

Nomic Audit - Response

The entire audit is inlined in gray.

Summary

We conducted a security audit of the Paxos Stablecoin system, and no vulnerabilities were found.

Audit results

Critical severity

No critical severity issues were found.

High severity

No high severity issues were found.

Medium severity

No medium severity issues found.

Low severity

No low severity issues found.

Comments & recommendations

- Consider using `pragma experimental "v0.5.0"`, as it's been recommended by Solidity since version 0.4.21. This pragma opt-ins to upcoming breaking changes.

We have followed Nomic's recommendation to add the experimental pragma "v0.5.0" in addition to the version pragma that we already have in our implementation contract.

Adding the additional pragma means that the compiled contract bytecode and memory model will be more likely to work consistently with bytecode compiled using future versions of Solidity. Upgrading the Solidity version may be necessary in the event that a future version includes a critical security fix.

- `StablecoinImplementation#initialize` returns an unused boolean. The intention for doing so is not clear. We recommend documenting it or removing the return value.

We have removed the unused boolean as recommended. The boolean was meant to indicate whether initialization succeeded, but require was used instead.

- `StablecoinImplementation#setSupplyController` and `transferOwnership` emit events before modifying the state. We recommend using the [Checks-Effects-Interactions Pattern](#) in every function that modifies the state.

The Check-Effects-Interactions is a standard pattern. However, emitting events are not interactions with other contracts but simply something added to the event log. Since emitting the event after setting the new owner would require keeping a copy of the old owner (and similarly for the supplyController) we have decided to leave these functions the same.

- `StablecoinImplementation#setSupplyController` doesn't check that `_newSupplyController` is not `0x0`, which can lead to accidental misconfigurations in the system.

We have added this check as recommended. Checking that the address is not the zero address is a standard safety check for the assignment of addresses.

Notes on ERC-20 compatibility

ERC-20's functions `allowance`, `approve` and `transferFrom` are not present.

Removing this functions will decrease the interoperability of the token, as most contracts dealing with ERC-20 use them. For instance, the 0x protocol uses them to execute trades without getting custody of the users' funds.

Paxos provided us a system design document that links to [an explanation](#) about why they are not needed. We consider the explanation to be incomplete. Before EIP-150 this was the only safe way of getting a contract to transfer an user's funds, and after it new alternatives appeared. But some alternative is needed, just removing them prohibits many use-cases. One example

alternative is ERC-223. But none of them has been widely adopted, so ERC-20 is the safest choice.

The design document also mentions the withdraw pattern in this context. We want to clarify that this is not relevant to ERC-20 tokens. When transferring ETH or an ERC-223 token the receiving account can execute arbitrary code, leading to many possible attacks (see The DAO hack). The withdrawal pattern aims to isolate transfers because of this. ERC-20 tokens don't call the receiving account, so it's not affected by this class of attacks.

We have added standard implementations for these three methods as recommended. The 0x protocol is a good example among many use cases for the approve/allowance/transferFrom pattern in ERC-20.

Notes on the Proxy Pattern implementation

The Paxos Stablecoin uses an implementation of the Proxy Pattern with Unstructured Storage. This implementation has some unique properties that can lead to confusion, and one of them may increase the attack surface of the system.

Inlined interface in the proxy

The token implementation's interface has been copied into the proxy contract. We understand that the purpose of this is to have a single ABI definition json to simplify the interaction with the system.

The problem with it is that the proxy's interface can't be changed in the future. If a function is added or removed from the implementation, the interfaces won't match anymore. This situation would be more confusing than not inlining the implementation and having to deal with two ABI definitions.

We consider that it's possible that the industry adopts new extensions to the ERC-20 standard in the future, leading to changes in the token interface and making this issue relevant.

The interface declaration on the proxy has been removed. Instead the ABI for the token will be published in the public github repository.

Mixed responsibilities of the proxy and its implementation

`StablecoinProxy#upgradeTo` doesn't implement the actual upgradeability, but delegates the responsibility of doing so to the implementation. This makes the system harder to understand and test in isolation. Furthermore, if a new version of the implementation breaks the `upgradeTo` functionality it won't be fixable.

The proxy also delegates the authentication of `upgradeTo` to the implementation. We consider that it should be part of the proxy.

Refactoring this can lead to a simpler system, as there wouldn't be a need to access the proxy's `implementation` field from the actual implementation.

Based on all of the feedback on the proxy, and the desire to follow a standard, we decided to use `AdminUpgradeabilityProxy` from `zeppelinox/zos-lib` for our proxy, which stands on its own.

The `owner` role has too many responsibilities

`StablecoinImplementation` has an `owner` role that has some administrative privileges on the system (ie: pausing/unpausing and reassigning the different roles) and is responsible for managing upgrades.

We believe that these responsibilities should be split in two different roles, one to administer the system, and another one to upgrade the system. The reason for doing so is that the former can be used during normal operations, and the latter is the most critical part of the system and rarely used. Assigning these privileges to the same role means exposing the upgrade mechanism every time an admin task is done.

Splitting these into two separate roles would lead to a cleaner implementation, as there wouldn't be a need to access the proxy's role from the implementation.

See below. `AdminUpgradeabilityProxy` has an additional admin role for upgradeability and the owner is purely responsible for pause.

Upgrades are not atomic

The proxy offers no way to upgrade its implementation and migrate its storage in a single transaction. This functionality is needed to enable future upgrades that can't work before some migration logic is run.

Not changing the implementation and running the migration logic in a single transaction can lead to users interacting with uninitialized parts of the contract.

AdminUpgradeabilityProxy has `upgradeAndCall` to enable upgrades to atomically initialize any new state at the same time that the contract is upgraded.

Recommendations

Consider using one of the available implementations of upgradability instead of implementing your own. We highly recommend using [ZeppelinOS Lib](#).

We have taken this recommendation. AdminUpgradeabilityProxy from ZeppelinOS stands on its own and is failsafe against bad upgrades. We can no longer update the methods on the proxy, but they are only callable by the admin.

Paxos Stablecoin Audit Report v2

Summary

We conducted a security audit of the updated Paxos Stablecoin system, and no vulnerabilities were found.

Audit results

Critical severity

No critical severity issues were found.

High severity

No high severity issues were found.

Medium severity

No medium severity issues found.

Low severity

No low severity issues found.

Comments & recommendations

- Consider making the constants in `PAXImplementation` uppercase as recommended by Solidity's style-guide.

We have kept the three constants (name, symbol, and decimals) lower case following the ERC20 specification.

- `PAXImplementation#initialize` sets `initialized = true` before the contract is completely initialized. There is no problem in the current setup, but it's a best practice to do it at the end.

We have followed Nomic's recommendation to set `initialized = true` last in `initialize`.

- `PAXImplementation#setLawEnforcementRole` doesn't check that `_newLawEnforcementRole` is not `0x0`, which can lead to accidental misconfigurations in the system.

We have decided to initialize `lawEnforcementRole` to `0x0` and have left the ability to set it to `0x0` in case we no longer need to use the role or do not have a party identified to use it. The `lawEnforcementRole` can also be set by the `owner`, allowing Paxos to set the role whenever necessary.

Notes on law enforcement policies

Being able to freeze the systems is a desired capability to keep the token KYC friendly.

However, the current implementation doesn't protect against front running. A highly sophisticated attacker might observe non-settled freeze attempts in the blockchain and race it with a transaction to transfer the coins from the being-frozen address to a second address in a cat-and-mouse game.

The contract has the capability to pause the transactions so it can be used for this purpose. We recommend that every law enforcement action is done under paused contracts and that `LawEnforcementRole` can pause the contract in addition to the `owner`.

Pausing the contract is a highly visible and highly disruptive action for the utility of the token since it would not allow anyone to transfer. To ensure that the freezing process affects as few bystanding parties as possible, Paxos has decided to leave the separation between its ability to pause the contract for severe security issues and the ability for law enforcement to instruct the freezing of criminal accounts. To mitigate front running Paxos plans to submit freeze transactions with high gas prices to ensure that those transactions are quickly mined into the blockchain.