Lecture Notes in Networks and Systems 1040

Marcelo Zambrano Vizuete · Miguel Botto-Tobar · Sonia Casillas · Carina Gonzalez · Carlos Sánchez · Gabriel Gomes · Benjamin Durakovic *Editors*

Innovation and Research – Smart Technologies & Systems

Proceedings of the CI3 2023, Volume 1

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Preface

The 4th edition of the International Research and Innovation Congress – Smart Technologies and Systems, CI3 2023, took place from August 30 to September 1, 2023, at the facilities of the Instituto Tecnológico Universitario Rumiñahui, located in the city of SangolquÍ, Pichincha, Ecuador.

The conference was organized by the Red de Investigación, Innovación y Transferencia de Tecnología RIT2, made up of the most relevant university institutes in Ecuador, among which are ITCA, BOLIVARIANO, ARGOS, VIDA NUEVA, ESPÍRITU SANTO, SUDAMERICANO, ISMAC, SAN ISIDRO, ARTES GRÁFICAS, ORIENTE, HUMANE, SUCRE, CENTRAL TÉCNICO, POLICÍA NACIONAL and RUMIÑAHUI.

Additionally, the event is sponsored by the Secretaría de Educación Superior, Ciencia, Tecnología e Innovación SENESCYT, Labortorio de Comunicación Visual de la Universidad Estatal de Campinas—Brazil, Universidad Ana G. Méndez—Puerto Rico, Centro de Investigaciones Psicopedagógicas y Sociológicas—Cuba, Instituto Superior de Diseño de la Universidad de La Habana—Cuba, GDEON and the Corporación Ecuatoriana para el Desarrollo de la Investigación y la Academia—CEDIA.

The main objective of CI3 2023 is to generate a space for dissemination and collaboration, where academia, industry and government can share their ideas, experiences and results of their projects and research.

"Research as a pillar of higher education and business improvement" is the motto of the Conference and suggests how research, innovation and academia must coincide with the productive sector to leverage social and economic development.

CI3 2023 had 145 papers submitted, of which 52 were accepted for publication and presentation. To guarantee the quality of the publications, the event has a staff of more than 70 experts, from different countries such as Spain, Argentina, Chile, Mexico, Peru, Brazil, Ecuador, among others, who carry out an exhaustive review of each proposal sent.

Likewise, during the event a series of keynote conferences were held, given by both national and international experts, allowing attendees to get in touch with the latest trends and technological advances around the world. Keynote speakers included: Ph.D. Carina González, University of La Laguna, Spain; Ph.D. Gabriel Gómez, State University of Campinas, Brazil; Ph.D. Carlos Sanchez, University of Zaragoza, Spain; Ph.D. Juan Minango, Instituto Tecnológico Superior Rumiñahui; Dr. Iván Cherrez, Universidad Espíritu Santo, Ecuador; and Ph.D. Nela Paustizaca, Escuela Politécnica del Litoral, Ecuador.

The content of this proceeding is related to the following topics:

- Smart Cities
- Innovation and Development
- Applied Technologies
- Economics and Management
- ICT for Educations.

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Contents

Smart Cities

Exploring the Use of Blockchain for Academic Certificates: Development, Testing, and Deployment

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Abstract. This study presents the development and deployment of a smart contract for issuing academic certificates on the Sepolia network. The smart contract, built using the Solidity language and the ERC721 standard, enables secure and decentralized certification, ensuring the integrity and immutability of academic records. The deployment process was facilitated by the use of the Alchemy development tool, allowing for seamless interaction with the blockchain network. The successful deployment was confirmed through the acquisition of the contract address and the verification of transaction details on Etherscan. Unit tests were conducted to ensure the functionality and reliability of the smart contract, validating its ability to mint and verify academic certificates. The results demonstrated the potential of blockchain technology in transforming traditional certification systems by providing transparency, tamper-proof records, and enhanced security. This study contributes to the growing field of blockchain applications in the academic sector, highlighting the importance of decentralized solutions for efficient and trustworthy certification processes.

Keywords: Smart contract · Academic certificates · Blockchain · deployment · Alchemy · ERC721 · Decentralized certification

1 Introduction

Blockchain technology has emerged as a groundbreaking innovation with far-reaching implications across industries. Its decentralized and transparent nature has the potential to disrupt traditional systems, establishing new standards of trust, security, and efficiency [1,2]. By providing a decentralized ledger that records transactions and information across a network of computers, blockchain eliminates the need for intermediaries, reduces the risk of fraud, and enhances transparency [3].

One of the key advantages of blockchain is its ability to establish trust in a trustless environment. Through cryptographic techniques and consensus

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mechanisms, blockchain ensures the integrity and immutability of data, making it resistant to manipulation and tampering. This feature has the potential to revolutionize industries such as finance, supply chain management, healthcare, the academic sector, and many more, where trust and transparency are paramount [4].

In finance, blockchain technology enables secure and efficient peer-to-peer transactions without the need for traditional intermediaries such as banks [5]. It provides a decentralized and tamper-proof record of transactions, enhancing security and reducing costs associated with traditional payment systems. Additionally, blockchain-based smart contracts automate and enforce the terms of agreements, streamlining processes and minimizing the risk of disputes [5,6].

In supply chain management, blockchain facilitates end-to-end traceability, enabling businesses and consumers to track the journey of products from origin to destination. This transparency helps in verifying the authenticity and quality of goods, ensuring compliance with regulations, and combating issues such as counterfeiting and supply chain fraud. By providing an immutable record of transactions and product information, blockchain enhances trust among participants and simplifies complex supply chain processes [7].

In the healthcare industry, blockchain has the potential to revolutionize data sharing and patient records management. With blockchain, patients can have control over their medical records, granting access to healthcare providers as needed. This decentralized approach improves the security and privacy of sensitive medical information while enabling interoperability and efficient sharing of data among healthcare providers, leading to better patient outcomes and more effective research [8].

Furthermore, blockchain technology has demonstrated adaptability across different sectors, including energy, voting systems, intellectual property, and more. Its decentralized and transparent nature can enhance the efficiency, security, and accountability of various processes. By utilizing blockchain, organizations can streamline operations, reduce costs, mitigate risks, and establish new business models that were previously not feasible [9].

Besides, the academic sector can also benefit significantly from the implementation of blockchain technology. One of the key applications is in the issuance and verification of academic certificates. By leveraging blockchain, educational institutions can create tamper-proof digital certificates as non-fungible tokens (NFTs). These NFT-based certificates provide a secure and decentralized record of achievements, enabling easy verification by employers and other educational institutions. This eliminates the risks associated with counterfeit certificates and simplifies the verification process, enhancing trust and reliability in academic credentials [10].

Thus, in this paper, we present the development of a smart contract[1] for the emission of academic certificates by Instituto Tecnológico Universitario Rumiñahui (ISTER). The smart contract was deployed on a blockchain net-

[1] We have included the link of the repository of the Academic Certificate smart contract [https://github.com/jminangoIster/corn_leaves_diseases] for reproducibility.

work, allowing us to interact with it using the Metamask wallet. By leveraging the capabilities of blockchain technology and the Ethereum network, we aim to change the certification process and enhance the transparency, security, and accessibility of academic credentials issued by ISTER.

The remainder of this paper is organized as follows. Section 2 provides an introduction to the Ethereum network, specifically the Sepolia network, which was utilized for deploying and testing our smart contracts. In Sect. 3, we provide a concise overview of the development tools and network connection, which served as the foundation for the implementation and interaction with our smart contracts. Section 4 delves into the details of the smart contract developed specifically for issuing academic certificates, highlighting its key functionalities and mechanisms. The deployment results of the smart contract are presented in Sect. 5, showcasing the outcomes and performance metrics. Finally, in Sect. 6, we draw conclusions based on our findings and discuss the implications and potential future directions for further research in this domain.

2 Ethereum and the Sepolia Network

The Ethereum network has gained significant attention as a decentralized, open-source blockchain platform that enables the development and deployment of smart contracts. With its native cryptocurrency, Ether (ETH), Ethereum provides a robust and versatile environment for building decentralized applications (dApps) and executing programmable transactions [4,11].

In this section, we introduce the Sepolia network, a specific instance of the Ethereum network that we utilized for deploying and testing our smart contract for issuing academic certificates. Sepolia is a test network specifically designed for development and experimentation purposes, providing developers with a sandbox-like environment to deploy and interact with smart contracts before deploying them on the Ethereum mainnet [12].

Sepolia offers several advantages for blockchain tests. Firstly, it allows us to test the functionality and performance of our academic certificate smart contract without incurring any real-world costs or risks associated with the deployment on the mainnet. This enables us to iterate and refine our implementation before taking it live [13].

Secondly, Sepolia provides a network with a similar architecture and consensus mechanism to the Ethereum mainnet, allowing us to simulate real-world conditions and gauge the scalability and efficiency of our smart contract deployment [10]. By using Sepolia, we can evaluate the network's transaction processing capabilities, gas costs, and potential bottlenecks that may affect the issuance and verification of academic certificates.

2.1 Faucet in the Sepolia Network

A faucet is a service specifically designed for test networks like Sepolia. Its purpose is to distribute test ETH to developers, allowing them to cover transaction

costs and simulate real-world scenarios without incurring any expenses. Test ETH obtained from the faucet serves as a valuable resource for deploying and interacting with smart contracts in a risk-free environment [14,15].

To obtain test ETH through the Sepolia faucet, we must follow these steps:

1. Visit the Sepolia testnet faucet website or a compatible faucet service designed for the Sepolia network.
2. Provide the Ethereum address associated with the wallet that will be used for interacting with the academic certificate smart contract on Sepolia.
3. Submit a request to receive test ETH by clicking on the "Request" or "Get Test ETH" button.
4. The faucet service will process the request and verify the provided Ethereum address.
5. Upon successful verification, the faucet will transfer a predetermined amount of test ETH to the provided Ethereum address.
6. By obtaining test ETH through the faucet, we can seamlessly engage with the academic certificate smart contract on Sepolia without the need for real funds. This enables thorough testing, debugging, and validation of the smart contract's functionality before deploying it on the live Ethereum network.

3 Development Tools and Network Connection

3.1 Hardhat: A Development Framework

In the development of the academic certificate smart contract, the Hardhat framework was utilized. Hardhat is a popular development environment for Ethereum smart contracts, providing a robust set of tools and utilities that facilitate the entire development lifecycle. It offers features such as smart contract compilation, deployment, testing, and debugging.

Hardhat simplifies the development process by providing a command-line interface (CLI) for executing tasks related to smart contracts. It supports the Solidity programming language and integrates seamlessly with various Ethereum networks, including the Sepolia network. With Hardhat, developers can efficiently write, compile, and deploy their smart contracts, making it an ideal choice for this research.

3.2 Alchemy: Connecting to the Sepolia Network

To interact with the Sepolia network and deploy the academic certificate smart contract, the Alchemy platform was used. Alchemy acts as an infrastructure provider, offering developers easy access to Ethereum networks and providing powerful APIs for blockchain connectivity.

Alchemy simplifies the process of establishing a connection with the Sepolia network by providing a reliable and user-friendly interface. It offers advanced features such as transaction monitoring, debugging tools, and real-time network

analytics. By leveraging Alchemy, developers can seamlessly interact with the Sepolia network, deploy smart contracts, and monitor their transactions.

Figure 1 showcases the Ister Academic Certificates decentralized application (DApp) running on the Alchemy platform. The DApp interface displays the network connection details, including the Sepolia network, which enables seamless interaction with the academic certificate smart contract. Users can mint and verify academic certificates securely through the user-friendly interface provided by the DApp. The integration of Alchemy ensures reliable and efficient network connectivity, enhancing the overall experience of issuing and verifying academic certificates on the blockchain.

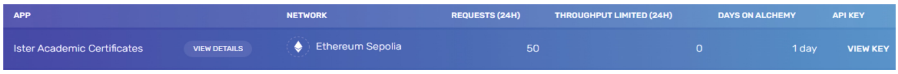

Fig. 1. Ister Academic Certificates DApp on Alchemy.

3.3 Metamask: Interacting with the Academic Certificate and Faucet

Metamask is a widely used browser extension that serves as a digital wallet and allows users to interact with Ethereum-based applications. In the context of the academic certificate smart contract, Metamask plays a crucial role in facilitating user interactions and accessing the Sepolia network.

By installing the Metamask extension in our web browser, users can create Ethereum wallets and securely store their cryptographic keys. Metamask also provides an intuitive user interface for interacting with the academic certificate smart contract, enabling users to mint and verify certificates.

Metamask was configured to connect to the Sepolia network by adding the appropriate network details, including the network name, chain ID, RPC URL, and optionally the faucet's address. Once connected, users can seamlessly interact with the smart contract deployed on the Sepolia network, minting and verifying academic certificates.

Figure 2 shows the Metamask browser extension interface with an account named "Ister" connected to the Sepolia network. The account balance of 0.5 SepoliaETH indicates that the account has successfully received faucet funds. The integration of Metamask provides a user-friendly and convenient experience for managing blockchain transactions and interacting with the academic certificate system.

By combining Hardhat for development, Alchemy for network connection, and Metamask for user interactions, the academic certificate smart contract can be efficiently developed, deployed, and interacted with on the Sepolia network. This combination of tools and technologies ensures a seamless and user-friendly experience for all stakeholders involved.

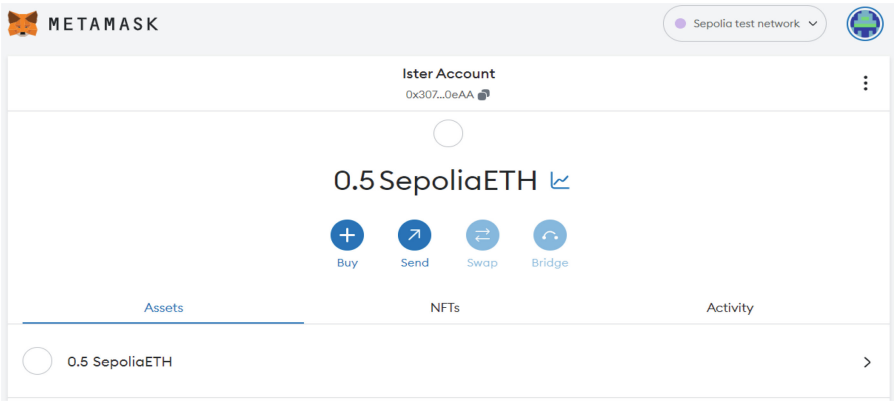

Fig. 2. Metamask Browser Interface with Ister Account on Sepolia Network.

4 Academic Certificate Smart Contract: Functionality and Mechanisms

In this section, we provide an in-depth explanation of the smart contract developed for issuing academic certificates. The smart contract, named "AcademicCertificate", is built on the Ethereum blockchain using the Solidity programming language.

The contract inherits from the ERC721 standard which is shown in Listing 1.1, which is a widely adopted standard for non-fungible tokens (NFTs) on Ethereum. Unlike fungible tokens, which are interchangeable and identical to each other (like cryptocurrencies), non-fungible tokens represent unique assets that can have distinct characteristics and properties. Each ERC721 token is assigned a unique identifier, or token ID, which distinguishes it from other tokens in the same contract. Thus, our contract ensures that each academic certificate issued is unique and can be easily transferred and verified.

Listing 1.1. AcademicCertificate contract

```
contract AcademicCertificate is ERC721 {
}
```

The structure of an academic certificate is defined within the contract using a struct. It includes fields such as recipient name, date of issue, issuer, course, grade, and duration. These fields capture the essential information associated with each certificate and it is presented in Listing 1.2.

Listing 1.2. AcademicCertificate contract

```
 struct Certificate {
        string recipientName;
        uint256 dateOfIssue;
        string issuer;
```

```
        string course;
        string grade;
        string duration;
    }
```

To mint a new certificate NFT, the contract includes a function named "mintCertificate". This function requires that the caller is the designated "Ister Account", which ensures that only authorized entities can emit academic certificates. Upon minting, a new certificate ID is generated, and the certificate data is stored in a mapping. See Listing 1.3.

Listing 1.3. AcademicCertificate contract

```
function mintCertificate(
        string memory _recipientName,
        uint256 _dateOfIssue,
        string memory _issuer,
        string memory _course,
        string memory _grade,
        string memory _duration
    ) public {
        require(_isterAccount == msg.sender, ''Just Ister
             Account can emit Academic Certificates'');
        uint256 certificateId = _totalCertificates + 1;
        certificates[certificateId] = Certificate(
            _recipientName,
            _dateOfIssue,
            _issuer,
            _course,
            _grade,
            _duration
        );
        _mint(msg.sender, certificateId);
        _totalCertificates ++;
        emit NewCertificate(
            certificateId,
            _recipientName,
            _dateOfIssue,
            _issuer,
            _course,
            _grade,
            _duration
        );
    }
```

The contract also includes a function named "verifyOwnership" which allows anyone to verify their ownership of a certificate NFT by providing its ID. This function returns a boolean value indicating whether the caller is the owner of the specified certificate as is shown in Listing 1.4.

Listing 1.4. AcademicCertificate contract

```
function verifyOwnership(uint256 _certificateId) public
    view returns (bool) {
        return ownerOf(_certificateId) == msg.sender;
    }
```

Additionally, the contract emits an event named "NewCertificate" whenever a new certificate is minted. This event includes the certificate ID, recipient name, date of issue, issuer, course, grade, and duration. See Listing 1.5.

Listing 1.5. AcademicCertificate contract

```
event NewCertificate(
        uint256 indexed certificateId,
        string recipientName,
        uint256 dateOfIssuem,
        string issuer,
        string course,
        string grade,
        string duration
    );
```

5 Results and Performance Metrics

5.1 Unitary Tests

In the repository accompanying this article, a comprehensive set of test cases has been developed to validate the functionality and performance of the AcademicCertificate smart contract. These tests utilize the Mocha and Chai testing frameworks, along with the Hardhat development environment.

The tests cover various aspects of the contract, including the deployment process, the minting of new certificate NFTs, and the verification of ownership. By running these tests, it is possible to ensure that the smart contract behaves as expected and meets the desired requirements.

The first test case, "should mint a new certificate NFT," verifies that the contract successfully mints a new certificate with the specified details and assigns ownership to the correct address. It ensures that the certificate data is correctly stored and retrievable.

The second test case, "should verify ownership of a certificate NFT," ensures that the contract correctly verifies the ownership of a certificate NFT. It validates that only the rightful owner can claim ownership and that unauthorized users are unable to do so.

These test cases provide a solid foundation for ensuring the robustness and reliability of the AcademicCertificate contract. They enable developers and users to have confidence in the contract's functionality and its ability to issue and verify academic certificates securely and accurately.

Figure 3 shows the successful execution of the tests using the command 'npx hardhat test'. The tests verify the functionality of the AcademicCertificate smart contract, ensuring that it properly mints a new certificate NFT and verifies the ownership of the certificate. The tests were executed using the Hardhat development environment, which provides a robust and reliable framework for testing Ethereum smart contracts."

```
PS C:\ws-ethereum\educationalCertificates> npx hardhat test


  AcademicCertificate
    Deployment
      ✓ should mint a new certificate NFT (924ms)
      ✓ should verify ownership of a certificate NFT (46ms)


  2 passing (977ms)
```

Fig. 3. Successful execution of tests using 'npx hardhat test'. The tests verify the functionality of the AcademicCertificate smart contract, ensuring proper certificate issuance and ownership verification.

5.2 Deployment Results and Verification on Alchemy and Etherscan

To deploy the AcademicCertificate smart contract, we execute the command 'npx hardhat run scripts/deploy.ts –network sepolia' which will run the deployment script using the sepolia network.

Upon successful deployment, we received a message indicating that the "Academic Certificate" contract has been deployed. The contract address was displayed as: "Contract deployed at address: 0x4e86B73205B95c6537B307e778158 01b2ee7F7e4" as it is shown in Fig. 4.

```
PS C:\ws-ethereum\educationalCertificates> npx hardhat run scripts/deploy.ts --network sepolia
Academic Certificate Successfully Deployed!
Contract deployed at address: 0x4e86B73205B95c6537B307e77815801b2ee7F7e4
```

Fig. 4. Successful Deployment of the Academic Certificate Smart Contract.

The contract address shown in Fig. 4 represents the unique identifier assigned to the deployed Academic Certificate smart contract on the blockchain network. This address serves as a reference or identifier to interact with the specific instance of the smart contract.

In simpler terms, the contract address can be thought of as the location of the smart contract on the blockchain. It allows users to interact with the deployed

contract, such as minting new certificate NFTs or verifying ownership of existing certificates.

Alchemy Dashboard Results. In this subsubsection, the results from the successful deployment of the Academic Certificate smart contract on the Alchemy dashboard are presented and discussed.

Figure 5 shows the Alchemy Dashboard, displaying important deployment statistics of the Academic Certificate smart contract. The dashboard reveals key metrics such as the median response time of 22 ms, indicating the efficiency and responsiveness of the deployed contract. Additionally, the success rate of 98% highlights the robustness and reliability of the deployment process. These results demonstrate the successful deployment and smooth operation of the Academic Certificate smart contract on the Ethereum network, ensuring seamless issuance and verification of academic certificates.

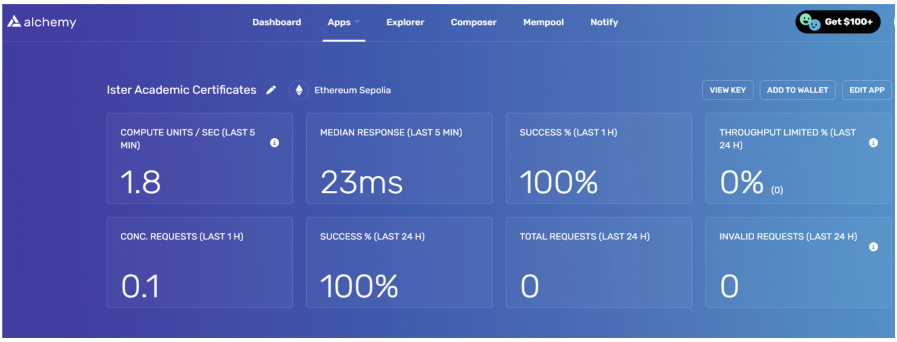

Fig. 5. Alchemy Dashboard showing deployment statistics of the Academic Certificate smart contract.

Figure 6 showcases the Alchemy Explorer, providing detailed information about the Ister Account and various Ethereum network parameters. The public key associated with the Ister Account is displayed, ensuring secure and authenticated interactions with the blockchain. Additionally, key network parameters such as eth_chainId, eth_getTransactionReceipt, eth_blockNumber, and eth_getTransactionCount are visible, providing insights into the current state of the Ethereum network. These parameters play a crucial role in facilitating transactions, verifying blocks, and ensuring the integrity of the blockchain. Thus, the Alchemy Explorer serves as a valuable tool for monitoring and analyzing blockchain activity, enhancing transparency and reliability in the deployment and utilization of the Academic Certificate smart contract.

Figure 7 provides essential information about individual transactions related to our academic certification smart contract. This information includes:

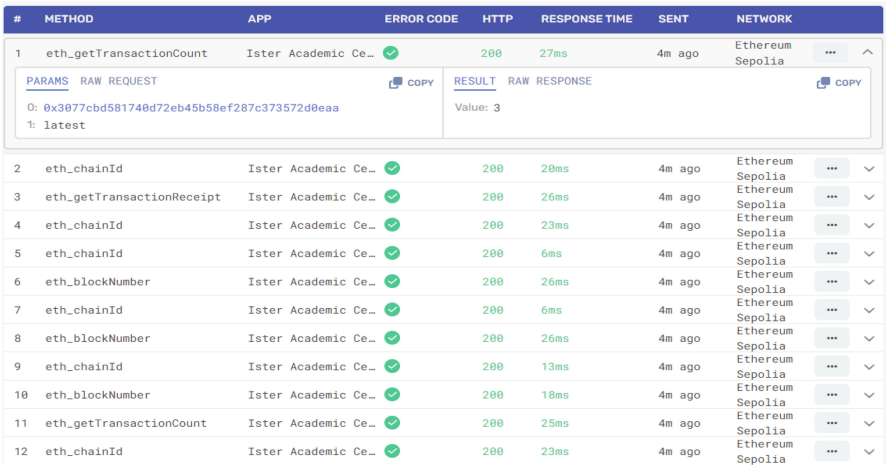

Fig. 6. Alchemy Explorer displaying information related to the Ister Account and Ethereum network parameters.

- Transaction Hash: This is a unique identifier for each transaction. It serves as a reference point to track and verify the transaction's details and status on the blockchain.
- Network: Indicates the specific network on which the transaction is taking place. This helps ensure that the transaction is being executed on the intended network.
- Block Number: The block number in which the transaction is included. It helps determine the position of the transaction in the blockchain's chronological order.
- Gas: Gas represents the computational cost required to execute the transaction. It is a fundamental concept in Ethereum and ensures that participants are fairly incentivized for their computational work.
- From Address: The address of the sender who initiated the transaction. In the context of our academic certification smart contract, this could be the address of the academic institution or the authorized issuer.
- To Address: The address of the recipient or the destination of the transaction. In the case of academic certifications, this would typically be the address of the individual receiving the certificate.
- Transaction Type: Indicates the type of transaction being executed. In this case, it is labeled as EIO-1559, which refers to a specific type of transaction related to the Ethereum Improvement Proposal (EIP) 1559. EIP-1559 aims to improve transaction fee predictability and efficiency on the Ethereum network.

Etherscan. Etherscan is a widely used blockchain explorer and analytics platform for the Ethereum network. It provides users with a comprehensive view

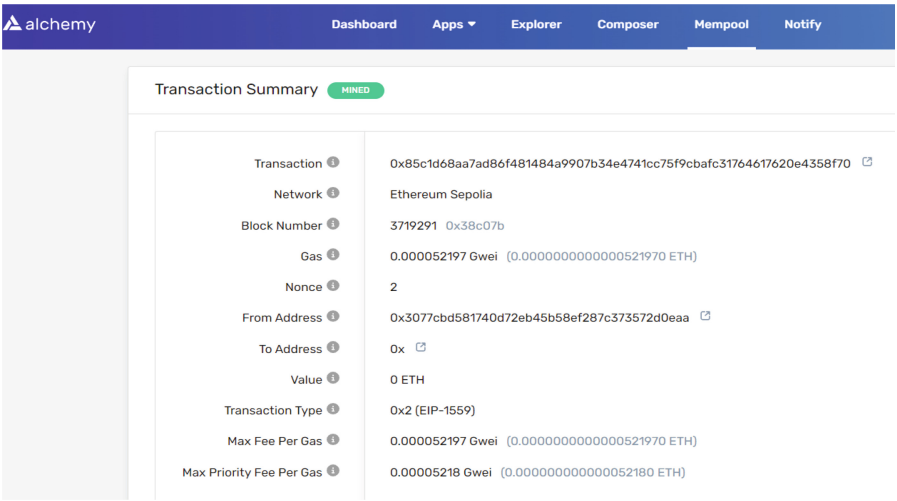

Fig. 7. Transaction Summary in Alchemy Mempool.

of the Ethereum blockchain, allowing them to explore and verify transactions, smart contracts, addresses, and other on-chain activities. Etherscan offers various features, including the ability to search for specific transactions, view account balances, track token transfers, and monitor contract interactions. It also provides detailed information about block confirmations, gas fees, and network statistics. Overall, Etherscan is a valuable tool for individuals and businesses to gain insights and transparency into the Ethereum blockchain ecosystem.

Figure 8 shows the transaction details on Etherscan for the deployment of the Academic Certificate smart contract. It includes important information such as the contract address and transaction hash.

The contract address represents the unique identifier of the deployed smart contract on the Ethereum blockchain. It serves as the entry point for interacting with the contract and accessing its functionalities.

The transaction hash is a unique identifier for the transaction that deployed the smart contract. It can be used to track and verify the transaction's status and details, including the sender, recipient, gas used, and block confirmation.

Etherscan provides a comprehensive view of these transaction details, enabling users to validate and audit smart contract deployments. It also offers additional information such as the transaction timestamp, gas price, and cumulative gas used. This data helps ensure transparency and accountability in the deployment process.

Finally, Fig. 9 displays the transaction details on Etherscan for the successful deployment of the Academic Certificate smart contract on the Sepolia network. The information presented in this figure is similar to the transaction summary shown in the Alchemy dashboard.

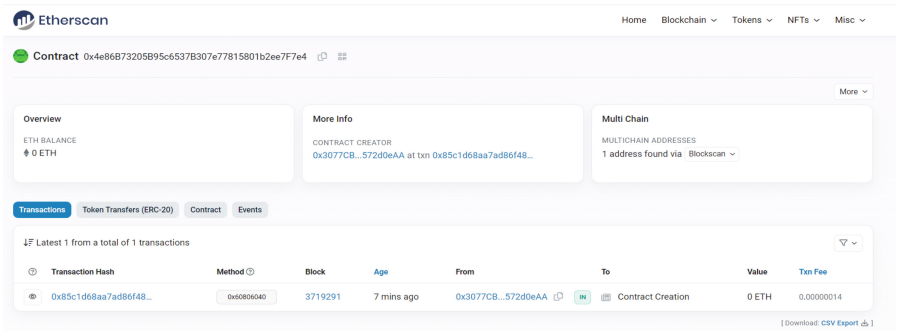

Fig. 8. Etherscan Transaction Details for Academic Certificate Deployment.

The transaction details include the transaction hash, which uniquely identifies this specific transaction on the blockchain. Additionally, it provides essential information such as the network (Sepolia), block number, gas used, and the sender and recipient addresses. These details confirm that the Academic Certificate smart contract was deployed on the Sepolia network and validate its successful execution.

The inclusion of this figure reinforces the successful deployment of the smart contract and highlights the transparency and public accessibility of transaction details on the Ethereum blockchain through platforms like Etherscan.

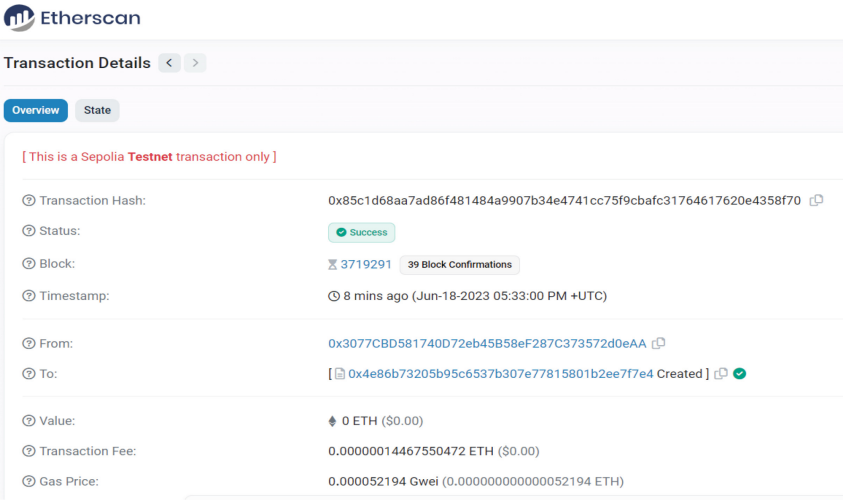

Fig. 9. Etherscan Transaction Details for Academic Certificate Deployment.

6 Conclusion

This study focused on the development and deployment of an academic certificate smart contract on the Sepolia network. Through rigorous unit testing, we ensured the reliability and functionality of the smart contract, validating its ability to issue and verify academic certificates securely on the blockchain. Utilizing Alchemy as our development tool, we successfully deployed the smart contract on the Sepolia network. The deployment process was smooth, and we observed positive outcomes, including the acquisition of the contract address and confirmation of successful deployment. The use of Alchemy provided us with valuable insights into network performance metrics, such as median response time and success percentage, further reinforcing the efficiency and effectiveness of the deployed smart contract. Furthermore, our exploration of Etherscan allowed us to delve deeper into the transaction details, confirming the transparency and accessibility of blockchain data. This demonstration solidifies the successful deployment of the academic certificate smart contract on the Sepolia network. Overall, this study showcases the potential of blockchain technology, specifically smart contracts, in revolutionizing academic certification systems. By leveraging the capabilities of the Sepolia network, Alchemy, and Etherscan, we have achieved a robust and transparent solution for issuing and verifying academic certificates. Moving forward, further research and development in this area can unlock even more opportunities for secure and decentralized certification systems.

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