SMART CONTRACT AUDIT REPORT

for

Chainhop

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1 Introduction

Given the opportunity to review the design document and related smart contract source code of the Chainhop, we outline in the report our systematic approach to evaluate potential security issues in the smart contract implementation, expose possible semantic inconsistencies between smart contract code and design document, and provide additional suggestions or recommendations for improvement. Our results show that the given version of smart contracts can be further improved due to the presence of several issues related to either security or performance. This document outlines our audit results.

1.1 About Chainhop

Chainhop implements a cross-chain decentralized exchange (DEX), which provides the cross-chain swap service with a one-transaction user experience. It provides the user with unprecedented performance and flexibility.

Table 1.1: Basic Information of Chainhop

Item	Description
Target	Chainhop
Type	Smart Contract
Language	Solidity
Audit Method	Whitebox
Latest Audit Report	April 20, 2022

In the following, we show the Git repository of reviewed files and the commit hash value used in this audit.

- https://github.com/chainhop-dex/chainhop-contracts.git (aec67c9)

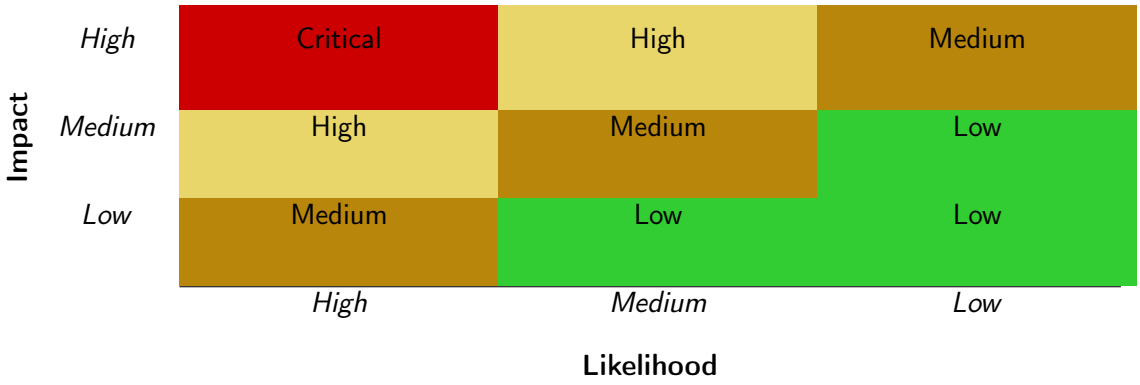
And this is the commit ID after all fixes for the issues found in the audit have been checked in:

- https://github.com/chainhop-dex/chainhop-contracts.git (5e9d4ee)

1.2 About PeckShield

PeckShield Inc. [10] is a leading blockchain security company with the goal of elevating the security, privacy, and usability of current blockchain ecosystems by offering top-notch, industry-leading services and products (including the service of smart contract auditing). We are reachable at Telegram (https://t.me/peckshield), Twitter (http://twitter.com/peckshield), or Email (contact@peckshield.com).

Table 1.2: Vulnerability Severity Classification



1.3 Methodology

To standardize the evaluation, we define the following terminology based on OWASP Risk Rating Methodology [9]:

- Likelihood represents how likely a particular vulnerability is to be uncovered and exploited in the wild;
- Impact measures the technical loss and business damage of a successful attack;
- Severity demonstrates the overall criticality of the risk.

Likelihood and impact are categorized into three ratings: *H*, *M* and *L*, i.e., *high*, *medium* and *low* respectively. Severity is determined by likelihood and impact and can be classified into four categories accordingly, i.e., *Critical*, *High*, *Medium*, *Low* shown in Table 1.2.

To evaluate the risk, we go through a list of check items and each would be labeled with a severity category. For one check item, if our tool or analysis does not identify any issue, the contract is considered safe regarding the check item. For any discovered issue, we might further deploy contracts on our private testnet and run tests to confirm the findings. If necessary, we would

Table 1.3: The Full List of Check Items

Category	Check Item
Basic Coding Bugs	Constructor Mismatch
	Ownership Takeover
	Redundant Fallback Function
	Overflows & Underflows
	Reentrancy
	Money-Giving Bug
	Blackhole
	Unauthorized Self-Destruct
	Revert DoS
	Unchecked External Call
	Gasless Send
	Send Instead Of Transfer
	Costly Loop
	(Unsafe) Use Of Untrusted Libraries
	(Unsafe) Use Of Predictable Variables
	Transaction Ordering Dependence
	Deprecated Uses
Semantic Consistency Checks	Semantic Consistency Checks
Advanced DeFi Scrutiny	Business Logics Review
	Functionality Checks
	Authentication Management
	Access Control & Authorization
	Oracle Security
	Digital Asset Escrow
	Kill-Switch Mechanism
	Operation Trails & Event Generation
	ERC20 Idiosyncrasies Handling
	Frontend-Contract Integration
	Deployment Consistency
	Holistic Risk Management
Additional Recommendations	Avoiding Use of Variadic Byte Array
	Using Fixed Compiler Version
	Making Visibility Level Explicit
	Making Type Inference Explicit
	Adhering To Function Declaration Strictly
	Following Other Best Practices

additionally build a PoC to demonstrate the possibility of exploitation. The concrete list of check items is shown in Table 1.3.

In particular, we perform the audit according to the following procedure:

- Basic Coding Bugs: We first statically analyze given smart contracts with our proprietary static code analyzer for known coding bugs, and then manually verify (reject or confirm) all the issues found by our tool.
- Semantic Consistency Checks: We then manually check the logic of implemented smart contracts and compare with the description in the white paper.
- Advanced DeFi Scrutiny: We further review business logics, examine system operations, and place DeFi-related aspects under scrutiny to uncover possible pitfalls and/or bugs.
- Additional Recommendations: We also provide additional suggestions regarding the coding and development of smart contracts from the perspective of proven programming practices.

To better describe each issue we identified, we categorize the findings with Common Weakness Enumeration (CWE-699) [8], which is a community-developed list of software weakness types to better delineate and organize weaknesses around concepts frequently encountered in software development. Though some categories used in CWE-699 may not be relevant in smart contracts, we use the CWE categories in Table 1.4 to classify our findings.

1.4 Disclaimer

Note that this security audit is not designed to replace functional tests required before any software release, and does not give any warranties on finding all possible security issues of the given smart contract(s) or blockchain software, i.e., the evaluation result does not guarantee the nonexistence of any further findings of security issues. As one audit-based assessment cannot be considered comprehensive, we always recommend proceeding with several independent audits and a public bug bounty program to ensure the security of smart contract(s). Last but not least, this security audit should not be used as investment advice.

Table 1.4: Common Weakness Enumeration (CWE) Classifications Used in This Audit

Category	Summary
Configuration	Weaknesses in this category are typically introduced during the configuration of the software.
Data Processing Issues	Weaknesses in this category are typically found in functionality that processes data.
Numeric Errors	Weaknesses in this category are related to improper calculation or conversion of numbers.
Security Features	Weaknesses in this category are concerned with topics like authentication, access control, confidentiality, cryptography, and privilege management. (Software security is not security software.)
Time and State	Weaknesses in this category are related to the improper management of time and state in an environment that supports simultaneous or near-simultaneous computation by multiple systems, processes, or threads.
Error Conditions, Return Values, Status Codes	Weaknesses in this category include weaknesses that occur if a function does not generate the correct return/status code, or if the application does not handle all possible return/status codes that could be generated by a function.
Resource Management	Weaknesses in this category are related to improper management of system resources.
Behavioral Issues	Weaknesses in this category are related to unexpected behaviors from code that an application uses.
Business Logics	Weaknesses in this category identify some of the underlying problems that commonly allow attackers to manipulate the business logic of an application. Errors in business logic can be devastating to an entire application.
Initialization and Cleanup	Weaknesses in this category occur in behaviors that are used for initialization and breakdown.
Arguments and Parameters	Weaknesses in this category are related to improper use of arguments or parameters within function calls.
Expression Issues	Weaknesses in this category are related to incorrectly written expressions within code.
Coding Practices	Weaknesses in this category are related to coding practices that are deemed unsafe and increase the chances that an exploitable vulnerability will be present in the application. They may not directly introduce a vulnerability, but indicate the product has not been carefully developed or maintained.

2 Findings

2.1 Summary

Here is a summary of our findings after analyzing the `Chainhop` implementation. During the first phase of our audit, we study the smart contract source code and run our in-house static code analyzer through the codebase. The purpose here is to statically identify known coding bugs, and then manually verify (reject or confirm) issues reported by our tool. We further manually review business logic, examine system operations, and place DeFi-related aspects under scrutiny to uncover possible pitfalls and/or bugs.

Severity	# of Findings	
Critical	0	
High	1	■
Medium	1	■
Low	1	■
Informational	2	■■
Total	5	

We have so far identified a list of potential issues: some of them involve subtle corner cases that might not be previously thought of, while others refer to unusual interactions among multiple contracts. For each uncovered issue, we have therefore developed test cases for reasoning, reproduction, and/or verification. After further analysis and internal discussion, we determined a few issues of varying severities that need to be brought up and paid more attention to, which are categorized in the above table. More information can be found in the next subsection, and the detailed discussions of each of them are in Section 3.

2.2 Key Findings

Overall, these smart contracts are well-designed and engineered, though the implementation can be improved by resolving the identified issues (shown in Table 2.1), including 1 high-severity vulnerability, 1 medium-severity vulnerability, 1 low-severity vulnerability, and 2 informational recommendations.

Table 2.1: Key Chainhop Audit Findings

ID	Severity	Title	Category	Status
PVE-001	High	Revisited Message Bridge Fee For Native Token Transfer	Business Logic	Fixed
PVE-002	Low	Accommodation Of Non-ERC20-Compliant Tokens	Coding Practices	Fixed
PVE-003	Informational	Suggested Whitelisted DEXes In Swapper::executeSwaps()	Security Features	Fixed
PVE-004	Informational	Meaningful Events For Important State Changes	Coding Practices	Fixed
PVE-005	Medium	Trust Issue Of Admin Keys	Security Features	Confirmed

Beside the identified issues, we emphasize that for any user-facing applications and services, it is always important to develop necessary risk-control mechanisms and make contingency plans, which may need to be exercised before the mainnet deployment. The risk-control mechanisms should kick in at the very moment when the contracts are being deployed on mainnet. Please refer to Section 3 for details.

3 Detailed Results

3.1 Revisited Message Bridge Fee For Native Token Transfer

- ID: PVE-001
- Severity: High
- Likelihood: High
- Impact: Medium
- Target: `TransferSwapper`
- Category: Business Logic [7]
- CWE subcategory: CWE-841 [4]

Description

The `Chainhop` protocol provides the cross-chain swap service. It allows the user to swap one token to another on the source chain via the user specified `DEXes` and then cross the swapped-out token to the destination chain. On the destination chain, the bridge token can be further swapped to the user expected token via the user specified `DEXes`. By design, the message containing the swap-related information on the destination chain will be transferred to the destination chain along with carrying out cross-chain assets transfer. Additionally, the user should pay a certain amount of native token (e.g., `ETH`) as message bridge fee (The fee is related to the length of the `message`). In particular, the internal `_transfer()` routine is called to trigger the cross-chain transaction. While examining its logic, we notice there is an improper implementation that needs to be improved.

To elaborate, we show below the related code snippet of the `TransferSwapper` contract. In the internal `_transfer()` routine, the `MessageSenderLib::sendMessageWithTransfer()` interface is called (line 185) to trigger the cross-chain transaction. It comes to our attention that its last input parameter indicating the message bridge fee is simply assigned to `msg.value` (line 195). However, it is incompatible to the native token transfer scenario, which may result in that the transaction is unfortunately reverted.

```
176     function _transfer(
177         bytes32 _id,
178         address _dstTransferSwapper,
179         TransferDescription memory _desc,
180         ICodec.SwapDescription[] memory _dstSwaps,
```

```
181         uint256 _amount,
182         address _token
183     ) private returns (bytes32 transferId) {
184         bytes memory requestMessage = _encodeRequestMessage(_id, _desc, _dstSwaps);
185         transferId = MessageSenderLib.sendMessageWithTransfer(
186             _dstTransferSwapper,
187             _token,
188             _amount,
189             _desc.dstChainId,
190             _desc.nonce,
191             _desc.maxBridgeSlippage,
192             requestMessage,
193             _desc.bridgeType,
194             messageBus,
195             msg.value
196         );
197     }
```

Listing 3.1: `TransferSwapper::_transfer()`

Recommendation Correct the implementation of the `_transfer()` routine by properly dealing with the message bridge fee.

Status The issue has been addressed by the following commits: `c1b001a` and `a607aaa`.

3.2 Accommodation Of Non-ERC20-Compliant Tokens

- ID: PVE-002
- Severity: Low
- Likelihood: Low
- Impact: Low
- Target: `FeeOperator`
- Category: Coding Practices [6]
- CWE subcategory: CWE-1109 [1]

Description

Though there is a standardized ERC-20 specification, many token contracts may not strictly follow the specification or have additional functionalities beyond the specification. In this section, we examine the `transfer()` routine and possible idiosyncrasies from current widely-used token contracts.

In particular, we use the popular token, i.e., `ZRX`, as our example. We show the related code snippet below. On its entry of `transfer()`, there is a check, i.e., `if (balances[msg.sender] >= _value && balances[_to] + _value >= balances[_to])`. If the check fails, it returns `false`. However, the transaction still proceeds successfully without being reverted. This is not compliant with the ERC20 standard and may cause issues if not handled properly. Specifically, the ERC20 standard specifies the following: *"Transfers _value amount of tokens to address _to, and MUST fire the Transfer event.*

The function SHOULD throw if the message caller's account balance does not have enough tokens to spend."

```
64    function transfer(address _to, uint _value) returns (bool) {
65        //Default assumes totalSupply can't be over max (2^256 - 1).
66        if (balances[msg.sender] >= _value && balances[_to] + _value >= balances[_to]) {
67            balances[msg.sender] -= _value;
68            balances[_to] += _value;
69            Transfer(msg.sender, _to, _value);
70            return true;
71        } else { return false; }
72    }
73
74    function transferFrom(address _from, address _to, uint _value) returns (bool) {
75        if (balances[_from] >= _value && allowed[_from][msg.sender] >= _value &&
              balances[_to] + _value >= balances[_to]) {
76            balances[_to] += _value;
77            balances[_from] -= _value;
78            allowed[_from][msg.sender] -= _value;
79            Transfer(_from, _to, _value);
80            return true;
81        } else { return false; }
82    }
```

Listing 3.2: ZRX.sol

Because of that, a normal call to `transfer()` is suggested to use the safe version, i.e., `safeTransfer()`. In essence, it is a wrapper around ERC20 operations that may either throw on failure or return false without reverts. Moreover, the safe version also supports tokens that return no value (and instead revert or throw on failure). Note that non-reverting calls are assumed to be successful.

In the following, we show the `FeeOperator::collectFee()` routine. If the `USDT` token is supported as `_tokens[i]`, the unsafe version of `IERC20(_tokens[i]).transfer(_to, balance)` (line 27) may revert as there is no return value in the `USDT` token contract's `transfer()` implementation. We may intend to replace `IERC20(_tokens[i]).transfer(_to, balance)` (line 27) with `safeTransfer()`.

```
24    function collectFee(address[] calldata _tokens, address _to) external
          onlyFeeCollector {
25        for (uint256 i = 0; i < _tokens.length; i++) {
26            uint256 balance = IERC20(_tokens[i]).balanceOf(address(this));
27            IERC20(_tokens[i]).transfer(_to, balance);
28        }
29    }
```

Listing 3.3: FeeOperator::collectFee()

Recommendation Accommodate the above-mentioned idiosyncrasy with a safe-version implementation of ERC20-related `transfer()`.

Status The issue has been addressed by the following commit: `5175468`.

3.3 Suggested Whitelisted DEXes In Swapper::executeSwaps()

- ID: PVE-003
- Severity: Informational
- Likelihood: N/A
- Impact: N/A
- Target: Swapper
- Category: Security Features [5]
- CWE subcategory: CWE-287 [2]

Description

As mentioned in Section 3.1, the Chainhop protocol provides the cross-chain swap service. It allows the user to swap one token to another on the source chain via the user specified DEXes and then cross the swapped-out token to the destination chain. On the destination chain, the bridge token can be further swapped to the user expected token via the user specified DEXes. In particular, one routine, i.e., Swapper::executeSwaps(), is designed to swap one token to another via the user specified DEXes. While examining its logic, we observe the current implementation can be enhanced.

To elaborate, we show below the related code snippet of the Swapper contract. In the executeSwaps() function, we notice the used DEXes ((ok,) = _swaps[i].dex.call(data)) (line 72) is specified by the input _swaps parameter without any authentication. If the used DEXes are crafted by the malicious actor, it may cause unpredictable losses to the protocol.

```
63      function executeSwaps(
64          ICodec.SwapDescription[] memory _swaps,
65          ICodec[] memory _codecs // _codecs[i] is for _swaps[i]
66      ) internal returns (bool ok, uint256 sumAmtOut) {
67          for (uint256 i = 0; i < _swaps.length; i++) {
68              (uint256 amountIn, address tokenIn, address tokenOut) = _codecs[i].
                    decodeCalldata(_swaps[i]);
69              bytes memory data = _codecs[i].encodeCalldataWithOverride(_swaps[i].data,
                    amountIn, address(this));
70              IERC20(tokenIn).safeIncreaseAllowance(_swaps[i].dex, amountIn);
71              uint256 balBefore = IERC20(tokenOut).balanceOf(address(this));
72              (ok, ) = _swaps[i].dex.call(data);
73              ...
74          }
75      }
```

Listing 3.4: Swapper::executeSwaps()

Note that another routine, i.e., executeSwapsWithOverride(), shares the same issue.

Recommendation Whitelist the DEXes so that only authenticated DEX can be used.

Status The issue has been addressed by the following commit: 3f041a6.

3.4 Meaningful Events For Important State Changes

- ID: PVE-004
- Severity: Informational
- Likelihood: N/A
- Impact: N/A
- Target: `Multiple Contracts`
- Category: Coding Practices [6]
- CWE subcategory: CWE-563 [3]

Description

In `Ethereum`, the `event` is an indispensable part of a contract and is mainly used to record a variety of runtime dynamics. In particular, when an `event` is emitted, it stores the arguments passed in transaction logs and these logs are made accessible to external analytics and reporting tools. `Events` can be emitted in a number of scenarios. One particular case is when system-wide parameters or settings are being changed. Another case is when tokens are being minted, transferred, or burned.

While examining the events that reflect the protocol dynamics, we notice there are several privileged routines that lack meaningful events to reflect their changes. In the following, we show several representative routines.

```
29    function setCodec(string calldata _funcSig, address _codec) public onlyOwner {
30        _setCodec(_funcSig, _codec);
31    }
```

Listing 3.5: `Codecs::setCodec()`

```
31    function setFeeCollector(address _feeCollector) external onlyOwner {
32        feeCollector = _feeCollector;
33    }
```

Listing 3.6: `FeeOperator::setFeeCollector()`

```
21    function setSigner(address _signer) public onlyOwner {
22        signer = _signer;
23    }
```

Listing 3.7: `SigVerifier::setSigner()`

```
421   function setNativeWrap(address _nativeWrap) external onlyOwner {
422       nativeWrap = _nativeWrap;
423   }
```

Listing 3.8: `TransferSwapper::setNativeWrap()`

With that, we suggest to emit meaningful events in these privileged routines. Also, the key event information is better `indexed`. Note each emitted event is represented as a topic that usually consists of the signature (from a `keccak256` hash) of the event name and the types (`uint256`, `string`,

etc.) of its parameters. Each indexed type will be treated like an additional topic. If an argument is not indexed, it will be attached as data (instead of a separate topic). Considering that the key information is typically queried, it is better treated as a topic, hence the need of being `indexed`.

Recommendation Properly emit the above-mentioned events with accurate information to timely reflect state changes. This is very helpful for external analytics and reporting tools.

Status The issue has been addressed by the following commit: `3fe69d0`.

3.5 Trust Issue Of Admin Keys

- ID: PVE-005
- Severity: Medium
- Likelihood: Medium
- Impact: Medium
- Target: `Multiple Contracts`
- Category: Security Features [5]
- CWE subcategory: CWE-287 [2]

Description

In the `Chainhop` implementation, there is a privileged account that plays a critical role in governing and regulating the protocol-wide operations (e.g., configuring various system parameters). In the following, we show the representative functions potentially affected by the privilege of the account.

```
21      function setSigner(address _signer) public onlyOwner {
22          signer = _signer;
23      }
```

Listing 3.9: `SigVerifier::setSigner()`

We emphasize that the privilege assignment is indeed necessary and consistent with the protocol design. However, it will be worrisome if the privileged account is a plain EOA account. A multi-sig account could greatly alleviate this concern, though it is still far from perfect. Note that a compromised privileged account would allow the attacker to modify a number of sensitive system parameters, which directly undermines the assumption of the protocol design.

Recommendation Suggest a multi-sig account plays the privileged `owner` account to mitigate this issue. Additionally, all changes to privileged operations may need to be mediated with necessary timelocks.

Status The issue has been confirmed by the team.

4 | Conclusion

In this audit, we have analyzed the Chainhop design and implementation. Chainhop implements a cross-chain decentralized exchange (DEX), which provides the cross-chain swap service with a one-transaction user experience. The current code base is well structured and neatly organized. Those identified issues are promptly confirmed and addressed.

Meanwhile, we need to emphasize that smart contracts as a whole are still in an early, but exciting stage of development. To improve this report, we greatly appreciate any constructive feedbacks or suggestions, on our methodology, audit findings, or potential gaps in scope/coverage.

References

[1] MITRE. CWE-1126: Declaration of Variable with Unnecessarily Wide Scope. https://cwe.mitre.org/data/definitions/1126.html.

[2] MITRE. CWE-287: Improper Authentication. https://cwe.mitre.org/data/definitions/287.html.

[3] MITRE. CWE-563: Assignment to Variable without Use. https://cwe.mitre.org/data/definitions/563.html.

[4] MITRE. CWE-841: Improper Enforcement of Behavioral Workflow. https://cwe.mitre.org/data/definitions/841.html.

[5] MITRE. CWE CATEGORY: 7PK - Security Features. https://cwe.mitre.org/data/definitions/254.html.

[6] MITRE. CWE CATEGORY: Bad Coding Practices. https://cwe.mitre.org/data/definitions/1006.html.

[7] MITRE. CWE CATEGORY: Business Logic Errors. https://cwe.mitre.org/data/definitions/840.html.

[8] MITRE. CWE VIEW: Development Concepts. https://cwe.mitre.org/data/definitions/699.html.

[9] OWASP. Risk Rating Methodology. https://www.owasp.org/index.php/OWASP_Risk_Rating_Methodology.

[10] PeckShield. PeckShield Inc. https://www.peckshield.com.