LightLink: The gasless blockchain network

v2.1

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Abstract

This paper presents LightLink, the Layer 2 gasless blockchain network for enterprises, decentralised applications (dApps), and millions of users. LightLink solves key blockchain challenges, including limited scalability, complex user experiences (UX), and low adoption rates, and creates a unified Web2–Web 3 economy. LightLink achieves its high transaction throughput and enhanced security with reduced gas fees through an optimistic rollup and proprietary stack built on Ethereum Layer 1. The new Hummingbird upgrade integrates Celestia's advanced data availability solutions and the novel Enterprise Mode to deliver gasless transactions, significantly reducing UX barriers for businesses with large pre-existing user bases. The paper details LightLink's architectural innovations, its potential to facilitate mass adoption of public blockchain technology in the enterprise sector, and its strategic approach to fostering a seamless, interconnected digital economy.

1. Introduction

Blockchain technology has sparked a new era of digital innovation, offering unparalleled security, transparency, and decentralisation to individuals and large businesses. However, its integration into enterprise-scale applications has been hindered by operational challenges including limited scalability, cost prohibitive transaction fees, and overwhelming user experiences. LightLink provides a Layer 2 blockchain network that addresses these challenges while retaining the security and decentralisation of Ethereum Layer 1.

This paper outlines LightLink's protocol architecture and features, and highlights its role in unlocking blockchain technology for mainstream enterprise-scale use. LightLink's innovative approach inspired by the best practices of Ethereum's Geth client, and complemented by the advanced data availability solutions of Celestia, sets a new standard for security and scalability. LightLink's novel Enterprise Mode aims to scale blockchain infrastructure, reduce transaction costs, and dramatically simplify the user experience.

Through a comprehensive analysis, this paper aims to provide insights into how LightLink is not just innovating blockchain infrastructure, but is paving the way for mass new user adoption.

2. Problem

In the early 2010s, enterprises began adopting blockchains for their ability to provide secure and transparent transaction recording and verification. Distributed ledger technology (DLT) allowed businesses to create a shared record of transactions that could not be easily altered, making it useful for a variety of enterprise applications such as supply chain management and financial transactions.

In practice, public blockchain technology provides an array of value propositions. However, for most enterprises, the emphasis often lies on transaction speed and privacy rather than decentralisation. To securely meet these requirements, enterprises have tended to adopt private blockchain infrastructures, consequently missing out on the opportunity to leverage the network effects of public blockchains such as Ethereum.

Network effects occur when the value of a product or service increases exponentially as its user base grows. Public blockchains like Bitcoin and Ethereum, experience robust network effects [1, 2]. As more individuals engage with the network, its utility and value increase. This benefit is amplified as additional users join, building upon the value established by earlier adopters. Public blockchains attract a large, diverse user base, enhancing their security, stability, and liquidity. In contrast, private blockchains, limited to a few participants, suffer from restricted network effects, which prevents them from harnessing the full advantages of a decentralised network. Private, isolated blockchains lack the robust interoperability that makes network effects possible. As a result, the potential benefits and wider adoption that public blockchain technology offers has been lost on enterprises using DLT.

Due to the limited throughput of most blockchain networks, it is difficult to support large numbers of users and transactions without encountering significant delays or costly spikes in gas fees. Limited throughput has hindered Web3 applications' ability to attract large user bases and provide a smooth and seamless user experience (UX). Another issue facing the industry is the lack of interoperability between different blockchain platforms, which creates barriers to entry across different applications. Overall, these challenges have made it difficult for Web3 applications to fully realise their potential and become mainstream.

Transaction fees on blockchain networks are traditionally paid in the native gas token of the network, which is a special type of cryptocurrency that is used to power the network and incentivise transaction processing. End users who are not familiar with cryptocurrency may find it confusing or intimidating to purchase and manage native gas tokens to pay transaction fees and use the network. The volatility profile of most cryptocurrencies also forms a sense of transactional cost unpredictability, further impeding the usability of a network. Ultimately, the use of native gas tokens as a means of paying transaction fees can be a significant barrier to entry for end users who are not familiar with cryptocurrency and blockchain technology.

3. Solution

LightLink is a Layer 2 blockchain network designed to bridge dApps with millions of users from enterprise partners, fostering an interconnected economy. It enables instant, gasless transactions for a seamless user experience. Built as an optimistic rollup on a proprietary stack atop the Ethereum Layer 1 network, and integrating with Celestia for state-of-the-art data availability, LightLink offers optimal scalability, interoperability, and user-friendly features. These capabilities are crucial for supporting the expansion and adoption of on-chain blockchain applications across dApps and enterprises.

LightLink greatly exceeds Ethereum's maximum capacity of 15 transactions per second (TPS), thanks to its use of optimistic rollup technology [2]. It achieves this enhanced performance by first processing transactions off-chain and then compressing them into rollups via a sequencer node, before posting them onto Ethereum. This process negates the high gas fees and execution bottlenecks of Layer 1 blockchains. By designing LightLink from the ground up to be compatible with Celestia's data availability solutions, the Layer 2 network can achieve unprecedented throughput and efficiency, making blockchain technology more accessible and affordable for users and enterprise partners alike.

LightLink operates at a maximum of 1,428 TPS, facilitated by a 15M gwei block gas limit and a 0.5s block time. This capacity is currently limited to ensure thorough testing and control, and is planned to increase to 5,712 TPS with a proposed gas limit of 60M gwei. While the theoretical maximum TPS is around 5,000, based on ETH transfers and base gas fees alone, this number might be slightly lower in practice due to smart contract executions, which consume more gas. Nonetheless, LightLink stands as one of the fastest Layer 2 EVM chains, processing over 400k transactions daily with fees as low as $0.001. The sequencer node's gas fees are efficiently distributed among all batched transactors, enhancing cost-effectiveness.

Today, LightLink simplifies the user experience by accepting ETH, a popular cryptocurrency in many popular Layer 2 solutions, to pay gas fees. This approach reduces the learning curve and lowers the entry barrier by eliminating the need for a new native token. With the launch of the LightLink token ("LL token"), enterprise businesses will have the ability to pay gas fees with predictability and certainty. Looking ahead, the LL token's utility will expand even further, and serve as a public gas token playing a crucial role in operating a Layer 3 network. After the LL Token Generation Event (TGE), gas payments made in LL will be discounted, reflecting reduced costs for the sequencer node. The revenue from gas fee discrepancies will be allocated to the community controlled treasury, directly benefiting stakers and aligning the interests of all stakeholders in the LightLink ecosystem.

As an optimistic rollup, when transactions are compressed into a batch which are eventually posted on the Ethereum mainnet, an assumption is made that all transactions are valid. Over a short period of time, network participants can challenge this assumption with cryptographic proofs which locate flaws in the transaction batch. These individuals are incentivised with rewards for successful fraud proofs from additional funds accrued by LightLink's sequencer node. Once the window to challenge batches has ended, the relevant transactions reach finality and cannot be reversed. The use of this technology allows LightLink to be highly compatible with Ethereum, encouraging developers that desire to use the optimised technology to move to the Layer 2 and bring along existing Solidity-based smart contracts.

Enterprise Mode: Core Advantage

LightLink's novel Enterprise Mode stands out as a purpose-built feature that meets the specific needs of enterprises and dApps. Enterprise Mode operates like a subscription model for gas, allowing enterprises to whitelist their applications to provide gas-free transactions to their users. By subsidising transaction fees, enterprises get an affordable, predictable monthly expense, in exchange for a seamless blockchain onboarding experience for their users.

Enterprise Mode Benefits:

- **Subsidising Transaction Costs**: Enterprises can subscribe to whitelist their applications to be gas-free and ensure their users are not responsible for paying transaction fees. This setup allows for the smooth operation of applications on LightLink, making it an attractive option for businesses looking to transition to blockchain technology.
- **Economic Freedom for Users**: Users gain the freedom to send, swap, or trade any digital asset, providing unparalleled economic flexibility.
- **Permissionless and Autonomous**: The permissionless nature of LightLink ensures users complete autonomy, enhancing trust and engagement with the network.
- **Security Backed by Ethereum**: Ethereum's robust security infrastructure provides LightLink with top-tier protection, instilling confidence in users and enterprises.
- **User-Friendly Experience**: The integration of popular custodial wallets simplifies the UX, and gasless transactions unthrottle advanced blockchain applications with high transaction volumes.
- **Predictable Fixed Fee Model**: LightLink's fixed fee subscription model provides financial predictability for enterprises, eliminating the typical volatility of transaction fees in public blockchain networks.

Adopting LightLink's Enterprise Mode offers businesses a significant advantage, enabling them to deploy an array of efficient and effective use cases in enterprise environments. (*See: 9. Business Applications*)

4. Design Principles

LightLink is led by CEO Roy Hui, a serial tech entrepreneur with three successful exits over two decades, and COO Olivia Romero, formerly of Boston Consulting Group with two exits. Among LightLink's core developers are Daniel Hayden, with over 15 years of experience at companies like Dell Technologies and Alchemy, and Senior Web3 Engineer Shayne Brady, Linktree contributor and full-stack developer with 10 years of experience.

LightLink's design philosophy is driven by three core principles: ease of use, adoption and composability. LightLink's underlying architecture and user experience (UX) is fundamentally focused on realising these three guiding principles.

4.1. Ease of Use

In the ever-changing context of blockchains, simplicity and ease of use are two features that are invariably challenging to come by. Hence, through a number of features, LightLink strives to offer its users with a superior user interface (UI) and UX.

As detailed above, rollups are typically limited in their usability because of the need to pay gas in its native token. LightLink renders itself a usable platform given that users will never be solely required to pay for transaction execution with LL, but can additionally decide to utilise their bridged ETH. This feature means that users can efficiently bridge their ETH onto the Layer 2 and immediately be able to transact, interact and utilise the various applications present on the network. Simultaneously, once the token is launched, there is no intention to prohibit users from leveraging their LL to pay gas fees should they choose to hold tokens for their utilities. One such utility is the ability to pay gas fees at a discounted rate. Accordingly, following the public launch of the token, users satisfying transaction costs with LL on the LightLink network, will receive a 10% reduction in fees.

With the optimistic rollup technology used by LightLink, compatibility with the Ethereum Virtual Machine (EVM) can be optimised [2]. As such, smart contracts can be executed in the EVM bytecode, enabling developers to create and deploy their contracts on LightLink using the same tools and languages used for the Ethereum mainnet. In addition, this feature ensures interoperability between LightLink, other Layer 2s as well as other EVM-compatible blockchains.

LightLink champions ease of use for its enterprise partners and their clients through gasless transactions and unparalleled speed. LightLink's novel Enterprise Mode empowers users to engage with blockchain technology without any pre-existing cryptocurrency holdings, such as ETH or LL. This means that new wallets can be created instantly and transactions executed, without the added steps and complexity of having to onboard fiat or crypto. This functionality effectively removes a significant barrier to blockchain adoption, inviting a new segment of users who have yet to purchase any cryptocurrency into the network.

Enterprises utilising LightLink protocols contribute a monthly fee to cover all associated gas fees, thereby enabling end-users to transact at no cost. This model is not only user-friendly but also taps into an untapped market segment, potentially expanding the reach and adoption of blockchain technology. LightLink's continual uptime and high-capacity transaction throughput further improves UX for applications in areas like supply chain, ticketing, or metaverse projects where a responsive, seamless and efficient UX are critical and efficient.

4.2. Composability

In order to support a range of different enterprise and non-enterprise applications, LightLink offers unparalleled composability and flexibility in its design. Composability is an important design principle for blockchains, as it allows the technology to be used in combination with other systems and technologies. This design principle is important because it allows businesses to tailor the technology to their specific needs. Indeed, LightLink is able to support custom smart contracts that enable enterprises to automate complex processes and reduce the need for manual intervention.

LightLink’s composability as it relates to NFT games and metaverses drives adoption given that it allows for one in-game item to be used across multiple platforms. Notably, due to LightLink’s prioritisation of composability and interoperability, NFTs minted on the Layer 2 can be used on games and metaverses that exist on other blockchains and networks. This results in each NFT having more utility as they are not siloed to a single protocol. Accordingly, the composability feature has the potential to drive the development and use of a wider ecosystem, correspondingly catalysing adoption.

LightLink’s focus on composability allows for seamless integration and interaction with Ethereum’s smart contracts and dApps using Solidity [3]. As an EVM-compatible chain, it not only supports composability within the Ethereum ecosystem but also promotes interoperability with various blockchains and Layer 2 networks. The increased liquidity attracted by LightLink's interoperability strengthens the protocol's stability, creating a positive flywheel effect that, in turn, encourages broader adoption.

4.3. Adoption

Since the Bitcoin whitepaper's release, blockchain technology has grown and evolved, with platforms like LightLink leading this transformation. LightLink's mission goes beyond just leveraging blockchain technology as a selling point. Instead, it focuses on delivering the tangible benefits that distributed computation offers to businesses and individuals. LightLink’s strategy emphasises scalability, broad industry applications, and enterprise integration. The following strategic pillars demonstrate LightLink's commitment to driving blockchain technology towards mainstream adoption and are designed to attract millions of new users.

Expanding Beyond Crypto Native Users

LightLink targets a broader audience across various sectors, including finance, payments, and transportation. Central to this will be the "Great Merge," where LightLink integrates Web3 capabilities into enterprise services. This strategy will transform digital wallets into multifunctional platforms with advanced features like micro-lending and currency conversion, attracting new users by enhancing utility and ease of use.

Enterprise-Centric Adoption and Wider User Growth

LightLink’s strategy extends beyond traditional blockchain communities, aiming to bring more users into the blockchain space. This is achieved by providing tangible value to enterprises in diverse industries. The development of a comprehensive Web3 infrastructure, including DEX, lending, NFT, and tooling, as a part of LightLink's first stage of development, lays a foundation for a thriving ecosystem that appeals to both developers and enterprises.

Practical Implementations and Real-World Impact

LightLink's practical applications are already showing results in its collaborations with FORUS Digital and Coala Pay. FORUS is utilising LightLink for digital banking services in Ethiopia and enhancing public transportation systems in Cape Town, demonstrating LightLink’s impact in various sectors. Coalapay's partnership with LightLink effectively showcases its practicality and real-world impact, streamlining aid management and disbursement while improving transaction security and transparency.

Scalable Solutions for Diverse Industries

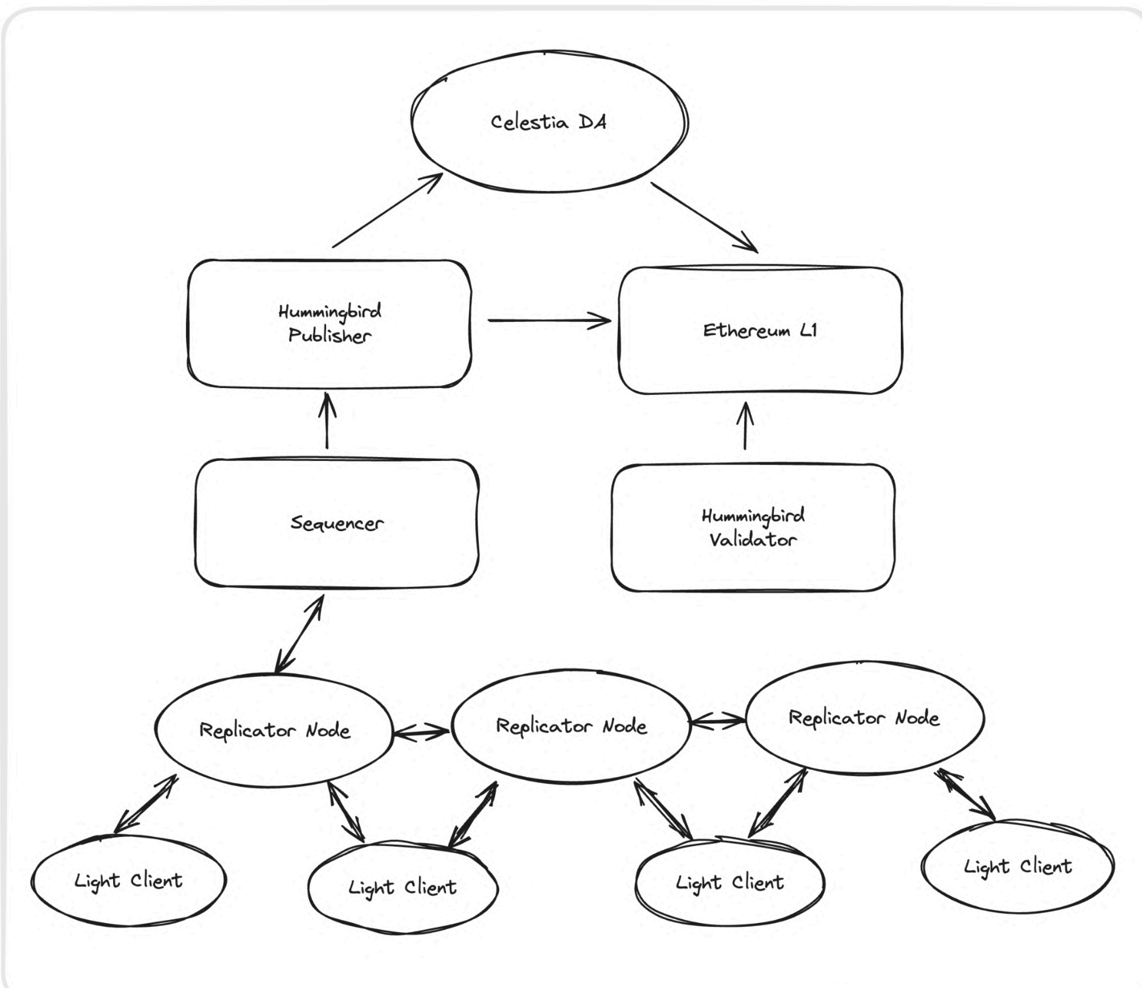
Scalability is a cornerstone of LightLink’s approach, with a focus on Layer 3 configurations to manage large-scale projects like national payment systems. This strategic scaling enables significant partnerships in the finance and payments sectors, anticipated to be announced in 2024. Fostering competition among developers to create superior services is a natural consequence of LightLink’s expanding and versatile ecosystem.

Through these four strategic pillars, LightLink is not just adding blockchain technology to the mix but creating an ecosystem where enterprises and their customers experience the real benefits of blockchain integration. This approach sets a new standard for blockchain adoption across various sectors, underpinning LightLink's pivotal role in the blockchain revolution.

5. The LightLink Protocol

5.1. Overview

LightLink's novel Layer 2 design comprises several interconnected components, each playing a crucial role within the ecosystem. LightLink harnesses the Ethereum platform as its settlement layer, housing the Canonical State Chain. Operating at the execution layer is our custom client, heavily inspired by the renowned open-source Ethereum client Geth. LightLink builds upon the remarkable advancements achieved by the Celestia team to provide secure, modular data availability.



The architecture diagram presented above illustrates the comprehensive data flow within the protocol. For most users, interaction primarily revolves around light clients or replicator nodes. These key components facilitate seamless submission of new transactions and enable direct querying of the Layer 2 blockchain through their JSON-RPCAPIs. Transactions submitted to a replicator node or light client undergo eventual ordering by the sequencer, culminating in their inclusion within a block.

The pivotal role of consolidating multiple Layer 2 blocks into a singular bundle rests with the Hummingbird Node running in publisher mode. Subsequently, this bundle serves as the foundation for crafting a new roll-up block header on Layer 1. The publisher's duties extend to posting bundle data to Celestia, while concurrently issuing new block headers to the Canonical State Chain contract with each bundle iteration. Lastly, the Hummingbird Smart Contracts serve as the linchpin, orchestrating seamless integration within the system.

5.2. Layer 2

The launch of LightLink's Layer 2 network marks a significant advancement in Ethereum's ongoing development roadmap. The primary objective of LightLink is to augment Ethereum's scalability and performance. This is achieved by processing transactions off-chain on LightLink and then consolidating these transactions into compressed batches. These batches are subsequently posted on Ethereum's Layer 1 mainnet.

The initial phase of LightLink's rollout will concentrate on fostering the growth of its Layer 2 network. The focus will be on enhancing network scalability and reducing gas fees, while still leveraging Ethereum's robust framework for security and decentralisation. As LightLink evolves, there is a strategic plan to progressively bolster its native security and decentralisation capabilities.

A key aspect of LightLink's integration with Ethereum is its ability to address the Blockchain Trilemma effectively [4]. By handling scalability at the Layer 2 level and harnessing Ethereum's Layer 1 for security and decentralisation, LightLink creates a harmonious balance. This approach ensures that users benefit from the strengths of both layers, resulting in an efficient and secure blockchain experience.

5.3. Optimistic Rollup

LightLink is not a fork of any existing project but a unique optimistic rollup built on a proprietary stack.

Operating optimistically, LightLink presumes sequencer-computed proofs to be correct, relying on honest actors for validation. Errors in transaction batches are monetized, with rewards given to those who uncover them. This process prevents erroneous batches from finalising and maintains the integrity of the LightLink state.

Embracing Solidity, the leading smart contract language, LightLink leverages the Ethereum Virtual Machine (EVM) for full compatibility. The Geth codebase enables developers to use standard tools like Visual Studio Code, Ganache, and Hardhat for writing, testing, and deploying smart contracts. This compatibility facilitates the migration and scaling of dApps on LightLink without code rewrites. Amidst the highly competitive market of emerging L2's, LightLink distinguishes itself with its independent development and focus on ecosystem partnerships, offering an optimal experience for its users.

5.4. Data Availability

LightLink is one of the first Layer 2 blockchains to leverage Celestia's novel data availability (DA) protocol. Celestia is a modular data availability network enabling consensus around whether a piece of data is available. DA ensures that the data required to verify a block is available to all network participants at all times.

For LightLink replicator nodes, this is relatively simple, as replicator nodes download every new block from Layer 2 and independently verify every transaction and block by re-executing them. However, Hummingbird validator nodes validate block data directly from Layer 1 Ethereum. This means that even if the L2 network was offline, users could still withdraw their funds from LightLink by submitting their withdrawal transactions directly to the L1 smart contract. Validator nodes can then validate the withdrawal based on the state of the available historical data. Users can exit the network once a single validator is in operation and the historic chain data is available.

Since anyone can easily run a validator, the main concern is ensuring the data is always available and ready to be downloaded whenever required. Early Layer 2 scaling solutions achieved data availability by compressing and storing the transaction data on their Layer 1 network, such as Ethereum. This is the obvious solution. However, it has some drawbacks.

1. **Cost**: It is very expensive to store data on Ethereum. This cost is usually borne by the end user of the Layer 2 protocol and increases the overall transaction fee.
2. **Congestion**: Submitting batches of transactions directly to Ethereum can result in unnecessary network congestion, resulting in higher fees.

Celestia's Blobstream is the first data availability solution for Ethereum that securely scales with the number of users. Blobstream relays commitments to Celestia's data root to an on-chain light client on Ethereum for integration by developers into L2 contracts. This enables Ethereum developers to build high-throughput L2s using Celestia's optimised DA layer, the first with Data Availability Sampling (DAS). LightLink was designed to work with Celesita from the ground up, enabling cost-effective data availability and therefore, cheaper fees for LightLink users.

5.5. Sequencer Node

The sequencer node assumes the pivotal role of constructing Layer 2 blocks within the system. Tasked with receiving and validating transactions from replicator nodes, it proceeds to order and process them accordingly. Upon successfully processing a transaction and embedding it within a Layer 2 block, the state of the Layer 2 chain progresses accordingly. Subsequently, the newly formed L2Block is disseminated across all peers within the Layer 2 network.

Transactions are prioritised for inclusion in the next L2Block based on their gas price, with those offering the highest gas price given precedence. Furthermore, the sequencing of transactions within the block is determined by their nonce and gas price.

Presently, the sequencer produces a new L2Block every 500 milliseconds, with these blocks cryptographically appended to the Layer 2 chain. This 500ms production rate is deemed reasonable;

however, it remains adjustable to suit evolving requirements. The sequencer diligently populates each new L2Block until it reaches the predetermined gas limit, presently set at 15,000,000 gwei. Plans are underway to significantly elevate this block gas limit as the network matures, thereby enhancing the protocol's theoretical throughput from 1428 transactions per second (TPS) to over 10,000.

Transactions committed to L2Blocks attain a level of "soft finality", signifying their status as final as long as the sequencer operates with integrity. The veracity of transactions processed by the sequencer undergoes independent validation by community validators, ensuring the sequencer's continued honesty and integrity.

In the event of sequencer downtime, seamless continuity is assured through the deployment of a new sequencer. The chain persists, with the new sequencer inheriting the chain's history from existing replicators and seamlessly assuming the task of block production. The LightLink DAO is responsible for replacing the sequencer if required.

5.6. Replicator Nodes

Replicator nodes are full nodes that download every L2Block from the sequencer and independently validate and process its transactions. Replicators allow the LightLink network to scale as the number of replicators increases. Each replicator stores a local copy of the entire LightLink chain.

For a replicator to connect to the sequencer, it must first be safe-listed by the sequencer. The replicator will then download the chain from the sequencer and process every historic transaction. Every replicator keeps their own copy of the Layer 2 chain state, transactions and blocks.

Replicators provide their own JSON-RPC server, which can be used to query the chain. Replicators will also validate the integrity of the blocks by verifying the block hashes and signatures.

5.7. Light Clients

As the LightLight network grows, the hardware requirements to run a full node will increase. Most users will opt to use third-party node infrastructure providers; however, some will want to verify the data they receive for themselves. Light clients connect to replicator full nodes and only download and validate the L2Block headers from them. Instead of downloading the L2Blocks transactions, the light client requests data from replicator nodes as required and verifies this data via Celestia's fraud-proving system.

5.8. EVM Compatibility

LightLink sets itself apart from zero-knowledge rollups by being directly compatible with the Ethereum Virtual Machine (EVM). This compatibility enables the efficient migration of Ethereum-native smart contracts from the Ethereum mainnet for deployment and execution on LightLink. Utilising the same JSON RPC endpoints as Ethereum, LightLink can serve as a direct drop-in replacement for the blockchain. LightLink developers also gain access to Ethereum’s extensive ecosystem of tools and libraries thanks to its Ethereum’s go-ethereum (Geth) codebase.

5.9. Hybrid Gas Token Mechanics

LightLink sets itself apart from other Layer 2 rollups with its hybrid gas token mechanics, offering flexible payment options for gas fees. Unlike many alternatives, LightLink does not mandate the use of its native token, LL, for gas fees. Initially, ETH will be the exclusive token for this purpose, streamlining the process from asset bridging to network transactions, which is a notable improvement over other rollups. After the LL Token Generation Event, both LL and ETH will be accepted for transactions on non-enterprise protocols, eliminating the need for users to purchase or exchange tokens specifically for LL.

Following the Token Generation Event, LL will offer long-term advantages to users due to its diverse utilities. To encourage the adoption of LL, transactions using it for gas fees will cost 10% less than those using ETH. This pricing strategy means that regular users might only notice a slight difference when choosing between LL and ETH for gas payments. However, for frequent users, this discount becomes more significant, making LL an increasingly attractive option for gas fees.

5.10. Storing and Posting Batch Information

The need for rollups emerged from the scalability limitations of Ethereum. Before Layer 2s had dominated blockspace on Ethereum, calldata was not an issue as nodes only stored the state of the chain at each block. Calldata is the data that is passed to the smart contract as part of a transaction, and it is used to provide input to the contract and specify how it should be executed. With the rise of rollups, many more state changes required validation and storage along with the functions executed by smart contracts, resulting in expensive calldata structures for the Ethereum-native contracts. Consequently, many of the potential cost benefits of rollups have been cut short by the continued and asymmetric price increase of storing Layer 2 calldata.

However, Ethereum's rollup-centric roadmap seeks to resolve these issues through the establishment of a sharded, data availability layer which stores information in Binary Large Objects (BLOBs) [7]. This layer is an important step that must be taken to reduce rollup fees and scale Ethereum; yet, effective innovation that lowers calldata costs is needed now.

Accordingly, LightLink is presently using a modular solution whereby only rollup block headers, which store the changing state of the rollup each block, are posted on-chain, incurring the normal Ethereum gas fees. On the other hand, the transaction data which is referenced in the block header, is compressed and subsequently stored on our data availability layer Celestia or other data availability systems to ensure that it is secured in a decentralised fashion. Utilising a third-party data availability layer for storing transaction data simultaneously guarantees that fraud proofs can be levied against transaction batches as all relevant information is available and that network transactors do not incur elevated fees due to the data availability guarantee [8]. This innovation is an early step toward a fully modular Ethereum blockchain, whereby different layers, such as the Execution Layer and the Data Availability Layer operate independently.

5.11. Fraud Proofs

Leveraging optimistic rollup technology allows LightLink to execute transactions efficiently as a Layer 2 without losing EVM-compatibility like zero knowledge rollups. As well as deriving security from

Ethereum, LightLink enables network participants to use fraud proofs to demonstrate that a transaction in a batch, that is pending approval on the Ethereum mainnet, is true or false. If the fraud proof is valid, that is, an incorrect, impossible or imperfect transaction was appended to the batch by the sequencer node, the rollup will negate and revert any of the state changes impacted by the transaction.

LightLink will provide the specific infrastructure to create fraud proofs via github docs. However, the process is as such: users must utilise the smart contract on the Ethereum mainnet to obtain the proof, and subsequently compare it with their own generated proof that is generated from hashed transactions that were executed and calldata stored via a third-party data availability layer. Notably, as LightLink will be an open source software, the computational approach used by the publisher to compress transactions will be publicly available.

Taking inspiration from the unparalleled mechanism design of the PoS consensus algorithm, those seeking to raise fraud proofs against a transaction batch must first provide collateral. This is because the incentives offered for successful fraud proofs must be balanced by disincentives for unsuccessful, obstructive fault proofs considering the computation burden on the network when determining the validity of said proofs. In this way, users who initiated a successful fraud proof will receive a reward from a contract funded by network revenue or the LightLink DAO. Simultaneously, if any user sequentially puts in three unsuccessful fraud proofs, they will have 20% of their collateralised ETH/LL slashed, that is, burnt. This number can change in the future based on analysing network data relating to fraud proofs and the portion of users raising the proofs to slow down LightLink. If, as a result of the slashing, the user no longer has the collateral, they will be unable to raise additional fraud proofs until they collateralise more tokens.

Fraud proofs are a key part of the security and trustless nature of LightLink as they allow users to verify the correctness of the rollup's state without placing all their faith in the sequencer, a third party or an off-chain oracle. During a period of time, known as the challenge window, participants are able to verify transactions; this is possible because the batch has not reached finality on the Ethereum blockchain, meaning that the rollups state can be reversed. For the foreseeable future, LightLink will be utilising a seven day challenge window. Accordingly, seven days after the compressed transaction rollup has been posted on chain, it will reach finality.

In the case of a fraud proof being levied against a transaction batch, network participants initiate a validation process to determine whether the relevant transaction was valid or invalid. In the case of successfully challenged batches, the invalid transaction will be rolled back on LightLink and removed from the commitment posted on the Ethereum Anchor. Notably, this ensures that all the blocks in the batch do not need to be reversed, saving users gas fees in the face of reverifying and publishing state changes.

6. Hummingbird Module

6.1. Overview

The Hummingbird Module integrates LightLink's speed, low fees, and enterprise features with Ethereum, transforming LightLink chains into Optimistic Rollups using a novel system rather than the conventional tactic of forking the Optimism engine. It also ensures Layer 2's verifiability on Layer 1, transaction uncensorability, and data availability.

The Hummingbird module is a set of internal components responsible for building and securing the Layer 2 roll-up Canonical State Chain on Layer 1. The components comprise the Hummingbird Client, which can run multiple roles such as a rollups publisher, or as a validator. Hummingbird also includes several smart contracts on both Layer 1 and Layer 2. These contracts are responsible for passing messages between Layers 1 and 2, updating the Canonical State Chain on Layer 1 and proving the integrity of the Canonical State Chain.

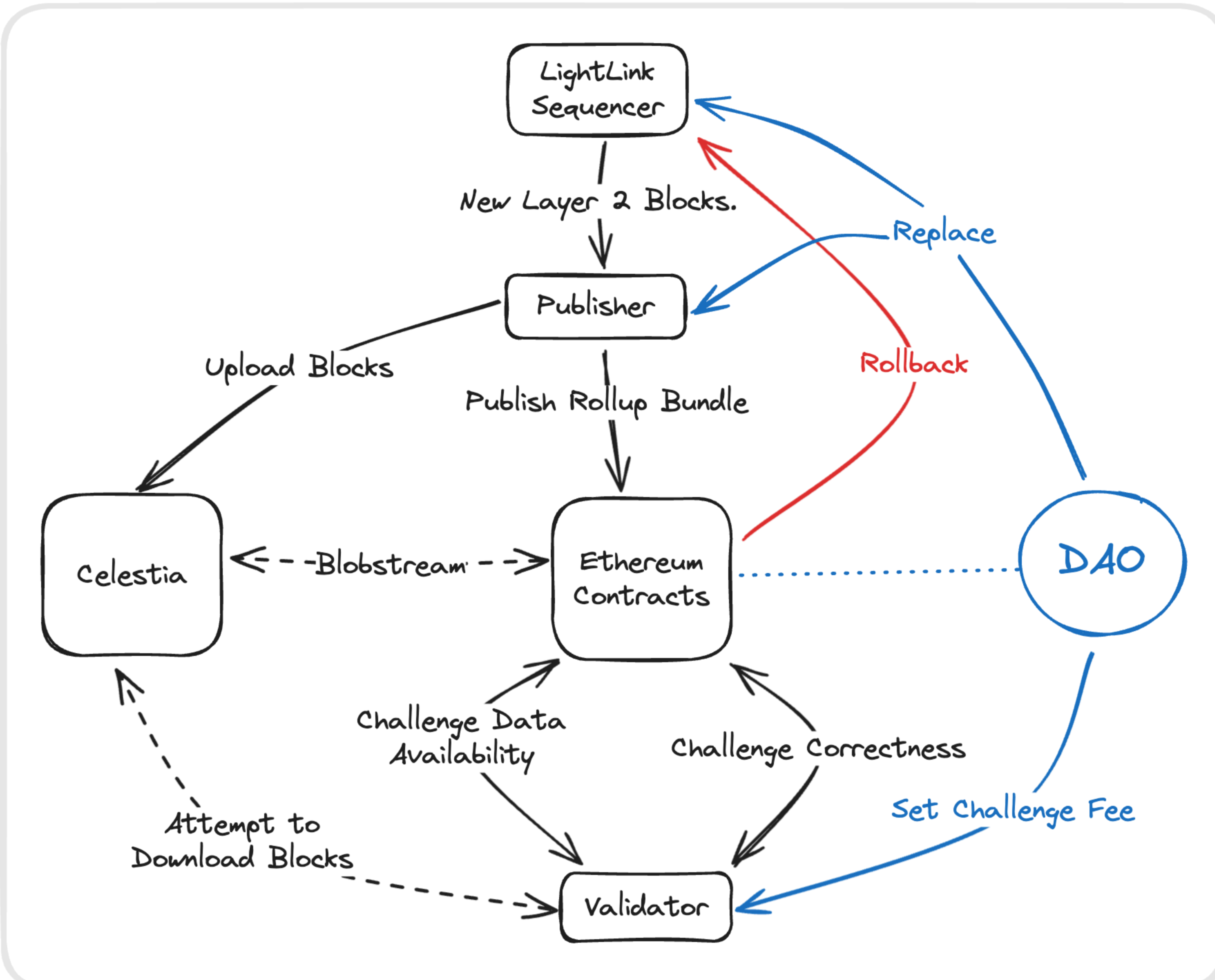
Since most users only need to interact with the Layer 2 network over JSON-RPC via a replicator node or light client, they will never have to worry if the sequencer is behaving honestly. The protocol only requires at least one honest validator to confirm the sequencer and publisher are behaving honestly. A single validator has the capability to prove:

1. State execution was performed correctly.
2. The data in each roll-up block was made available and is consistent with Layer 2.
3. Each roll-up block header is valid according to the protocol parameters.
4. That no valid transactions have been censored.

If the sequencer or publisher behaves dishonestly and does not follow the protocol rules, the Layer 2 Canonical State Chain will be rolled back to preserve integrity.

The sequencer is responsible for building and processing new Layer 2 blocks. The Hummingbird publisher is responsible for bundling those blocks and making the block's data available on Celestia. The publisher is only allowed to append new block headers to the Canonical State Chain on Layer 1.

Hummingbird's novel design allows LightLink to scale Ethereum efficiently and transparently while maintaining security. This is achieved by providing provable data availability and correctness via Celestia's Blobstream data availability oracle on Layer 1 and provable state execution via our on-chain MIPS EVM.



6.2. Operations

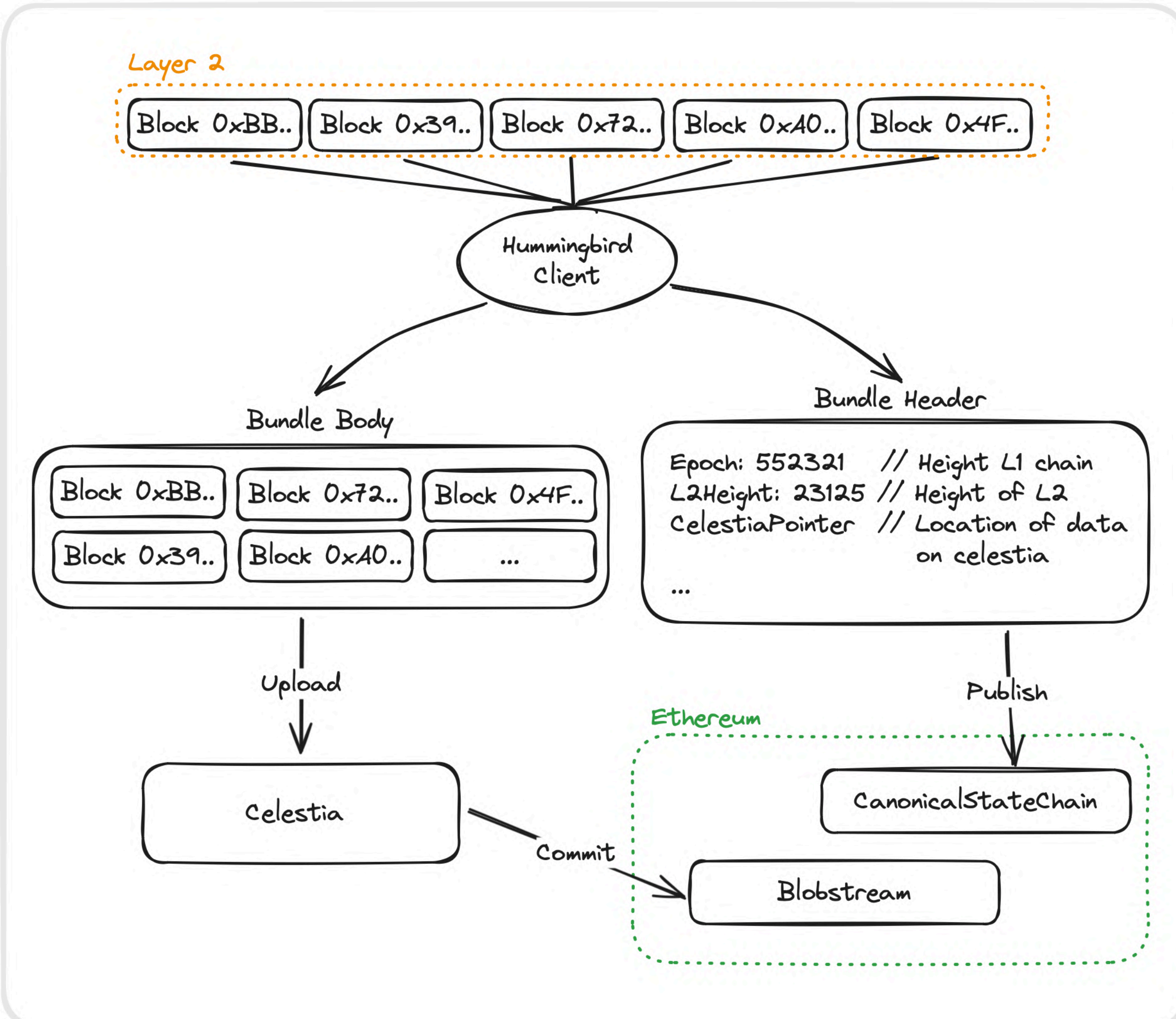
Hummingbird is currently undergoing development and testing, as a result the details of the system might change. For the most recent specs, [please see our docs](#).

Hummingbird comprises a collection of smart contracts, as well as a client application.

- **The Client** is responsible for publishing rollup blocks, performing validation and interacting with challenges. To fulfil its purpose it must interact with three blockchains: A LightLink Chain (Layer 2), Celestia (data availability layer), and Ethereum (Layer 1).
- **Smart Contracts** define the rollup chain, store rollup blocks, and contain methods for validating the integrity of Layer 2.

Rolling Up

The Hummingbird Client first downloads a bundle of Layer 2 blocks from the LightLink sequencer. This bundle is then uploaded to Celestia (Data availability layer). Finally a rollup header is created – including a pointer to the data on Celestia, and is submitted to the CanonicalStateChain contract on Ethereum (Layer 1).



Each rollup block body is a bundle, which contains up to 5000 LightLink blocks. This unique approach provides ultra low Layer 2 fees, but requires special care when it comes to data availability and on-chain validation.

Data Availability Layer

Layer 2 blocks are uploaded to Celestia as shares, validators attest to the availability of a binary Merkle root which contains these shares. These attestations can be verified on Ethereum using the Blobstream contracts. If a Celestia validator withholds data or produces incorrect blocks it can be detected by anyone running a Light node and be slashed.

Hummingbird provides a ChainOracle contract for Layer 1 which allows the cost effective loading of Layer 2 headers and transactions from Celestia shares. All items loaded through the ChainOracle are proven to correspond to the Celestia pointer inside a submitted Rollup block. The proofs also include the

Binary Merkle proof showing the shares are part of an attested Celestia data root committed to the blobstream.

Validating

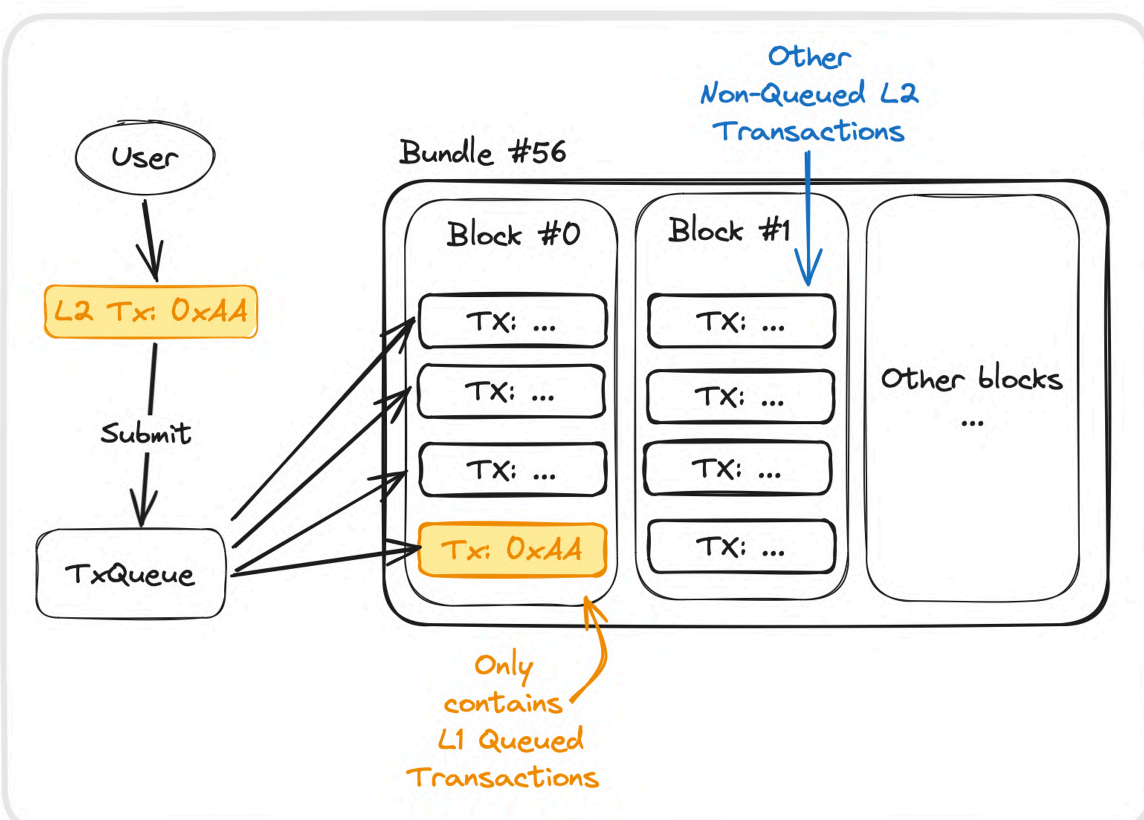
Any user can serve as a network validator by interacting with the challenge contracts on Ethereum. The Challenge contracts can be broken into three groups: Data availability, Censorship, and Execution.

Each challenge is typically a two party game where the challenger pays a fee to initiate, a defender must provide on-chain verifiable proof of correctness, and the winner receives the fee.

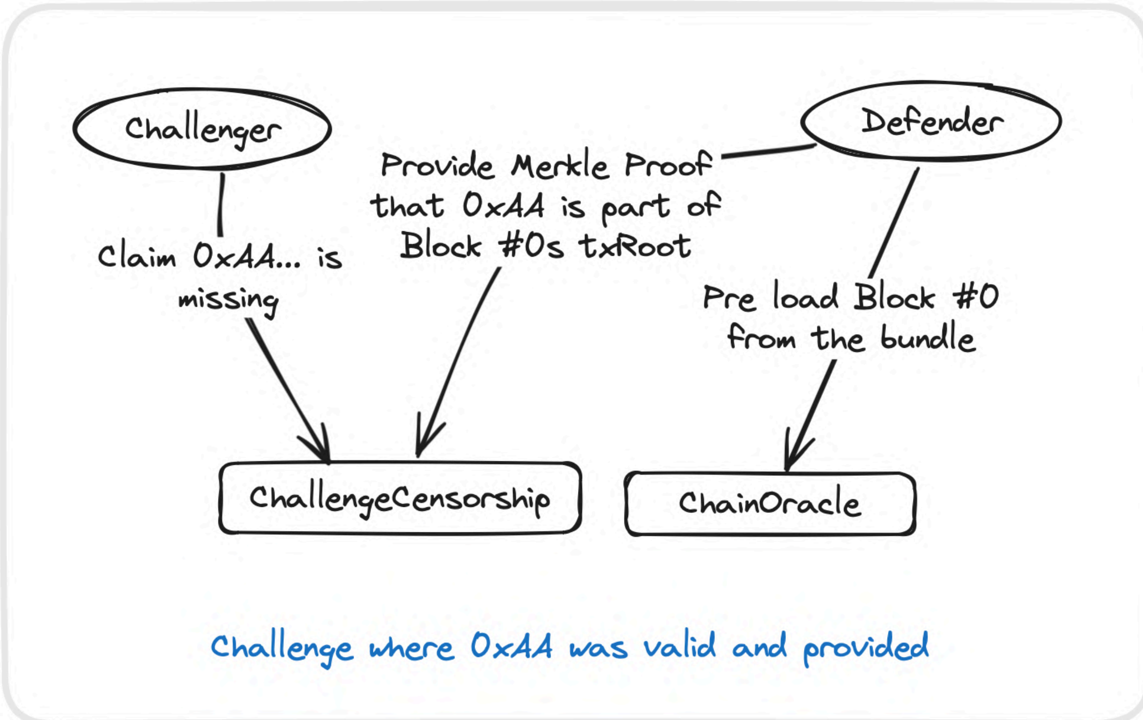
- **Data availability Challenges** rely heavily upon the ChainOracle to prove that data is available and has been since the rollup block was submitted.
- **Censorship Challenge** relies upon the ChainOracle, Cannon and TxQueue contracts to check a queued transaction was included and valid.
- **Execution Challenges** implement Cannon to compute correct state roots and compare the results.

Censorship Resistance

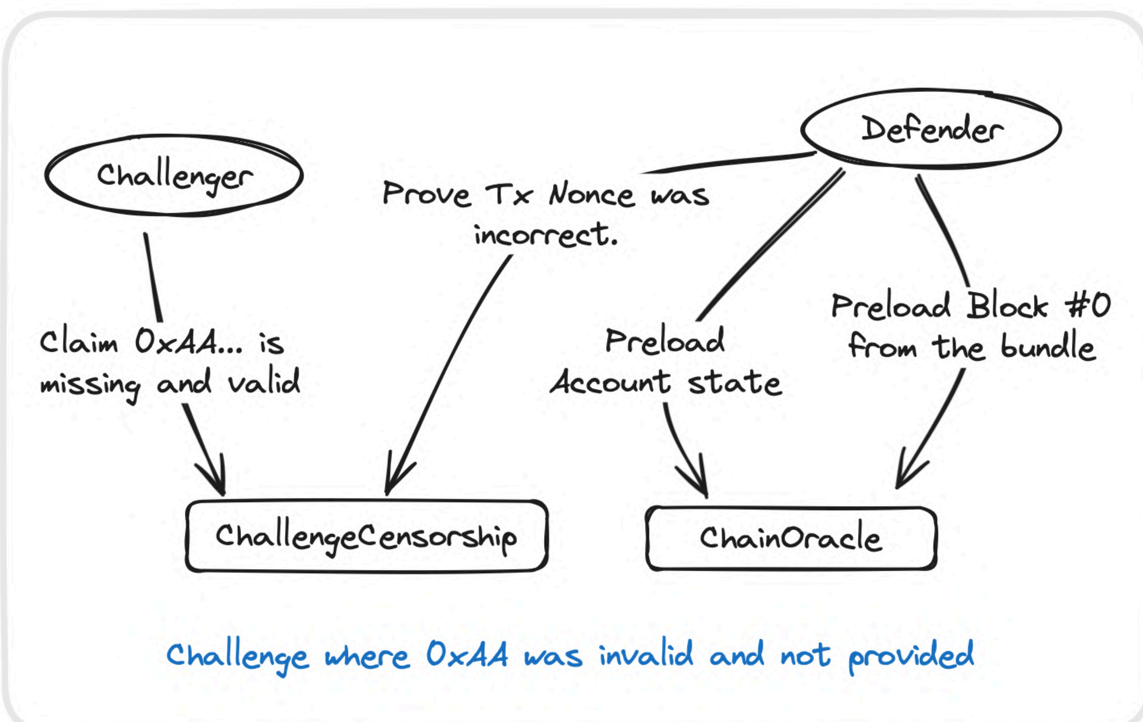
The network prevents transaction censorship by the sequencer through a mechanism that permits users to directly submit Layer 2 transactions to a TxQueue Contract on Layer 1. Transactions in the queue must be included in the first block of the rollup bundle, matching the epoch of the Layer 1 block where they were submitted.



If the transaction was not included the user can challenge the rollup bundle which should have included it:



If the transaction is valid, and not included in the correct rollup block then the block can be rolled back following a censorship challenge. This forces the sequencer to include it, otherwise it will be replaced by a sequencer that will.



Hummingbird implements George Hotz's Cannon as a fault-proof system. The essence of Cannon is a MIPS emulator in Solidity, enabling EVM (or any state transition engine) execution on-chain. This setup permits LightLink's EVM operation within the Ethereum EVM framework.

This architecture allows direct derivation of correct Layer 2 state roots on Layer 1. The Execution challenge contract requires executing only a single step on-chain, from which an intermediate state root is obtained and verified as part of the tree yielding the final state root.

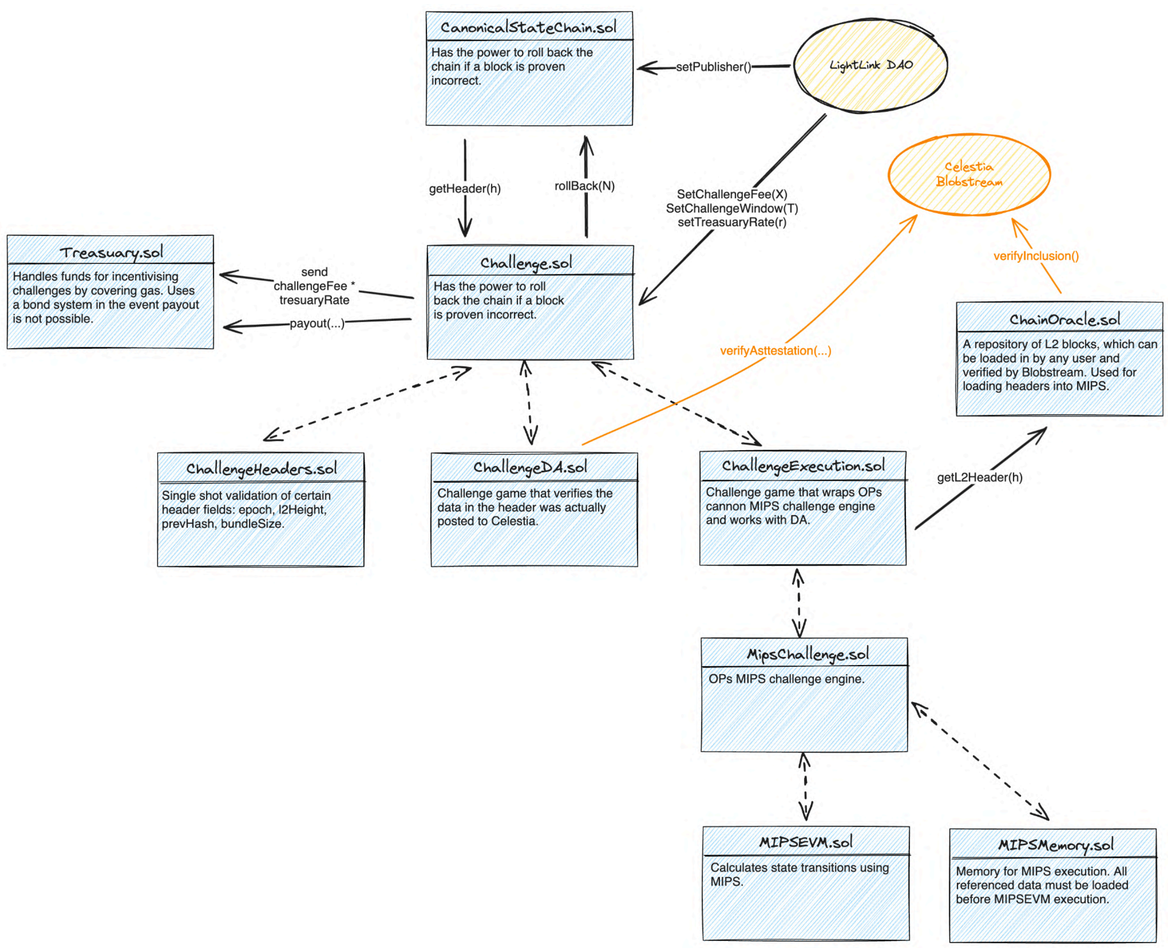
Rollbacks and the Publisher

A single publisher is allowed to submit new blocks to Layer 1. Each rollup block submitted has a window of time (1 day) in which it can be rolled back following a successful challenge. If the current publisher has 3 rollbacks it can be replaced by the DAO. This prevents a malicious publisher from halting the network indefinitely.

The LightLink sequencer and replicator nodes dynamically respond to rollbacks, and will continue working from the new chain head.

6.3 Smart Contracts

The Hummingbird smart contracts repository can be found [here](#).



CanonicalStateChain.sol

The Canonical State Chain (CSC) can be considered the source of truth for the Layer 2 chain. All Layer 2 blocks will eventually be bundled up by the Hummingbird publisher and published to the CSC. Blocks in the CSC are pending for seven days. This gives validators enough time to challenge an incorrect block and roll back the chain if necessary. Only one publisher is allowed to push new blocks to the CSC contract. If a bad block is submitted, leading to a rollback, the LightLink DAO can initiate the election of a new publisher.

A roll-up block header has the following anatomy:

```
struct Header {
  uint64 epoch; // Epoch refers to a block number on the Ethereum blockchain.
  uint64 l2Height; // L2Height is the index of the Last L2 Block in this bundle.
  bytes32 prevHash; // PrevHash is the hash of the previous block bundle.
  bytes32 txRoot; // The root of a merkle tree containing all the transactions in the Bundle.
  bytes32 blockRoot; // The root of a merkle tree containing all the blocks in the Bundle.
  bytes32 stateRoot; // The Stateroot after applying all the blocks in the Bundle.

  // Pointer to the blocks contents on Celestia.
  // See https://docs.celestia.org/developers/blobstream-offchain#defining-a-chain
  uint64 celestiaHeight;
  uint64 celestiaShareStart;
  uint64 celestiaShareLen;
}
```

Every header contains enough information about a bundle of Layer 2 blocks to be independently verified on Layer 1. The `celestiaHeight`, `celestiaShareStart` and `celestiaShareLen` values provide details of where the block data is stored in Celestia so that it can be retrieved or proven to be available.

The `stateRoot` provides the expected state hash of the chain after applying all of the blocks contained within the data bundle. The `blockRoot` and `txRoot` allow easy verification if a given block or transaction is contained within the bundle.

This contract has the ability to roll back the Canonical State Chain to a specific block. The challenge contract, which is defined within the canonical state chain contract, is the only contract allowed to initiate a chain rollback in the event of a successful challenge.

Challenge.sol

Challenge allows anyone to challenge the validity of a block. As mentioned, if a block is proven to be invalid, the chain is rolled back to the previous block. Most challenges require a challenge fee, which is paid to the winner of the challenge. The fee mechanism serves three purposes:

- To incentivise good challenges
- To disincentivise frivolous challenges
- To reimburse the defender for the cost of providing proof (gas)

Challenges must be initiated within a valid challenge window. This is a time window that starts when the block is published, and ends after a certain time has passed. If a challenge is made outside of this window, it will be rejected. The window may be different for certain challenges.

This contract is used as a base for all challenges in the protocol. As seen below, a multitude of different types of challenges are imported into the challenge contract.

ChallengeHeader.sol

This contract lets any user challenge a block header against the following basic validity checks:

1. The epoch is greater than the previous epoch
2. The `l2Height` is greater than the previous `l2Height`
3. The `prevHash` is the previous block hash
4. The bundle size is less than the maximum bundle size

If any of these checks fail, the chain is rolled back to the previous block. Like with all challenges, the challenge window must be open – however, there is no challenge fee.

ChallengeDataAvailability.sol

This is a challenge game in which any user can challenge the DA of a block.

Once initiated, the defender (block publisher) must provide proof within a short time window. (This proof is verified via the Blobstream contract). If they fail to do so, the challenger wins the challenge, and the chain is rolled back to the previous block.

The window on this challenge starts 80 mins after the block is published, and ends 6 hours after the block is published. The delay in the challenge window's start gives Celestia enough time to validate the data and publish the proof. The shortened end window gives time for subsequent challenges after data availability is proven.

Any user can challenge data availability by calling `challengeDataRootInclusion()`.

- If a challenge is detected, a Hummingbird Defender will query the Celestia pointer info from the block header.
- Query Celestia node to generate a data inclusion proof
- Submit that proof to `defendDataRootInclusion()` via Challenge.sol
- Challenge.sol will use the Celestia Blobstream DAOracle to verify the proof, and the challenge will be marked as completed "defender won"
- if the DA challenge is not defended in a set time period; anyone can call `settleDataRootInclusion()`, the challenger will win & CSC will be rolled back

ChainOracle.sol

This contract enables any user to directly upload valid Layer 2 blocks from the data availability layer, to Layer 1. Data is loaded in two parts:

1. Celestia shares are loaded, along with the required merkle proofs and validator attestations.
2. Stored shares can then be decoded into Layer 2 headers and transactions.

Once loaded, the headers and transactions can be fetched from the ChainOracle by their respective hashes. This mechanism is crucial for the other challenges listed below.

ChallengeL2Block.sol

This is a challenge game that any user can call `challengeL2Block()` to validate the correctness of a Layer 2 block:

- To initiate a challenge a user must provide the number of the Layer 2 block which they are challenging.
- The Defender will then have to load that Layer 2 block using the `ChainOracle`.
- The Defender will then call `defendL2Block()` . The challenge contract will fetch the headers and transactions from the `ChainOracle` and check the following fields are correct: `transactionsRoot`, `parentHash`, `number`, `timestamp`

Note: The `stateRoot` is not checked here. The `stateRoot` is validated by the challenge below.

ChallengeExecution.sol

This contract is an implementation of Cannon – the fault proof engine. The primary function of this contract is to verify that the `stateRoot` of a Layer 2 block is correct by executing a block on Layer 1, calculating the correct `stateRoot` and comparing the results. This smart contract is under development as of 2/20/24.

A challenge can be initiated by any user by doing the following:

- Load the challenged block and its parents header into the Canonical state chain.
- Load initial state that will be accessed during execution into `MipsMemory.sol` .
- Call `challengeExecution()` to initiate the challenge.
- LightLinks state transition engine (EVM) is compiled to the MIPs instruction set.
- The challenger and defender do a binary search until they find the exact MIPS operation where their reported state executions differ.
- The operation is run in `MIPS.sol` – an on chain MIPS emulator. The emulated EVM calculates the correct output of the operation.
- If the output matches the challenger's expectation the challenger wins. Otherwise, the defender wins.

6.10. Client

The Hummingbird client is a tool for creating and validating rollups. It interacts with all three layers: Layer 1, Layer 2 and the data availability layer to rollup, inspect, challenge and defend. The repository can be found here.

It can be run in three different modes:

1. **Rollup**: Publishing new bundles to Celestia and the Canonical State Chain.
2. **Challenge**: Prepare and initiate new challenges.
3. **Defender**: Listen for new challenges and attempt to defend them.

Creating Rollup Blocks

Rollups can be create using the following commands:

```
hb rollup next  # Generates only the next rollup block.
hb rollup start # Generates rollup blocks automatically.
```

The client begins by retrieving the latest state of the rollup from the `CanonicalStateChain` smart contract deployed on Layer 1, to ensure synchronisation.

Following this, it will fetch a set of blocks from the Layer 2 network. These blocks are bundled up, encoded (RLP) and uploaded to the data availability layer: Celestia.

Finally the rollup block is assembled to encapsulate key information which includes: `epoch` the current Layer 1 height, `l2Height` the height of the Layer 2 blocks in this bundle and fields which point to the block bundle on Celestia. The rollup block is then published to the `CanonicalStateChain` contract on Layer 1.

Managing Challenges

Challenges are used to validate the integrity of the rollups. Some challenges, like challenging execution, require complex preparation, multiple calls and watching for responses. While others are simple and require only a single step of initialization.

Challenges can be triggered manually from the CLI

```
hb challenger challenge-da <block_number> # See ChallengeDataAvailability.sol
```

Defending the chain

Some challenges may be baseless and require a defender to submit proofs of correctness. Defending may require fetching the source data of the challenged block from Celestia, providing data to the chain oracle and the generation of proofs.

Defences can be triggered manually or automatically via the CLI:

```
hb defender defend-da <block_hash> # See ChallengeDataAvailability.sol
hb defender start # Manually listen for challenges and prepare defences.
```

7. Transaction Economics

Early predictions paint a positive picture relating to the performance of LightLink. The use of optimistic rollup proving technology enables LightLink to reach a theoretical capacity of 5,712 TPS, far outpacing Ethereum's maximum throughput of 15. Whilst the Layer 2's throughput will only get this high during times of peak demand, the network is estimated to facilitate over 400k transactions per day. Concurrently, on LightLink, transactions reach finality and cannot be reversed directly on the Layer 2 network, after 500 milliseconds - this value far eclipses the finality speed of other networks.

Importantly, the state of LightLink, and hence transactions, can be reversed, in the face of successful fraud proofs whereby invalid transactions are located in a batch posted on Ethereum. Network participants will have 7-day challenge window when they can question the validity of transactions in a batch, through the process detailed above, before batches are deemed final on the Ethereum mainnet; at this point, the transactions that were executed on LightLink have reached finality on both the Layer 1 and Layer 2.

After a number of blocks containing transactions are constructed on the Layer 2 network, a Merkle Tree is used to compute a Merkle root known as the transaction root.. The hashed transaction root is included in the block posted on the Ethereum mainnet. With thousands of LightLink-facilitated transactions being included in each batch, Layer 1 gas fees and Merkle Tree computation fees are distributed amongst a large number of transactors. Accordingly, it is predicted that the average transaction cost is $0.01, yet can be as little as $0.001. These low fees are possible for LightLink given its use of a third-party data availability layer when storing compressed batches [8]. Notably, upon the implementation of ProtoDanksharding and Danksharding at the Ethereum-base layer, these gas costs are expected to drop further [9].

8. Enterprise Mode

Enterprise Mode allows businesses to subscribe their application to operate as if it were gas-free to their users. On LightLink, Enterprise Mode is facilitated through the use of unique smart contracts, be they ERC-20 or ERC-721 contracts — depending on the application.

In collaboration with LightLink administrators, enterprises can be set up with their own smart contract for their protocol(s). On the LightLink network, enterprises will register by providing organisation name, LightLink wallet address, gas units and gas price. The latter two variables will be initialised as zero, increasing relative to the payment described below. Correspondingly, based on the gas price per user interaction with the contract, the gas units will be equated to the quota × gas price, ensuring enterprise users receive the fair number of transactions for what the underlying organisation paid.

Every enterprise client is granted access to a unique smart contract on LightLink, which is activated at the start of each month. Enterprises operating on the LightLink Layer 2 protocol are required to pay a predetermined monthly fee. This fee functions as a quota, offsetting the gas fees that would otherwise be incurred by users executing transactions on the platform.

Users engaging with an enterprise's specific smart contract are exempt from paying gas fees. This exemption is subject to a cap based on the enterprise's chosen fee tier. The daily cumulative gas fees saved by users are limited and, as the quota nears depletion, protocol users under Enterprise Mode will be required to pay standard transaction fees in ETH. If an enterprise consistently reaches its daily limit due to higher platform usage and demand, they can upgrade to a higher fee tier to increase their smart contract's monthly cap.

This novel approach is significant as it enables enterprises to move their protocols off private networks and onto public networks with minimal backlash from their users given that they are not required to pay expensive gas fees. In this context, Enterprise Mode allows LightLink to act on its design philosophy of ease of use; at any moment, one of two events can be occurring:

1. **Available Transactions in the Smart Contract -** in these cases, the daily transaction allocation that bypasses the need to pay gas fees has not been reached. Hence, users do not need to spend ETH on satisfying transaction fees.
2. **No Available Transactions in the Smart Contract -** in these cases, the daily transaction allocation that bypasses the need to pay gas fees has been reached. Subsequently, enterprise users pay in the ETH that they bridged to LightLink

In either of the above situations, the enterprise user is able to efficiently transact on the LightLink network without reaching an inconvenience impasse whereby a decentralised exchange to swap into LL is needed. LightLink's RPC layer enforces Rate Limitations that require proper authorization for transactions as a deterrent to a single-party exploiting the system by using all free transactions in a block in quick succession.

There are many examples as to when Enterprise Mode can herald substantial benefits to the business' users. One such example is an on-chain game which leverages NFT technology. If a player must pay transactions for every action they make, including picking up tokens and moving their avatar, the game would become unbearable. In situations where players sign a contract to autopay gas fees for on-chain transactions such that they are not distributed by constant private key signature requests, they are at risk of being exposed to severe spikes in gas fees.

For example, if a user allows transactions to be auto-signed on the assumption that gas will remain at gwei = 10, then a jump occurs, resulting in gwei = 30, this user will continue paying for exorbitant transactions without knowledge of the tokens they are spending. However, if the business offering that game were to opt into using LightLink's Enterprise Mode, their users would not face any inconveniences in engaging with the game or be at risk of accidentally paying exorbitant gas fees.

9. Business Applications

LightLink's unique architecture renders it suitable for a multitude of both untapped and/or sectors with insufficiently developed infrastructure. LightLink focuses on improving and benefiting several key applications, including:

1. **Enterprise Size Protocols -** Many enterprises are utilising private, scalable blockchains for their protocols, thereby failing to obtain the benefits of the network effects. LightLink is a highly secure, cheap and efficient blockchain that can scale horizontally. Irrespective of the size of the

protocol and its throughput, LightLink’s composable nature can be tailored to respond to the enterprises’ specific needs.

2. **Ticketing** - Among the many benefits that blockchain technology can bring to enterprise businesses, on-chain, NFT-based ticketing is a strong example. Through LightLink, tickets can be represented as NFTs that are tied to individuals. This rectifies many of the issues facing the ticketing industry as NFTs are 1:1, meaning no two wallets can hold the same NFTs. Furthermore, the NFT can shuffle the ticket code upon use, meaning that they cannot be shared once the first individual has been permitted entry. LightLink’s efficiency facilitates growth in this industry on the blockchain.
3. **Decentralised Exchanges -** LightLink DEXs can leverage Enterprise Mode for low-latency, fee-free token swapping. This opens up sophisticated UX possibilities like utilising AI-driven mechanisms supported by gasless transactions to efficiently manage on-chain liquidity. LightLink DEXs that use Enterprise Mode can offer users a superior experience by facilitating flexible liquidity allocation and reducing slippage. Enterprise Mode can also enhance user engagement by offering free transactions for: limited time periods, specific promoted pools, or as rewards in trading competitions.
4. **Gaming** - LightLink tackles the scalability and transaction latency issues plaguing NFT-based platforms. It ensures constant uptime and secure transactions, vital for a seamless gaming experience. LightLink's capability to handle unique digital assets efficiently revolutionises game dynamics, enhancing user engagement and expanding the gaming ecosystem by removing traditional blockchain barriers.
5. **Metaverse -** LightLink's EVM compatibility fosters metaverse user adoption by accepting the most popular wallets and eliminates the need for proprietary systems or native gas tokens. Metaverses built on LightLink’s Enterprise Mode can support diverse applications, from business integrations to creator-centric environments, equipping artists and creators with a cost-effective, straightforward platform for managing and publishing their work in the metaverse, and enhancing the creator economy.

10. Governance & Utility

10.1. Governance Rights

In the LightLink ecosystem, LL token holders are pivotal to governance, and will have substantial influence over strategic decisions. Their voting rights extend to crucial areas, including the platform's developmental trajectory, marketing approaches, and treasury management. This participatory governance model makes LL holders active stakeholders, integrally connected to LightLink's success.

LL token holders involvement is essential in steering LightLink's future and ensuring that the ecosystem’s long-term goals align with the community's collective vision and interests.

10.2. LL Token Utility

In the LightLink ecosystem, the LL token assumes a central role, bringing benefits to holders through its versatile utility, most notably in the LightLink treasury. This treasury, integral for collecting fees and accepting various tokens, including LL, underlines the token's importance as a medium of exchange within the ecosystem.

Token holders are not merely passive participants; they have a say in the platform's decisions. Holding LL grants governance rights, allowing the community to vote on how the treasury funds are used. This could include decisions on development, marketing strategies, and many more.

The progress of the platform is intrinsically connected to the utility of the LL token. Funds from the treasury, partly comprising LL, are invested back into the ecosystem, improving its offerings and, in turn, the token's utility. User engagement initiatives like achievement systems and quests also integrate LL, further increasing its practical applications within the platform.

Moreover, the token offers tangible benefits to its holders. For example, holding or staking LL can lead to discounts on transaction fees on the platform. This not only makes holding the token practical but also encourages more activity within the LightLink ecosystem.

The platform also rewards protocols based on their usage on the LightLink network, integrating LL into the reward mechanism. This approach fosters a competitive and innovative environment, contributing to the enrichment of the ecosystem. This, in turn, underscores the significance of the LL token as an integral part of the platform's operational framework.

In essence, the LL token is a key component of the LightLink ecosystem. Its multifunctional role spans from governance to operational utility, aligning the interests of token holders with the platform's overall health and functionality. The focus of the LL token is on providing tangible benefits within the ecosystem, enhancing the user experience and platform efficiency. As LightLink continues to develop and adapt, the LL token remains a key component, reflective of the platform's commitment to innovation and user-centric development.

10.3. Tokenomics

Allocations & Vesting Schedules

Below is a table of the intended distribution and vesting schedules for each portion of LL tokens. These figures are subject to change, please find most current figures here.

Allocation	LL Amount		Initial Unlock (%)	Lock-up (Months)	Vesting (Months)
Private Seed Raise VC	14%	140M	0	12	18
Advisors	5%	50M	0	12	18
LightLink Team	14%	140M	0	15	18
Airdrop	6%	60M	20	3	Variable
Token Generation Event	6%	60M	Variable	0	Variable
Ecosystem Growth Fund	40%	400M	2	0	60
Staking Reserve	10%	100M	0	0	60
Liquidity-Market Making	5%	50M	50	0	12

Private Seed Raise

No tokens are released at the TGE, followed by a 12-month cliff, a period during which the tokens cannot be sold. After this initial period, token distribution for early strategic partners and contributors will occur over the subsequent 18 months.

Advisors

No tokens will be released at the TGE, a 12-month cliff, and gradual release over the subsequent 18 months. This portion is reserved for advisors who contribute to the project's continuing development.

LightLink Team

No immediate release at TGE, with a 15-month cliff, followed by an 18-month distribution period.

Community Airdrop

The community airdrop program is in place to provide a fair distribution to those who are actively exploring and utilising dApps on the network.

Token Generation Event

This portion of tokens is allocated for distribution to initial public contributors. The TGE is designed to be versatile, potentially encompassing a combination of methods such as a Launchpad, a Liquidity Bootstrapping Pool, or an offering via a Centralized Exchange.

Ecosystem Growth Fund

Gradual release starting 2 months post-TGE over a 60-month period. This large allocation will be used for various activities that promote ecosystem growth, such as partnerships, community incentives, and development funding. The extended vesting period supports sustained ecosystem development.

Staking Reserve

No release until 6 months post-TGE, followed by a 5 year distribution. Reserved for staking rewards to those who are helping secure the network via observer/validator nodes.

Liquidity-Market Making

A 50% immediate release will occur at the TGE, with the remainder over the next 12 months. This allocation is used to support liquidity on exchanges to ensure a healthy and stable market for participants.

10.4. Token Issuance & Dynamics

The LL token incorporates mechanisms within its tokenomics model that aim to manage its supply. In line with the vesting schedule, the model includes a system where monthly enterprises joining the platform will acquire tokens using fiat currency based on their specific fee tier. These tokens are then allocated for subsidising gas fees for transactions on enterprise protocols.

Further development of these mechanics, particularly in terms of how stakers might benefit from network activity, is an area of ongoing consideration. Details regarding these enhancements will be provided in future updates to the roadmap and subsequent versions of the whitepaper.

10.5. Validator Nodes

LightLink plans to implement an open-source validation program that encourages broad participation. This program will allow any qualified individual to review and verify the data published on the network, ensuring that blocks are processed correctly. This approach not only democratises the validation process but also enhances the network's transparency and reliability.

The network will maintain a public web page displaying details of verified proofs. This public record serves two primary purposes: it increases transparency by allowing anyone to verify the network's integrity and fosters public trust by demonstrating the network's commitment to openness and accuracy.

The verification process on the LightLink network is designed to be not computationally intensive. This means it does not require significant processing power, making it accessible to a broader range of participants and reducing barriers to entry.

To become a validator on the LightLink network, participants will need to purchase a Validator Non-Fungible Token (NFT) using LightLink tokens. This NFT acts as a form of licence or accreditation, granting the holder the right to participate in the validation process. The Validator NFT is not just a symbolic asset but a requirement for the operation of a validator. This approach ensures that validators have a vested interest in the network, as they must first acquire a stake in the form of the NFT.

Validators are incentivized through the receipt of LightLink tokens. These tokens are awarded as a reward for their efforts in validating blocks, thereby aligning the validators' interests with the health and integrity of the blockchain.

There is a stipulated delay before rewards are issued to validators. This delay can serve multiple purposes, such as allowing time for the validation to be double-checked, preventing abuse of the system, and ensuring that validators are committed to the long-term health of the network.

An open question remains regarding whether direct token rewards are the sole incentive for validators. Exploring additional or alternative reward mechanisms could potentially attract a wider range of validators and further secure the network. This could include non-monetary incentives or rewards that are based on the quality and consistency of a validator's contributions.

Overall, LightLink's incentivised validator program aims to create a robust, transparent, and accessible blockchain network. By leveraging NFTs for validator qualification and providing token-based rewards, LightLink seeks to ensure a high level of participation and network integrity. The consideration of alternative reward mechanisms could further enhance the program's effectiveness and appeal.

11. Conclusion

LightLink has been engineered to optimise blockchain technology for enterprises while drastically improving individual user experiences. At its core, LightLink's novel Enterprise Mode, enabling gas-free transactions for whitelisted applications, alongside its scalable architecture and Ethereum interoperability, offers targeted solutions to public blockchain's high transaction costs and network congestion. Enterprise Mode also accelerates broader adoption by significantly easing the friction of onboarding new users.

The LightLink protocol excels in interoperability, seamlessly integrating with Ethereum and other networks, making it a practical solution across a diverse array of blockchain applications. With a strategic focus on partnerships and continuous innovation, LightLink is well-positioned as an effective tool for businesses and individuals seeking to harness blockchain technology in scalable and practical ways.

References

[1] S. Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," 2008. [Online]. Available: https://bitcoin.org/bitcoin.pdf.

[2] V. Buterin, "Ethereum whitepaper," ethereum.org, Nov. 2014. [Online]. Available: https://ethereum.org/en/whitepaper/.

[3] P. Hegedűs, "Towards analyzing the complexity landscape of solidity based ethereum smart contracts," in Proc. 1st Int. Workshop on Emerging Trends in Software Engineering for Blockchain, 2018.

[4] V. Buterin, "Why Sharding is great: Demystifying the technical properties," Vitalik Buterin's website, Apr. 2021. [Online]. Available: https://vitalik.ca/general/2021/04/07/sharding.html.

[5] W. Pugh, "Skip lists: A probabilistic alternative to balanced trees," Lecture Notes in Computer Science, pp. 437–449, 1989. [Online]. Available: https://doi.org/10.1007/3-540-51542-9_36.

[6] G. Bertoni, J. Daemen, M. J. Peeters, and G. Van Assche, "RadioGatún, a belt-and-mill hash function," IACR Cryptology ePrint Archive, 2006:369, 2006.

[7] V. Buterin, "A Rollup-centric Ethereum Roadmap," Fellowship of Ethereum Magicians, Oct. 2, 2020.

[8] P. Wackerow and AlehNat, "Data availability," ethereum.org, 2022. [Online]. Available: https://ethereum.org/en/developers/docs/data-availability/.

[9] V. Buterin, "Proto-Danksharding FAQ," HackMD, Aug. 2022. [Online]. Available: https://notes.ethereum.org/@vbuterin/proto_danksharding_faq.