Celestia Whitepaper

Introduction to the Celestia Whitepaper

Celestia is a modular data availability network that aims to provide scalable, secure, and flexible infrastructure for decentralized applications by decoupling key components of blockchain technology. Unlike traditional monolithic blockchains, where consensus, execution, and data availability are tightly integrated, Celestia introduces a modular architecture where these layers are separated. This allows for a more efficient, scalable, and customizable blockchain ecosystem.

By employing a unique solution called data availability sampling (DAS), Celestia enables resource-constrained light nodes to verify the availability of large amounts of data without downloading the full blockchain. This innovation allows for the safe scaling of block size, and the number of users can grow without increasing verification costs for participants. Moreover, this approach empowers users and developers to launch their own blockchain networks easily, without the need for heavy infrastructure, further democratizing blockchain technology.

This whitepaper will explore the key components of Celestia's architecture, how it addresses scalability, and the role of its native token, TIA, in ensuring the network's security and governance.

Overview of Celestia

Introduction

Celestia represents a paradigm shift in blockchain architecture by embracing a modular approach, where different functionalities are isolated into separate layers. This design allows Celestia to specialize in data availability and consensus while enabling other networks to handle execution, enhancing the flexibility and scalability of the entire system.

Traditional blockchains, referred to as **monolithic blockchains**, bundle consensus, data availability, and execution into one single system. This makes them harder to scale as all nodes must perform every task: verify transactions, reach consensus, and store data. Celestia decouples these components, laying the foundation for **modular blockchains**, where each layer can be optimized separately.

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Monolithic vs. Modular Blockchains

In a **monolithic blockchain**, like Bitcoin or Ethereum, nodes are required to verify both the execution of transactions and the data availability of blocks, which means that every participant in the network must perform all the tasks involved in running a blockchain. This has led to significant limitations in scalability as transaction throughput is constrained by the capacity of the network's consensus layer.

Conversely, a **modular blockchain architecture** separates the blockchain stack into three layers:

1. **Execution Layer**: Responsible for executing transactions and smart contracts.
2. **Consensus Layer**: Ensures that all participants agree on the order of transactions.
3. **Data Availability Layer**: Guarantees that the data necessary to verify transactions is available to all participants.

Celestia focuses solely on the consensus and data availability layers. This separation allows the execution layer to be outsourced to other systems, such as rollups or application-specific blockchains (appchains). As a result, developers can deploy their own execution environments without worrying about consensus or data availability.

By removing the need for consensus nodes to execute every transaction, Celestia significantly increases throughput and makes the system more scalable. The modular approach allows different layers to be optimized independently, creating a more adaptable blockchain ecosystem.

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Data Availability Layer

At the core of Celestia's architecture is its innovative approach to the **data availability problem**. Traditional blockchains suffer from a critical issue: ensuring that all transaction data in a block is available to the network for verification. Celestia solves this through a novel technique called **data availability sampling (DAS)**.

Data Availability Sampling (DAS)

In a traditional blockchain, all nodes must download and store the entire history of transaction data to verify the blockchain. However, as block sizes increase, this becomes impractical for smaller or resource-constrained nodes. Celestia

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introduces a solution that allows light nodes to verify the availability of data without needing to download the entire block.

In data availability sampling, nodes randomly sample small portions of a block's data (referred to as shares). If a sufficient number of shares are available and valid, it can be assumed that the entire block's data is available. The process works as follows:

1. A block proposer creates a block and encodes the data using **erasure coding**, breaking it into multiple shares.
2. Light nodes in the network sample random shares from the block.
3. If enough light nodes successfully retrieve shares, they can collectively confirm the availability of the entire block's data.

This method ensures that even with minimal resources, nodes can participate in verifying the network, contributing to the security and scalability of the system.

Scaling with Light Nodes

An interesting outcome of Celestia's architecture is that as more light nodes participate in data availability sampling, the network can safely handle larger blocks. This is because the probability of detecting unavailable data increases as more nodes sample different parts of the block. As a result, block sizes can grow without disproportionately increasing the cost of verifying the chain. This provides Celestia with the ability to scale efficiently with an increasing number of participants, creating a system where higher network activity is met with enhanced scalability and security.

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TIA Token Overview

Introduction to TIA

Celestia's native token, **TIA**, plays a critical role in maintaining the security, governance, and economic model of the network. TIA is a utility token that is used for securing the network through staking, paying for data availability (blobspace), and participating in governance.

Paying for Blobspace

In Celestia, **blobspace** refers to the data storage capacity within each block. Users who wish to store data on the Celestia network must pay for this space using TIA.

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The cost of blobspace is determined by the amount of data being stored and the current demand for space within blocks. This mechanism ensures that users are incentivized to use data storage efficiently and that the network remains decentralized and secure.

By paying for blobspace, users can upload their transaction data, which is then encoded and included in blocks by validators. Light nodes sample this data to ensure its availability, thereby contributing to the overall security of the network.

Staking, Governance, and Supply

How to Stake TIA

Staking is a core component of securing the Celestia network. Validators stake TIA to participate in consensus and produce blocks. The amount of TIA staked directly influences a validator's chance of being selected to propose the next block. Validators are rewarded in TIA for their participation, providing a strong incentive to act honestly and secure the network.

Users who do not wish to run their own validator can delegate their TIA to existing validators and earn a share of the rewards. Delegated staking allows for a broader participation base, ensuring that the network remains decentralized.

Governance

TIA token holders also play an essential role in the governance of Celestia. Major decisions regarding protocol upgrades, changes to the economic model, or the allocation of resources are decided through on-chain governance mechanisms. Token holders can vote on proposals using their staked TIA, ensuring that the future of the network is shaped by its community.

Token Supply

TIA has a capped supply, with an initial allocation distributed to early contributors, developers, and the broader community through a combination of airdrops and token sales. A portion of the supply is reserved for network incentives, ensuring that validators and other participants are rewarded for securing the network over time.

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Conclusion

Celestia represents the next step in blockchain scalability, providing a modular infrastructure where consensus, execution, and data availability are decoupled. Through innovations like data availability sampling, Celestia ensures that light nodes can verify the availability of large amounts of data without high resource costs, allowing for greater scalability and decentralization.

With the TIA token underpinning the network's security, governance, and economic model, Celestia empowers users to launch their own blockchains while benefiting from the shared security of its robust data availability network. This makes Celestia a key player in the future of blockchain development, enabling a new generation of scalable, flexible, and secure decentralized applications.

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