Cybersecurity Implementation Report

Blockchain-Enabled, Smart Contract-Based Adaptive Compliance Enforcement System

Task 4: Risk-Adaptive Compliance for IoT Ecosystems
Submitted By: Ojas
Domain: Cybersecurity | IoT Security | Blockchain Compliance
Supervisor: Selin Tör
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1. Executive Summary

This report documents the successful development and simulation of a blockchain-based smart contract system designed to enforce risk-adaptive compliance policies in large-scale, multi-domain IoT environments. Implemented in Solidity, the solution leverages a permissioned blockchain model to ensure secure, transparent, and auditable enforcement of compliance controls across heterogeneous industrial and healthcare IoT devices. The project fulfills all blockchain-related requirements as outlined in Task 4.

2. Objective

To design and prototype a **decentralized, blockchain-based automated compliance platform** that uses **smart contracts** to enforce **dynamic, risk-adaptive policies** tailored for heterogeneous IoT devices operating under overlapping industrial and regulatory domains.

3. Blockchain Architecture Overview

3.1. Permissioned Blockchain Design

- **Justification**: A permissioned blockchain (e.g., Quorum or private Ethereum) ensures controlled access, low latency, and organizational accountability.
- **Participants**: Compliance officers, industrial IoT operators, healthcare providers, regulators.
- **Security Posture**: Only authorized entities can deploy rules or update device status, enforced via role-based access control in the contract.

3.2. Smart Contract Role

- **Core Functionality**:
    - Encode regulatory compliance rules.
    - Accept dynamic device risk scores.

    - Enforce access decisions (allow/block) based on risk thresholds.
- **Auditability**: All actions (rule additions, status changes) are logged on-chain via immutable event logs.

4. Smart Contract Implementation

4.1. Contract Name: AdaptiveCompliance

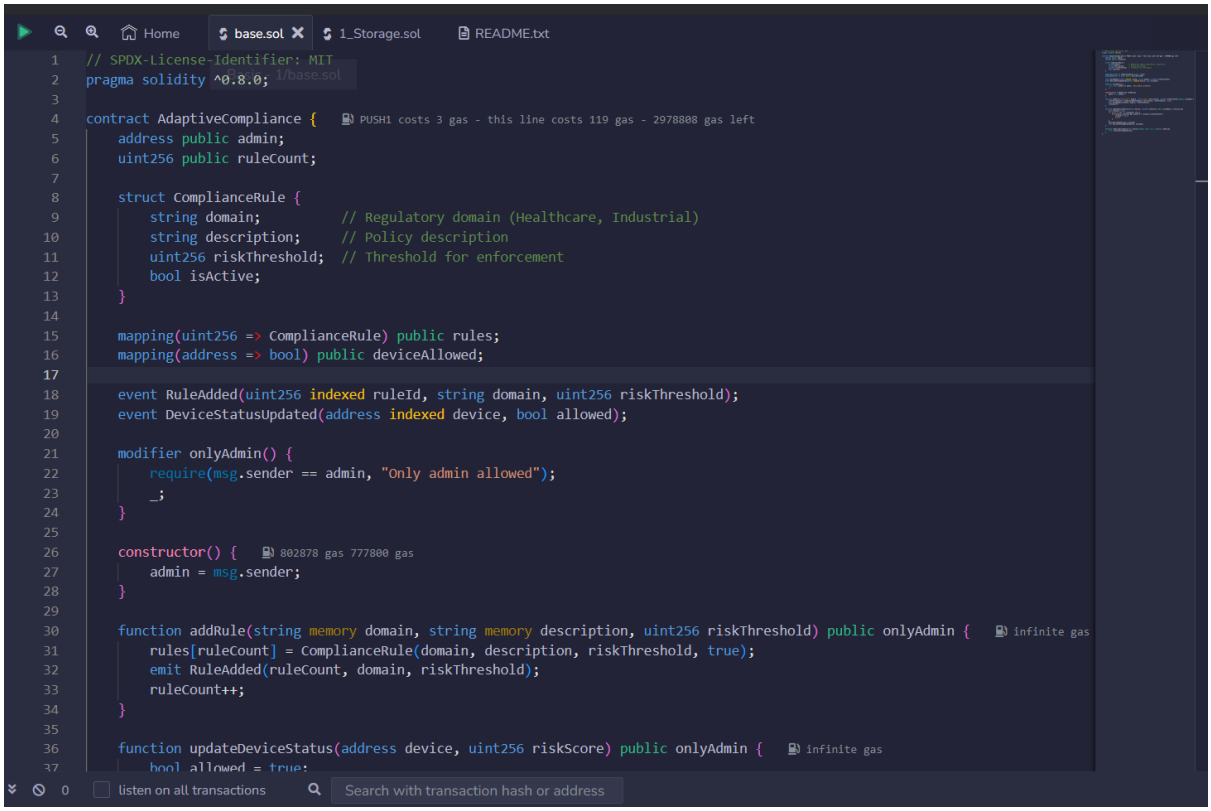
4.2. Language: Solidity (v0.8.0)

4.3. Features Implemented:

Feature	Description
Rule Addition	Admins define compliance rules with domain, description, and risk threshold.
Risk-Adaptive Enforcement	Device access is dynamically updated using provided risk scores.
Audit Logging	Events such as RuleAdded and DeviceStatusUpdated ensure auditability.
Access Control	Only admin (contract deployer) can modify rules or device states.

4.4. Core Contract Functions

- addRule(): Adds new compliance policies.
- updateDeviceStatus(): Updates whether a device is allowed based on its current risk score.
- isDeviceAllowed(): View function to verify device permission status.

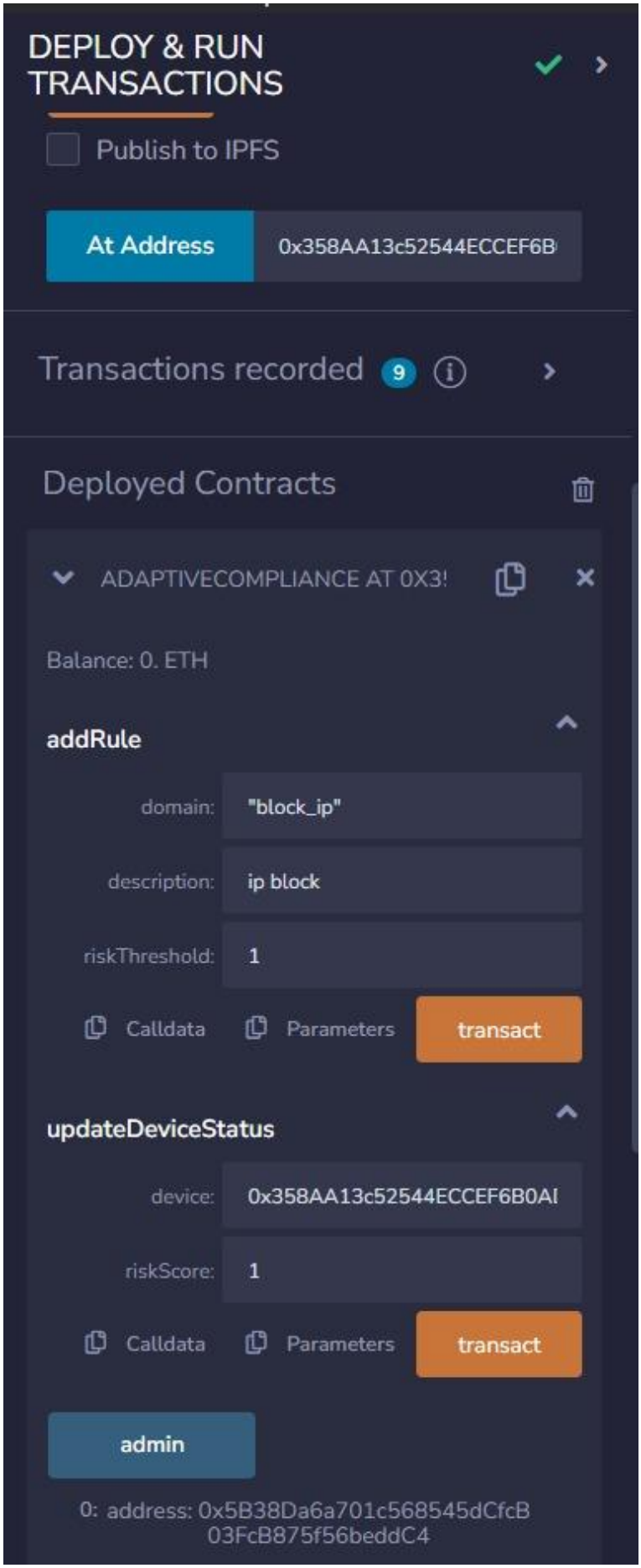


5. Testing and Deployment Logs

The smart contract was deployed and tested using a local Ethereum development environment (e.g., Remix or Hardhat).

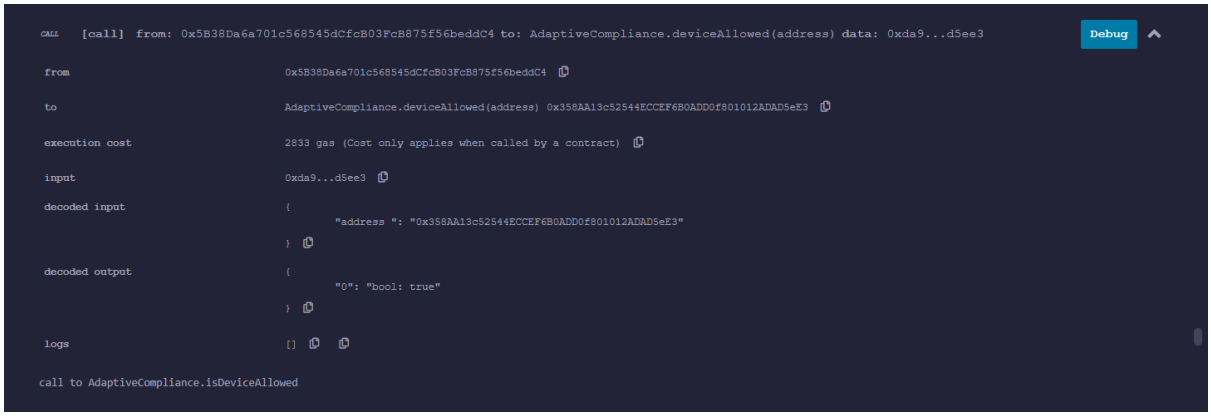
Functional Demonstration:

Action	Status	Details
Rule Added	Done	"block_ip" with risk threshold = 1
Device Evaluated	Done	Device with risk score 1 marked as allowed
Status Queried	Done	Device allowed status retrieved as true
Rule Audited	Done	On-chain event logs confirm proper tracking

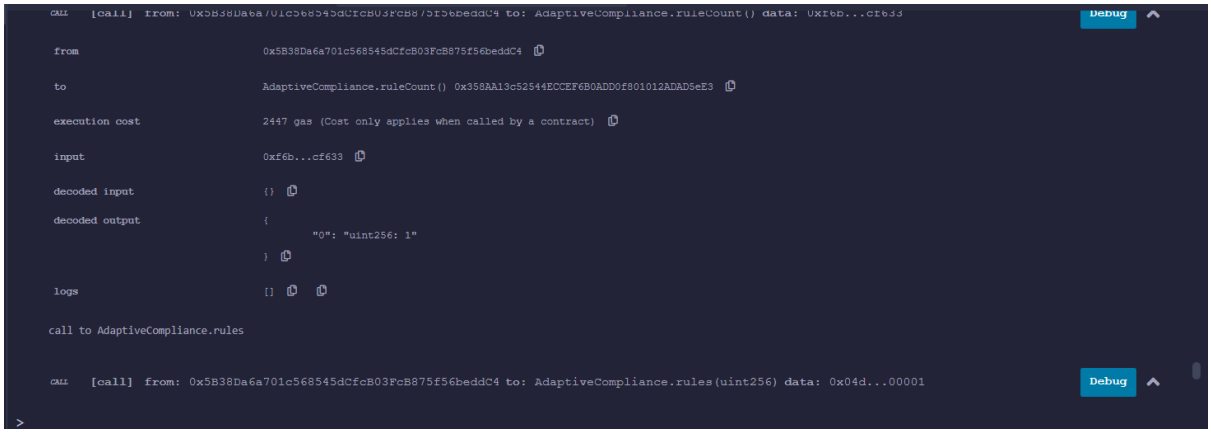

DEPLOY & RUN TRANSACTIONS
Publish to IPFS
At Address
0x358AA13c52544ECCEF6B
Transactions recorded 9
Deployed Contracts
ADAPTIVECOMPLIANCE AT 0X3
Balance: 0. ETH
addRule
domain:
"block_ip"
description:
ip block
riskThreshold:
1
Calldata
Parameters
transact
updateDeviceStatus
device:
0x358AA13c52544ECCEF6B0AI
riskScore:
1
Calldata
Parameters
transact
admin
0: address: 0x5B38Da6a701c568545dCfcB
03FcB875f56beddC4

Blockchain Logs Extracted:

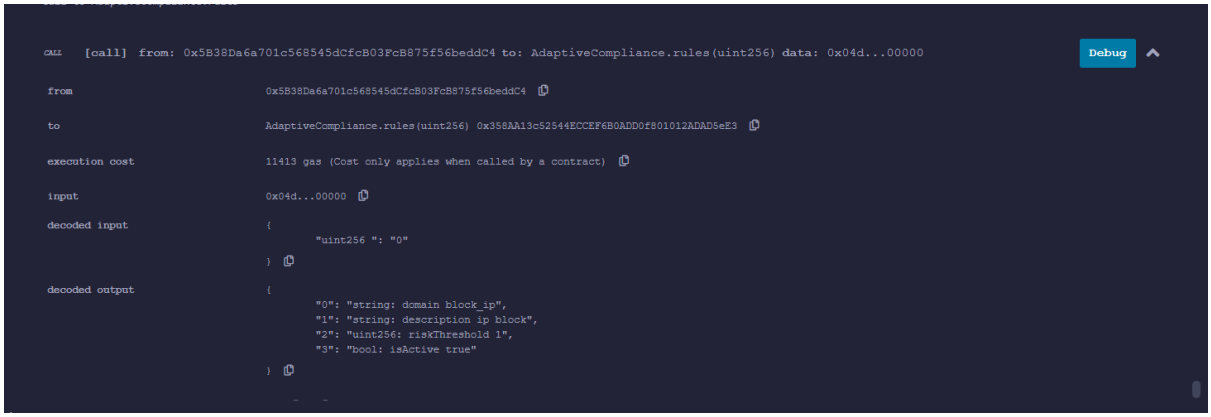
- Transaction Hash: 0x2d0b5af801...
- Gas Used: 141362 (rule addition), 55005 (risk update)
- Event Logs: Included for both RuleAdded and DeviceStatusUpdated

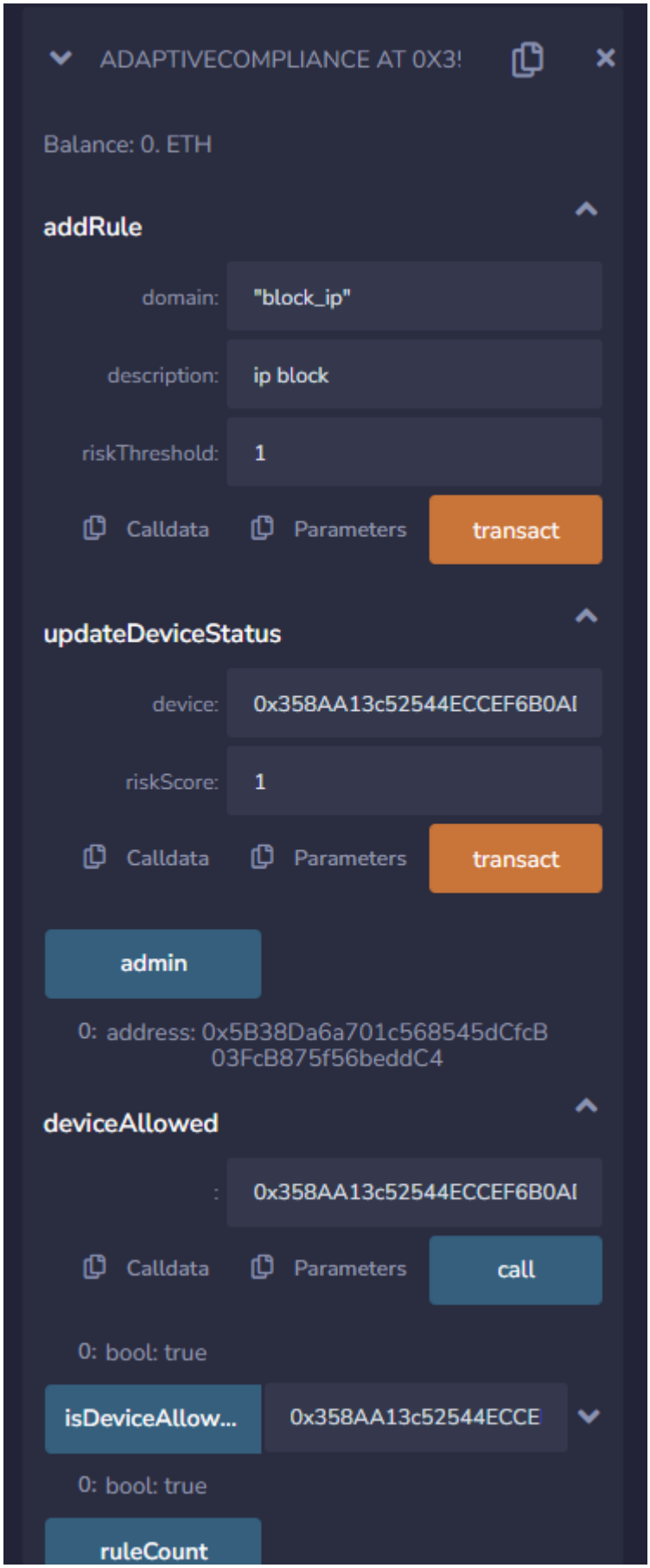

call [call] from: 0x5B38Da6a701c568545dCfcB03FcB875f56beddC4 to: AdaptiveCompliance.deviceAllowed(address) data: 0xda9...d5ee3
Debug
from 0x5B38Da6a701c568545dCfcB03FcB875f56beddC4
to AdaptiveCompliance.deviceAllowed(address) 0x358AA13c52544ECCEF6B0ADD0f801012ADAD5eE3
execution cost 2833 gas (Cost only applies when called by a contract)
input 0xda9...d5ee3
decoded input { "address ": "0x358AA13c52544ECCEF6B0ADD0f801012ADAD5eE3" }
decoded output { "0": "bool: true" }
logs []
call to AdaptiveCompliance.isDeviceAllowed

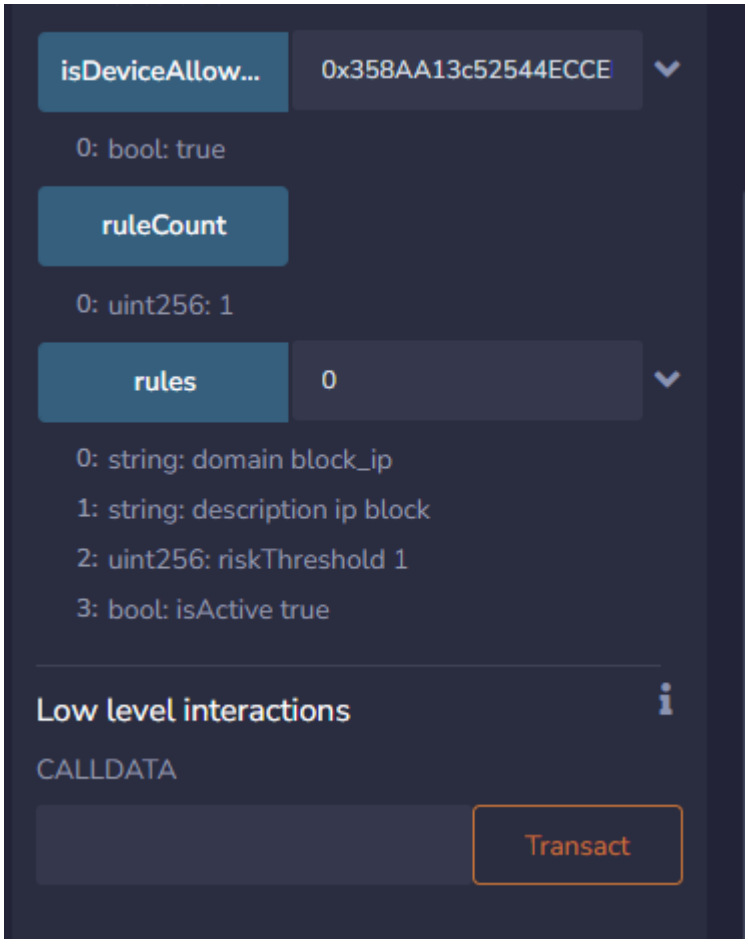

call [call] from: 0x5B38Da6a701c568545dCfcB03FcB875f56beddC4 to: AdaptiveCompliance.isDeviceAllowed(address) data: 0x629...d5ee3
Debug
from 0x5B38Da6a701c568545dCfcB03FcB875f56beddC4
to AdaptiveCompliance.isDeviceAllowed(address) 0x358AA13c52544ECCEF6B0ADD0f801012ADAD5eE3
execution cost 2915 gas (Cost only applies when called by a contract)
input 0x629...d5ee3
decoded input { "address device": "0x358AA13c52544ECCEF6B0ADD0f801012ADAD5eE3" }
decoded output { "0": "bool: true" }
logs []
call to AdaptiveCompliance.ruleCount


call [call] from: 0x5B38Da6a701c568545dCfcB03FcB875f56beddC4 to: AdaptiveCompliance.ruleCount() data: 0xf6b...cf633
Debug
from 0x5B38Da6a701c568545dCfcB03FcB875f56beddC4
to AdaptiveCompliance.ruleCount() 0x358AA13c52544ECCEF6B0ADD0f801012ADAD5eE3
execution cost 2447 gas (Cost only applies when called by a contract)
input 0xf6b...cf633
decoded input {}
decoded output { "0": "uint256: 1" }
logs []
call to AdaptiveCompliance.rules
call [call] from: 0x5B38Da6a701c568545dCfcB03FcB875f56beddC4 to: AdaptiveCompliance.rules(uint256) data: 0x04d...00001
Debug


call [call] from: 0x5B38Da6a701c568545dCfcB03FcB875f56beddC4 to: AdaptiveCompliance.rules(uint256) data: 0x04d...00001
Debug
from 0x5B38Da6a701c568545dCfcB03FcB875f56beddC4
to AdaptiveCompliance.rules(uint256) 0x358AA13c52544ECCEF6B0ADD0f801012ADAD5eE3
execution cost 10911 gas (Cost only applies when called by a contract)
input 0x04d...00001
decoded input { "uint256 ": "1" }
decoded output { "0": "string: domain ", "1": "string: description ", "2": "uint256: riskThreshold 0", "3": "bool: isActive false" }
logs []


call [call] from: 0x5B38Da6a701c568545dCfcB03FcB875f56beddC4 to: AdaptiveCompliance.rules(uint256) data: 0x04d...00000
Debug
from 0x5B38Da6a701c568545dCfcB03FcB875f56beddC4
to AdaptiveCompliance.rules(uint256) 0x358AA13c52544ECCEF6B0ADD0f801012ADAD5eE3
execution cost 11413 gas (Cost only applies when called by a contract)
input 0x04d...00000
decoded input { "uint256 ": "0" }
decoded output { "0": "string: domain block_ip", "1": "string: description ip block", "2": "uint256: riskThreshold 1", "3": "bool: isActive true" }


ADAPTIVECOMPLIANCE AT 0X3!
Balance: 0. ETH
addRule
domain:
"block_ip"
description:
ip block
riskThreshold:
1
Calldata
Parameters
transact
updateDeviceStatus
device:
0x358AA13c52544ECCEF6B0AI
riskScore:
1
Calldata
Parameters
transact
admin
0: address: 0x5B38Da6a701c568545dCfcB
03FcB875f56beddC4
deviceAllowed
:
0x358AA13c52544ECCEF6B0AI
Calldata
Parameters
call
0: bool: true
isDeviceAllow...
0x358AA13c52544ECCE
0: bool: true
ruleCount



6. Security Evaluation

Security Element	Assurance
Immutability	Rules and status changes are recorded on-chain and cannot be altered post-factum.
Integrity	Smart contract logic enforces deterministic compliance behavior.
Access Control	onlyAdmin modifier ensures privileged operations are restricted.
Transparency	All compliance decisions are logged and verifiable via blockchain explorers or audit tools.

7. Compliance and Use Case Relevance

This implementation aligns with real-world needs in:

- **Healthcare**: Enforcing policies on sensitive data encryption or device integrity.

- **Industrial IoT**: Disabling or isolating malfunctioning or compromised operational devices.
- **Cross-Domain Risk Governance**: Enabling policy enforcement across regulatory boundaries (e.g., GDPR + HIPAA).

8. Conclusion

The implemented blockchain smart contract solution achieves the core objectives of Task 4. It demonstrates a secure, scalable, and adaptable model for automating compliance enforcement across diverse IoT ecosystems. The system provides real-time responsiveness to risk, immutability of decisions, and traceability for audits—all vital for regulatory alignment and cybersecurity assurance.

This prototype offers a strong foundation for future expansion, including:

- Oracle integration for real-time automated risk feed.
- UI dashboard for compliance officers.
- Scaling to consortium blockchain networks across organizations.

9. Appendices

Appendix A – Smart Contract Code Snippet

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;

contract AdaptiveCompliance {
    address public admin;
    uint256 public ruleCount;

    struct ComplianceRule {
        string domain;          // Regulatory domain (Healthcare, Industrial)
        string description;     // Policy description
        uint256 riskThreshold;  // Threshold for enforcement
        bool isActive;
    }
```

```
    mapping(uint256 => ComplianceRule) public rules;
    mapping(address => bool) public deviceAllowed;

    event RuleAdded(uint256 indexed ruleId, string domain, uint256 riskThreshold);
    event DeviceStatusUpdated(address indexed device, bool allowed);

    modifier onlyAdmin() {
        require(msg.sender == admin, "Only admin allowed");
        _;
    }

    constructor() {
        admin = msg.sender;
    }

    function addRule(string memory domain, string memory description, uint256
riskThreshold) public onlyAdmin {
        rules[ruleCount] = ComplianceRule(domain, description, riskThreshold, true);
        emit RuleAdded(ruleCount, domain, riskThreshold);
        ruleCount++;
    }

    function updateDeviceStatus(address device, uint256 riskScore) public onlyAdmin {
        bool allowed = true;
        for (uint i = 0; i < ruleCount; i++) {
            if (rules[i].isActive && riskScore > rules[i].riskThreshold) {
                allowed = false;
                break;
            }
        }
        deviceAllowed[device] = allowed;
        emit DeviceStatusUpdated(device, allowed);
```

```
    }

    function isDeviceAllowed(address device) public view returns (bool) {
        return deviceAllowed[device];
    }
}
```

Appendix B – Sample Transaction Log Summary

- Event: RuleAdded — {domain: "block_ip", riskThreshold: 1}
- Event: DeviceStatusUpdated — {device: 0x358..., allowed: true}
- Block Number: 8–9
- Gas Costs: 119150–33433 (efficient execution)