

Advanced Topics in Software Engineering
CSE - 6324 - Section 001

TEAM 4

ITERATION 2
(Written Deliverable)

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I. Project Objective

Slither is a static analysis framework that provides rich information about Ethereum smart contracts [1]. Slither's plugin architecture lets you integrate new detectors from the command line [2].

We propose to add three new detectors using the Python API [3].

The first detector will be targeted toward the improper usage of the `ecrecover()` function in solidity smart contracts [4]. The `ecrecover` function can be used to process meta transactions in smart contracts and verifies signed data coming from someone other than the transaction signer [5], but due to the nature of public key private key signatures, this function is vulnerable to replay attacks [11]. The proposed detector will detect usage of the `ecrecover` function without nonce or chain id and flag it as a security vulnerability. The detector will also check the validity of the ECDSA signature based on the conditions defined in the Ethereum yellow paper [16]. This detector is based on the pull request ([#2015](#)) [17] which checks for nonce protection. Chain ID and ECDSA signature verification are being added to this detector to expand its use cases.

The second detector will detect API Keys stored as plain text within the solidity code (SWC 136) [6]. Hardcoded credentials present a grave security risk and compromise the security setup associated with the keys [6]. Since the inherent nature of smart contracts is public, any hard-coded secret is not safe irrespective of whether it is stored in a public or private variable [8]. The second detector will target common API key types.

The third detector will detect passwords hardcoded into the solidity code (SWC 136) [6]. Hardcoded passwords in solidity smart contracts are not private and can be seen by third parties due to the public nature of smart contracts [7] [8]. The third detector will specifically target passwords.

II. Project Plan

Task	Start	End	Current Status	Risk Associated
Setup Development Environment	Inception	Inception	Completed	Changing Solidity Standards
Define rules for improper use of ecrecover() detector	Iteration 1	Iteration 1	Completed	Incomplete rule definition
Build improper use of ecrecover() detector (SWC-121)	Iteration 1	Iteration 1	Completed	1. Incomplete rule definition 2. False Positives 3. False Negatives 4. Change in security standards
Test and iterate improper use of ecrecover() detector	Iteration 1	Iteration 2	Completed	Change in security standards
Define Rules for hardcoded API Key detector	Iteration 1	Iteration 2	Completed	Change in security standards
Define Rules for hardcoded password detector	Iteration 1	Iteration 2	Completed	Change in security standards
Review and implement feedback from Iteration 1	Iteration 2	Iteration 2	Completed	
Build hardcoded API Key detector	Iteration 2	Iteration 2	Completed	1. False Positives 2. False Negatives
Build hardcoded Password Detector	Iteration 2	Final Iteration	In Progress	1. False Positives 2. False Negatives
Review and implement feedback from Iteration 2	Final Iteration	Final Iteration	Not Started	
Generate Report	Final Iteration	Final Iteration	Not Started	

III. Risk Mitigation Plan

Risk	Risk Description	Mitigation Plan	Risk Exposure
Incomplete rule definition	Rules for detectors could miss edge cases.	Iteratively build and test the detectors with rules defined.	There is a 30% probability that this issue might occur, and we would need 10 hours to fix it. Hence, risk exposure would be 3 extra hours.
Changing Solidity Standards	Changing standards in solidity and Ethereum could make the detector and its recommendations obsolete.	Fix Solidity version 0.8.18 as the target version	There is a 20% probability that this issue might occur, and we would need 10 hours to fix it. Hence, risk exposure would be 2 extra hours.
Missing Slither User's needs from the detector's	Rules defined in the detector may not meet the slither user needs for analyzing smart contracts.	Thoroughly research the issue and interact with slither users to better understand detector needs	There is a 10% probability that this issue might occur, and we would need 10 hours to fix it. Hence, risk exposure would be 1 extra hour.
False Positive	The detector might detect that there is a data leak that does not exist.	Test with multiple negative scenarios	We need 4 hours to resolve this problem, which has a 20% chance of happening. Thus, 0.8 hours of risk exposure.
False Negatives	The detector may not detect that there is a data leak that exists.	Test with multiple positive scenarios	There is a 10% chance that this problem would arise, and it would take 4 hours to fix. Hence, risk exposure would be 0.4 extra hours.

IV. Specification and Design

1. Ecrecover Detector

In iteration 1, we checked for the improper usage of the ecrecover() function, which checked for certain conditions. The conditions are:

- i. ECDSA check: checks the validity of the signature based on the conditions defined in the Ethereum yellow paper [16] and checks implemented in openzeppelin [20][22] implementation of ECDSA signature validation. This check prevents signature malleability by enforcing the bounds for the keys in the ECDSA signature. Without this check, the ecrecover function would allow nonunique signatures[20].
- ii. ChainId check: By adding chain ID into the payload, replay attacks by sending a transaction from a different network as a valid transaction can be prevented [18].
Chain ID is unique for every chain so a transaction with chain ID would prevent transactions of different chains being replayed on another chain[18].

We are using a solidity smart contract as input to our detector. For iteration 1, we wrote the code into 'ecrecover.sol' which was created in the pull request #2015 [17]. To analyze and detect the improper usages we have defined various functions that satisfy either of these conditions, none of them, or both in our file.

In iteration 2 we added additional conditions for the ECDSA key validity check to prevent signature malleability described in the yellow paper [16], this is based on the open zeppelin implementation [20] for the ECDSA signature check.

A few code snippets of the 'ecrecover.sol' are below.

```

41 //Missing Chain ID or Nonce and valid ECDSA signature validation
42 function bad_missingChainId_missingNonce_withECDSACheck(
43     Info calldata info,
44     uint8 v,
45     bytes32 r,
46     bytes32 s
47 ) external {
48     bytes32 data = keccak256(
49         abi.encodePacked(
50             "\x19Ethereum Signed Message:\n32",
51             keccak256(abi.encode(info))
52         )
53     );
54     if((r>0 &&
55         uint256(s) <= 0x7FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF5D576E7357A4501DDFE92F46681B20A0
56         && s>0 && (v==0 || v==1))){
57         address receiver = ecrecover(data, v, r, s);
58         require(receiver != address(0), "ECDSA: invalid signature");
59         mint(info.tokenId, receiver);
60     }
61 }

```

```

118 //Valid with Chain Id and ECDSA singature validation
119 function good_withChainId_withECDSACheck(
120     Info calldata info,
121     uint8 v,
122     bytes32 r,
123     bytes32 s
124 ) external {
125     bytes32 hash = keccak256(abi.encode(info,chainId));
126     bytes32 data = keccak256(
127         abi.encodePacked("\x19Ethereum Signed Message:\n32", hash, chainId)
128     );
129     if((r > 0 && uint256(s) <= 0x7FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF5D576E7357A4501DDFE92F46681B20A0 &&
130     s>0 && (v == 0 || v == 1))){
131         address receiver = ecrecover(data, v, r, s);
132         require(receiver != address(0), "ECDSA: invalid signature");
133         mint(info.tokenId, receiver);
134     }
135 }

```

```

146 //Valid Nonce and missing ECDSA singature validation
147 function bad_withNonce_missingECDSACheck(
148     Info calldata info,
149     uint8 v,
150     bytes32 r,
151     bytes32 s
152 ) external {
153     bytes32 data = keccak256(
154         abi.encodePacked(
155             "\x19Ethereum Signed Message:\n32",
156             keccak256(abi.encode(info,nonces[msg.sender]++))
157         )
158     );
159     address receiver = ecrecover(data, v, r, s);
160     require(receiver != address(0), "ECDSA: invalid signature");
161     mint(info.tokenId, receiver);
162 }
163
164

```

```

135 //Valid with Nonce and ECDSA singature validation
136 function good_withNonce_withECDSACheck(
137     Info calldata info,
138     uint8 v,
139     bytes32 r,
140     bytes32 s
141 ) external {
142     bytes32 hash = keccak256(abi.encode(info,nonces[msg.sender]++));
143     bytes32 data = keccak256(
144         abi.encodePacked("\x19Ethereum Signed Message:\n32", hash, nonces[msg.sender]++)
145     );
146     if((r > 0 && s>0 &&
147         uint256(s) <= 0x7FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF5D576E7357A4501DDFE92F46681B20A0 &&
148         (v == 0 || v == 1))) {
149         address receiver = ecrecover(data, v, r, s);
150         require(receiver != address(0), "ECDSA: invalid signature");
151         mint(info.tokenId, receiver);
152     }
153 }
154

```

The detector analyzed the code and detected missing conditions for every function. The output of the ecrecover detector analysis is given below:

```

[navina@Navinas-MacBook-Air code % slither ecrecover.sol --detect ecrecover]
'solc --version' running
'solc ecrecover.sol --combined-json abi,ast,bin,bin-runtime,srcmap,srcmap-runtime,userdoc,devdoc,hashes --allow-paths ./Users/navina/Downloads/Adv SE/Code' running
Compilation warnings/errors on ecrecover.sol:
Warning: SPDX license identifier not provided in source file. Before publishing, consider adding a comment containing "SPDX-License-Identifier: <SPDX-License>" to each source file. Use "SPDX-License-Identifier: UNLICENSED" for non-open-source code. Please see https://spdx.org for more information.
--> ecrecover.sol

INFO:Detectors:
A.bad_withChainID_missingECDSACheck(A.Info,uint8,bytes32,bytes32).receiver (ecrecover.sol#35) lacks a zero-check on :
    - receiver = ecrecover(bytes32,uint8,bytes32,bytes32)(data,v,r,s) (ecrecover.sol#35)
A.bad_withChainID_missingECDSACheck(A.Info,uint8,bytes32,bytes32).receiver (ecrecover.sol#35) lacks a r > 0 ecdsa check on :
    - receiver = ecrecover(bytes32,uint8,bytes32,bytes32)(data,v,r,s) (ecrecover.sol#35)
A.bad_withChainID_missingECDSACheck(A.Info,uint8,bytes32,bytes32).receiver (ecrecover.sol#35) lacks a s > 0 ecdsa check on :
    - receiver = ecrecover(bytes32,uint8,bytes32,bytes32)(data,v,r,s) (ecrecover.sol#35)
A.bad_withChainID_missingECDSACheck(A.Info,uint8,bytes32,bytes32).receiver (ecrecover.sol#35) lacks a v ecdsa check on :
    - receiver = ecrecover(bytes32,uint8,bytes32,bytes32)(data,v,r,s) (ecrecover.sol#35)
A.bad_missingChainID_missingECDSACheck(A.Info,uint8,bytes32,bytes32).receiver (ecrecover.sol#49) lacks a zero-check on :
    - receiver = ecrecover(bytes32,uint8,bytes32,bytes32)(data,v,r,s) (ecrecover.sol#49)
A.bad_missingChainID_missingECDSACheck(A.Info,uint8,bytes32,bytes32) (ecrecover.sol#39-51) lacks a nonce or chainId on :
    - data = keccak256(bytes)(abi.encodePacked(Ethereum Signed Message:

```

2. API Key Detector

In Iteration 2 we developed an API key detector based on the implementation of a sonar-secrets API Key flag for Java code [21]. The detector looks for conditions based on the name of the variable storing the API key.

The detector is based on the ecrecover detector which was built upon the slither pull request (#2015) [17].

The conditions are:

- i. The variable has names like `api_key`, `api_token`, `google_key`, or any other combination of `api|gitlab|github|slack|google|aws|jenkins` **with** `'_'` and `key|token|secret|auth`.

```

 9
10     function useAPI() external {
11         //API key fetched from https://stackoverflow.com/questions/62073437/how-to-make-an-api-call-in-solidity
12         //for testing purpose
13         api_key = bytes32("c179a8180e034cf5a341488406c32827");
14     }
15
16     function doesNotUseAPI(bytes32 t) external {
17         tempId = t;
18     }

```

The output of the API Key detector analysis is given below:

```

INFO:Detectors:
APIData.useAPI() (apikey.s.sol#11-19)
  has hardcoded API key :
    - api = bytes32(c179a8180e034cf5a341488406c32827) (apikey.s.sol#15)

```


V. Code and Tests

i. Setup:

There are various versions available for the solc compiler [19].

```
navina@Navinas-MacBook-Air code % solc-select install
Available versions to install:
0.3.6
0.4.0
0.4.1
0.4.2
```

We are using version 0.8.18, which can be installed using the following command.

```
navina@Navinas-MacBook-Air code % solc-select install 0.8.18
Installing solc '0.8.18'...
Version '0.8.18' installed.
```

To use the specific version, we need to use the following command.

```
navina@Navinas-MacBook-Air code % solc-select use 0.8.18
Switched global version to 0.8.18
```

The next step is to add our ecrecover python file, 'ecrecover.py', and API key detector python file, 'apikey.py' which has the detector code, in 'all_detectors.py' which would be in the local directory where Slither is installed [2]. In our case, the path is: '/Library/Frameworks/Python.framework/Versions/3.10/lib/python3.10/site-packages/slither/detectors/all_detectors.py' and then move our detector code to the local directory path '/Library/Frameworks/Python.framework/Versions/3.10/lib/python3.10/site-packages/slither/detectors/statements'.

After the installations and setup, we are taking 'ecrecover.sol' as input and running slither only for the ecrecover detector using the following command.

```
navina@Navinas-MacBook-Air code % slither ecrecover.sol --detect ecrecover
```

Similarly for the API Key detector, we are taking ‘apikeysol’ as input and running slither only for the API Key detector using the following command.

```
navina@Navinas-MacBook-Air Code % slither apikeys.sol --detect apikey
```

ii. Code:

1. Ecrecover Detector

The code is built on `ecrecover.py` from pull request #2015 [17].

The detector looks for uses of `ecrecover()` which if returns true will check if the `keccak256` function is called and checks for the nonce or chain id conditions as well as the ECDSA signature validation. The `ecrecover` detector code snippets are as follows:

```

147 #Checks the ECDSA validation for the r value and returns true or false
148 def _r_ecdsa_validation(var: LocalVariable, function: Function) -> bool:
149     for node in function.nodes:
150         if node.contains_if():
151             for ir in node.irs:
152                 expression = str(ir.expression)
153                 if isinstance(ir, Binary):
154                     if (
155                         ir.type == BinaryType.GREATER or ir.type == BinaryType.LESS
156                     ) and "r > 0" in expression or "0 < r" in expression:
157                         return True
158     return False

```

```

165 #Checks the ECDSA validation for the s value and returns true or false
166 def _s_ecdsa_validation(var: LocalVariable, function: Function) -> bool:
167     for node in function.nodes:
168         if node.contains_if():
169             for ir in node.irs:
170                 expression = str(ir.expression)
171                 if isinstance(ir, Binary):
172                     if [
173                         ir.type == BinaryType.GREATER or ir.type == BinaryType.LESS or
174                         ir.type == BinaryType.LESS_EQUAL or ir.type == BinaryType.GREATER_EQUAL
175                     ] and (('s' > '0') in expression or ('0' < 's') in expression) or (
176                         ("uint256(s) <= 0x7FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF5D576E7357A4501DDFE92F46681B20A0")
177                         ) in expression):
178                     return True
179     return False

```

```

172
173 #Checks the ECDSA validation for the v value and returns true or false
174 def _v_ecdsa_validation(var: LocalVariable, function: Function) -> bool:
175     for node in function.nodes:
176         if node.contains_if():
177             for ir in node.irs:
178                 expression = str(ir.expression)
179                 if isinstance(ir, Binary):
180                     if (
181                         ir.type == BinaryType.EQUAL
182                         ) and ("v == 0" in expression) or ("v == 1" in expression):
183                         return True
184     return False
185

```

```

198
199 #If ecrecover function is called
200 if SolidityFunction("ecrecover(bytes32,uint8,bytes32,bytes32)") in function.solidity_calls:
201     address_list = []
202     var_nodes = defaultdict(list)
203     for node in function.nodes:
204         if SolidityFunction("ecrecover(bytes32,uint8,bytes32,bytes32)") in node.solidity_calls:
205             for var in node.local_variables_written:
206                 if "ecrecover(bytes32,uint8,bytes32,bytes32)" in str(var.expression):
207                     address_list.append(var)
208                     var_nodes[var].append(node)
209
210     #If keccak256 hash function is called
211     if SolidityFunction("keccak256(bytes)") in node.solidity_calls:
212         for ir in node.irs:
213             if isinstance(ir, SolidityCall) and ir.function == SolidityFunction(
214                 "keccak256(bytes)"
215             ):
216                 # Checking if nonce or chainId is present in the expression
217                 if "nonce" not in str(ir.expression) and "chainId" not in str(ir.expression):
218                     nonce_results.append(node)
219

```

2. API Key Detector

The detector finds the hardcoded API keys in smart contracts. It scans the contract code and looks for the pattern or regular expression with certain keywords.

The detector implementation is based on ecrecover.py from pull request #2015 [17] and the ecrecover.py from ecrecover detector.

The regular expression is built upon the regular expression used by sonar secrets to detect API Keys in Java code [21].

The detector code snippet is as follows:

```

62 def _detect_apikey(function: Function,) -> List[Tuple[Function, DefaultDict[LocalVariable, List[Node]]]]:
63     results = []
64
65     for node in function.nodes:
66         for ir in node.irs:
67             expression = str(ir.expression)
68             if re.compile('(api|gitlab|github|slack|google|aws|jenkins)?(key|token|secret|auth)?')
69                 .search(expression):
70                 results.append(node)
71
72     return (results)

```

iii. Test Cases

No.	Test Case	Expected Output
1.	Running the pull request (#2015) on the solidity code.	Analyzing the usage of nonce and zero address check.
2.	Implementing the chainId check on the pull request.	Analyzing the slither detector with chainId check.
3.	Implementing the ECDSA check on the pull request.	Analyzing the slither detector with ECDSA check.
4.	Implementing API key detector with API key regular expressions based on sonar secrets [21].	Analyzing the slither detector with API Key check.

VI. Competitors

- i. Slither:- The current stable build of slither (0.9.6) [9], has a robust set of public detectors like Dangerous usage of tx. origin and Unchecked low-level calls [10]. But Slither currently does not have a public detector for API Keys, Passwords, or a public detector for improper usage of the ecrecover function as described in the GitHub Issue #[1950](#) [4].
- ii. Mythril:- Mythril is a security analysis tool for Ethereum smart contracts [12]. It has a set of modules to detect vulnerabilities and issues in the Ethereum solidity code like External Calls and Unprotected Ether Withdrawal [13]. But there are no modules to detect unprotected use of the ecrecover function or hardcoded credentials.
- iii. MythX:- MythX is a tool that scans for security vulnerabilities in Ethereum and other EVM-based blockchain smart contracts [14]. However, it does not have a detector available for improper use of ecrecover or hardcoded API keys and passwords [15]. MythX is a closed-source tool.

VII. Customers and Users

User	Role	Feedback
Mehul Hivlekar	New User to Smart Contracts and Solidity	The API key detector solves a very common developer error which can be a major issue.
Shruthaja Patali Rao	CSE-6324-001 Team 5	More scenarios where the API key is exposed can be checked to improve the detector.
Devyani Singh	CSE-6324-001 Team 8	The additional ecrecover detector changes make it very useful in preventing vulnerable code from being deployed.

VIII. GitHub Repository

https://github.com/arjunsuvarna1/CSE6324_Team4_Fall23

IX. References

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