokens from 2.0.1 to 2.0.2 (`change_vouching(2.0.1, 2.0.2, 10)`) which results in a compensation to the developers of 2.0.2 (`payout(2.0.2, f(10))`).
- At time  $t_2$ , the other user of 2.0.1 moves their tokens to 2.0.2, and this results in the compensation to the developers (`payout(2.0.2, f(70))`).

### 4.3 Rewards

We acknowledge that it is impossible to measure the value of a contribution other than subjectively by the users of the OS. A change as small as a single character can save millions of dollars, while a very large changeset adding multiple contracts could be useless. There is no objective way of measuring this from the code itself, only by how many users adopt the changes.

As such, and as a result of the mechanics proposed above, each proposed upgrade is rewarded equally, given the same amount of tokens vouching for it. This will cause the developers proposing upgrades to adapt each of their contributions to the expected reward, and the market will determine whether the payout is fair by either vouching or not for the contribution.

For instance, if the proposed upgrade is too small in terms of value-added, the token holders will refrain from vouching for it, as the payout to the developer would be unfair. This will prevent developers from upgrade spamming, and incentivizes them to band-up to submit bigger contributions encompassing several small changes, with a payout address set to a fund-splitting contract.

Also, note that any damage done by malicious actors in the system is contained. Developers vouching for their own versions would end up losing tokens due to the associated costs of proposing new versions and the tokens paid as part of the change vouching operation. Malicious users vouching for buggy versions, as an attempt to introduce vulnerabilities in the Kernel, will not be followed by other users who will vouch for a different version in the development tree.

All in all, since the motivation for vouching users is to maintain a healthy development cycle of the OS and ensure the security of the underlying Kernel libraries, we expect each vouching operation to be done towards this end, regardless of the small number of tokens deducted from the user's balance upon vouching.

## 5 Kernel

### 5.1 Standard Library

`zeppelin_os` will provide an on-chain standard library of reusable contracts and functions. The goal for the `zeppelin_os` Kernel is to provide a set of functions to act as system calls for the smart contracts that run on top of it, thus requesting services from the OS rather than reimplementing them. Smart contracts building on the OS will call into this library.

### 5.2 Contract Upgradeability

In addition to having upgradeability of the `zeppelin_os` Kernel itself, the underlying implementation will be made available to users of the OS to enable upgradeability of their own smart contracts. This allows rolling out contract-specific security patches, as well as the progressive deployment of features.



### 5.3 Scheduler

Contract code execution is synchronous and linear, having the possibility to call other contracts but restrained to a single and contiguous execution thread. To support more complex operations, applications require off-chain infrastructure, defeating the very purpose of fully decentralized applications.

As a means to support richer execution models, the OS will provide, through the usage of a standardized set of signaling events, a bounty-based smart contract async execution scheduler. In it, different parties can offer to execute async operations and securely call back into the contract to resume operations. This also opens the way to standard mechanisms for requesting data from trusted and authoritative sources by adding a validation on the callback originator to ensure the response is provided by a secure oracle.

In order to accomplish this, the OS will define the required standards and provide code for simplifying their adoption, for both the scheduler clients and the providers who wish to offer the execution of async operations, effectively setting up nodes that power the distributed scheduling network.

### 5.4 Messaging Library

The OS will provide various mechanisms for inter-contract communication and networking, such as publish-subscribe messaging, message queues, and shared storage.

Though decentralized and secure, blockchain transactions are limited in frequency and cost by block mining times and fees. This caused the emergence of alternate off-chain transaction systems that could be consolidated back to the blockchain after multiple operations, with State Channels [4] being one of the latest proposals for intercommunication between two or more peers, verified and consolidated by a smart contract acting as a judge.

The OS will offer State Channels support through common protocol specs and reference implementations, plus all the on-chain infrastructure necessary for discovery, arbitration, and consolidation of state channels. Besides providing a cheaper communication mechanism, this also leaves the door open for future direct integration with off-chain state payment networks in the platform.

### 5.5 Trusted Oracles

The OS will provide a standard interface to access, from a smart contract, information on the blockchain currently unavailable from on-chain apps, such as current ETH price, gas price, transaction pool size, average mining block times, etc.

## 6 Marketplace

The `zeppelin_os` marketplace creates a plug and play experience for the developer when integrating various protocol services into a decentralized application. Without it, if a developer wants to utilize more than one protocol's service they would need to provide exchange functionality.

Applications built on `zeppelin_os` may include one or more external protocols via the marketplace. As the native token ZEP is used to operate applications built on the platform, there needs to be a mechanism by which the proxy for an external protocol converts ZEP into whichever token is required to use the external protocol. The marketplace thus needs to have some kind of exchange mechanism. We propose three different methods that we're experimenting with to achieve this, all of which are explored below.

## 6.1 Exchange

This method is relatively simple in that it does not require the developer of a marketplace integration to apply funds to ensuring the functioning of their application. The exchange method would utilize existing exchange infrastructure to manage conversions between ZEP and other tokens.

Each protocol providing services through the marketplace would connect to a zeppelin\_os exchange integration allowing for the conversion of ZEP into other protocol tokens. In the future, competitive mechanics can be added to the exchange process by creating a mechanism for exchanges to compete for any given transaction. If opened up to the market, traders could provide this service and benefit from the spread attainable by performing market making operations.

## 6.2 Buffer

The second option for providing marketplace exchange, this time without using an actual exchange, requires the developer delivering a service through the marketplace to load tokens of the external protocol to a smart contract, creating a buffer. These tokens will be used to pay for protocol services as users pay for services in the application using ZEP. The smart contract will have an oracle which dictates the exchange rate for converting ZEP to the external token. The developer then receives ZEP and spends the external tokens. The developer of the integration thus functions like a market maker.

This method may require the developer of an integration to hold significant amounts of the protocol token, which is not ideal for keeping barriers to entry low. However, this method would enable real time exchange and also allow the developer of the integration to charge a spread on the exchange to generate revenue. Eventually such a spread would decrease to the lowest point where it makes sense to provide such a service. On the user side, this competitive tendency to lower cost, will lead to the best achievable prices over time.

## 6.3 ZEP-based Economy

The third option would be for the developers who want to provide services through the marketplace to allow their smart contracts to receive payments denominated in ZEP. Prices would still be set in the service's native token, but the payment would be delivered as the equivalent value in ZEP, making this another truly real time option, without the need to stock a significant amount of tokens in a buffer.

### Considerations and Pending Challenges

- The exchange method suffers the same latency and scalability problems of any on-chain exchange.
- The ZEP-based solution requires the developers providing services through the marketplace to modify their smart code to accept ZEP, so the barrier to entry is high for existing projects.
- The buffer method requires the developer of the marketplace integration to hold some amount of the respective protocol's tokens, possibly increasing barriers to entry.

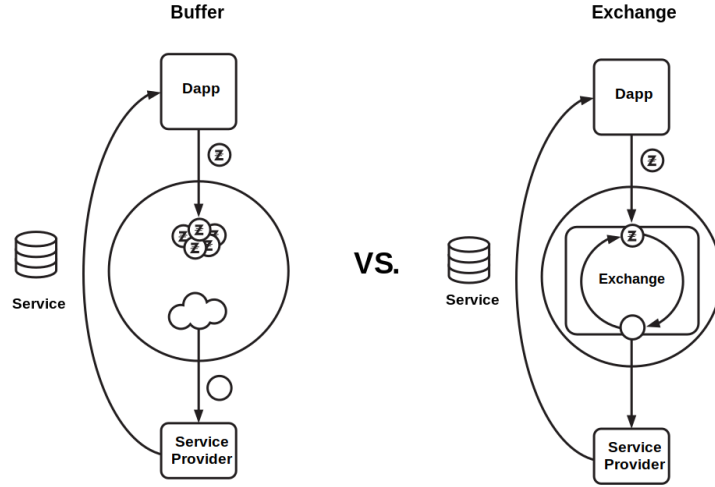


Figure 3: The alternative mechanisms for payments to external protocols.

## 6.4 Marketplace Curation

All submissions to the marketplace will be carefully reviewed to ensure the highest quality and security. Initially this review process will be conducted by the Zeppelin Solutions [5] team, along with a public review with a bug bounty. A centralized marketplace review has benefits in terms of maintaining quality of contents and efficiency of the review process, but history tells us it also allows the controlling party to exert non-competitive influence [6]. We understand this problem and are fully committed to transitioning into a decentralized review model once the most suitable model is found.

### Considerations and Pending Challenges

Decentralizing marketplace review needs to be efficient, scalable and maintain a high quality of accepted submissions. This can potentially be achieved using a delegation model, where the delegates are incentivized to review submissions and act along guidelines voted on by the community.

## 7 Software Development Kit

### 7.1 Analytics & Monitoring

Contract transactions and events provide invaluable insight on the usage of a deployed application, analogous to end-user actions and events performed on a web page. As such, an off-chain analytics dashboard can aggregate on-chain generated contracts events for research on their usage. Also, by tracking from which node each transaction is originated, it is possible to obtain information on how end-users actually connect to the network to interact with the contracts.

The other side of tracking contract-generated events and transactions is monitoring the health of each contract, by keeping record of the transaction error rate and failure-associated events, thus triggering alerts through both general and per-contract defined rules.

## 7.2 Continuous Integration for Contracts

Automated testing through continuous integration providers has become a standard in the software industry, as a means to increase the confidence on the project health by checking its tests in a separate environment at every stage of development. However, this requires a testing environment with conditions as similar as possible as the production one. As such, zeppelin\_os will provide the required services for effectively testing smart contracts and their interactions with other services in a continuous integration fashion, including replayability of previous transactions using the updated codebase to compare generated outcomes.

## 7.3 Automated Code Analysis

Static analysis is a long-running research field in academia, with occasional ports to industry-level tools, despite its enormous benefits towards the assurance of correctness and its ability to identify potential bugs. Given the high security requirements of decentralized applications, applying these strategies to smart contracts code is a must, and an area to be continuously researched and improved.

Having access to the code powering the smart contracts applications, zeppelin\_os shall offer automated code analysis services with increasingly powerful rules and techniques, preventing inadvertently deploying potentially unsecure code, and alerting owners of existing running contracts of newly found vulnerabilities.

## 7.4 Heroku [7] for Decentralized applications

In order to simplify the deployment process for unsophisticated users, the platform will provide the necessary open-source development tools to facilitate the specification of high-level interaction rules between smart contracts that are then executed on-chain. Submitting the rules to the platform will trigger a testing and analysis process, described in the previous sections, which will be followed by an actual deployment to the blockchain, or an upgrade powered by the aforementioned mechanisms, thus minimizing the devops complexity of dapps for programmers.

The Platform as a Service approach also includes acting as a one-stop platform for integration with other contracts, providing a user interface for the discovery and management of marketplace-offered services, so dapp owners can plug-and-play different infrastructure building blocks. Like IFTTT [8] recipes for smart contracts.

## References

- [1] Manuel Araoz, Jorge Izquierdo. Proxy Libraries in Solidity. <https://blog.zeppelin.solutions/proxy-libraries-in-solidity-79fbe4b970fd>
- [2] OpenZeppelin. <https://openzeppelin.org>
- [3] A plea for simplicity. [https://www.schneier.com/essays/archives/1999/11/a\\_plea\\_for\\_simplicit.html](https://www.schneier.com/essays/archives/1999/11/a_plea_for_simplicit.html)
- [4] State channels. <http://www.jeffcoleman.ca/state-channels>
- [5] Zeppelin Solutions. <https://zeppelin.solutions>
- [6] Time for Apple to face the music? <http://newsvote.bbc.co.uk/1/hi/technology/7002612.stm>
- [7] Heroku. <https://heroku.com>
- [8] IFTTT. <https://ifttt.com>
- [9] Ethereum. <https://ethereum.org>