Analog:

A Sovereign Network for Interoperability and Liquidity Unification

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Timepaper (Version 4.1)

Abstract

We present ***Analog***, a sovereign, interoperability-first network architected to unify liquidity and functionality across autonomous blockchains. This paper details the evolution of Analog's vision and technical infrastructure, designed to bridge traditional finance (TradFi) and Web3 ecosystems. At its core lies the Timechain, a bespoke blockchain built using the Substrate SDK and secured by a Nominated Proof-of-Stake (NPoS) consensus mechanism. The Timechain serves as the immutable ledger and execution hub for the Analog network. A significant advancement detailed herein is the integration of the **Timechain EVM**, an embedded Ethereum Virtual Machine execution environment powered by *PolkaVM* and enabled via the *pallet-revive* module, facilitating native Solidity smart contract deployment and execution directly within the Timechain runtime.

Analog addresses the critical challenges of blockchain fragmentation—siloed liquidity and complex cross-chain interactions—by providing a comprehensive suite of interoperability protocols and liquidity-focused applications. These include **Analog GMP** (General Message Passing) for secure cross-chain communication and contract calls, **Analog Watch** for verifiable cross-chain data indexing, and **Analog Automation** for sophisticated task scheduling. Building upon this foundation, Analog introduces applications designed to attract and manage liquidity: ***Zenswap***, a cross-chain decentralized exchange (DEX); ***Firestarter***, a launchpad for tokenizing Real-World Assets (RWAs); and ***Analog Staking***, a liquid staking solution offering dual yields. Analog provides the essential infrastructure for developers to build the next

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generation of chain-agnostic decentralized applications (dApps) that transcend network boundaries and leverage unified liquidity pools.

CONTENTS

1.0 Introduction & Hypothesis

1.1 The Evolving Web3 Landscape: Fragmentation and Opportunity

The decentralized web (Web3) continues its rapid expansion, characterized by a proliferation of blockchain networks, each offering unique capabilities and attracting distinct communities. The initial expectation of a single dominant blockchain solving all use cases has given way to the reality of a multi-chain future. This diversification, while fostering innovation, presents significant challenges. Evidence of this shift can be observed in the changing dynamics of Decentralized Finance (DeFi); for instance, Ethereum's share of total value locked (TVL) decreased from approximately $110 billion to $47 billion between early 2021 and mid-2024[1], a 57% decline driven by the rise of competing Layer 1 and Layer 2 networks such as Solana, BNB Chain, Avalanche, and various rollup solutions.

This burgeoning multi-chain ecosystem, however, often resembles the early internet before the advent of standardized protocols like TCP/IP[2]. Without seamless interoperability, blockchains operate as isolated "walled gardens." Developers face difficult choices regarding which platform to build on, limiting their reach and potential user base. Users, in turn, must navigate complex cross-chain interactions, often involving multiple steps and distinct interfaces, to utilize assets across different networks, hindering capital efficiency and user experience. Furthermore, the reliance on cross-chain bridges, necessary for transferring assets and data between networks, has introduced significant security vulnerabilities. A substantial number of major Web3 hacks between 2020 and 2022[3] exploited weaknesses in these bridges, highlighting the critical need for fundamentally secure interoperability solutions. The increasing adoption of modular blockchain architectures and rollups further emphasizes this requirement, as data and execution become distributed across specialized layers, necessitating robust and secure communication pathways.

1.2 Analog's Vision: A Sovereign Network for Interoperability and Liquidity Unification

Analog was conceived to address these fundamental challenges. Initially focused on providing secure and seamless interoperability through its core Timechain protocol and Proof-of-Time (PoT) consensus concept, Analog's vision has evolved in response to the maturing Web3 landscape. While the foundational thesis—that secure, chain-agnostic interoperability is crucial for unlocking Web3's potential—remains valid and has arguably strengthened, the scope has broadened.

Analog is now positioned as a sovereign, interoperability-first network designed not only to connect disparate blockchains but also to unify fragmented liquidity. The core objective extends beyond facilitating cross-chain communication to actively solving the liquidity challenges inherent in a multi-chain world. This involves creating an ecosystem that bridges the gap between traditional finance (TradFi) and Web3, enabling developers to build future-proof dApps that operate seamlessly across chain boundaries and access deep, unified liquidity pools.

Analog aims to be the foundational layer for this next generation of dApps. By providing a comprehensive suite of tools—including secure message passing (Analog GMP), verifiable data access (Analog Watch), cross-chain automation (Analog Automation), and native EVM compatibility (Timechain EVM)—Analog streamlines the development process. Furthermore, by introducing dedicated liquidity applications like Zenswap (cross-chain DEX), Firestarter (RWA launchpad), and Analog Staking (liquid staking), Analog actively cultivates a vibrant economic ecosystem built upon its interoperability infrastructure.

This refined vision has gained significant traction. Since its inception with fewer than 10 members, the Analog team has grown to over 30 professionals and secured over $16 million in early-stage funding. The project has established partnerships with over 20 Launch Partners, attracted commitments from over 50 builders to develop on the platform by mainnet launch, and garnered support from prominent industry players, including Outliers Capital, Tribe Capital, Orange DAO, and Wintermute. This momentum underscores the market's recognition of the need for a robust solution that addresses both interoperability and liquidity fragmentation.

1.3 About This Timepaper

This document represents Version 4.1 of the Analog Timepaper, superseding all previous iterations published since early 2022. Its purpose is to provide a comprehensive, updated overview of the Analog network, reflecting significant strategic evolution towards liquidity unification and key technical advancements, most notably the integration of the ***Timechain EVM.***

Consistent with prior versions, this Timepaper offers a medium-level technical overview of the Analog protocol and its components. It does not serve as an exhaustive, line-by-line specification but rather aims to articulate the overall architecture, explain the interplay between different components, and illuminate the design rationale underpinning Analog's approach to solving the challenges of the multi-chain landscape. It details the current implementation and future direction of the Analog network.

2.0 The Timechain: Analog Core Protocol

2.1 Architecture: The Sovereign Hub

The core aspect of Analog revolves around the ***Timechain***, a sovereign blockchain ecosystem that serves as a ledger for all its activities—essentially acting as an ***Accountability Layer***. Although the Timechain is built on Substrate SDK and leverages some of the platform's features, including forkless upgrades, fast block times, and security-focused development, it remains an independent blockchain.

To interact with external chains, the Timechain uses ***Multi-Party Computation*** (MPC), and in particular, ***Threshold Signature Schemes*** (TSS), to create aggregate keys held by off-chain validators (also called ***Chronicle Nodes***). These Chronicle Nodes manage and control simple contracts/gateways on the supported blockchains by attesting (reading) and executing (writing) on those chains. The Chronicle Nodes are paired with the Accountability Layer (i.e., the Timechain) that processes, tracks, and executes events/instructions.

2.2 Core Components

The Timechain integrates several critical components to deliver its core functionalities: a robust consensus engine, a secure cross-chain communication fabric, and a native EVM execution environment.

2.2.1 Consensus Engine (NPoS)

The Timechain employs Nominated Proof-of-Stake (NPoS)[4] as its consensus mechanism, inheriting this battle-tested protocol from the Substrate framework. NPoS is designed to achieve high security and decentralization by balancing the roles of validators and nominators.

- **Time Nodes (Validators):** These nodes are responsible for producing new blocks, validating transactions, and finalizing the Timechain's state. They run the necessary hardware and software infrastructure to participate in the consensus process. To become an active validator, a Time Node operator must stake a significant amount of Analog's native token ($ANLOG), representing both their own capital (self-stake) and capital delegated to them by nominators. This stake serves as collateral, disincentivizing malicious behavior.
- **Nominators**: $ANLOG token holders who wish to participate in securing the network without running a validator node can delegate their stake to trusted Time Node candidates. By nominating validators, token holders express their confidence in those operators and share in the staking rewards earned by their chosen validators. NPoS algorithms distribute nomination stakes to optimize for both security (maximizing the stake backing the active validator set) and fairness (providing opportunities for well-regarded validators with lower self-stake).

The NPoS system incorporates economic incentives and penalties to maintain network integrity. Validators and their nominators receive rewards (typically funded through token inflation and transaction fees) for successfully participating in block production and finalization. Conversely, malicious or negligent behavior, such as double-signing blocks or prolonged downtime, results in the slashing of the validator's (and their nominators') staked $ANLOG. This economic risk provides a strong deterrent against attacks and encourages reliable node operation.

2.2.2 Cross-Chain Communication Fabric

Secure and reliable communication with external blockchains is fundamental to Analog's purpose. This is achieved through a combination of advanced cryptography and a specialized network of off-chain nodes managed by the Timechain.

- **Threshold Signature Schemes (TSS):** Analog uses TSS, a secure Multi-Party Computation (MPC) method, to interact with other blockchains. This technology distributes control of accounts and gateways across Chronicle Nodes, requiring a majority to authorize actions without any single node holding the complete private key. TSS secures both data reading and transaction execution, with periodic key rotation for added protection.
- **Chronicle Nodes:** These are off-chain actors forming the backbone of Analog's cross-chain interaction capabilities. They perform two primary functions:
  - **Attestation Service:** Chronicle Nodes on Analog actively track supported blockchains for specific events or state changes, particularly those involving Gateway Smart Contracts (GSCs). To do this, each node runs a "***Connector***" that listens to its assigned chains, standardizes incoming data, and broadcasts it across the Chronicle Node network. Upon detecting a relevant event, the relevant Chronicle Nodes use a TSS protocol to jointly confirm its validity and finality. This validated confirmation is then recorded on the Timechain as verifiable evidence of the external event.
  - **Relaying Service:** Once the Timechain processes an attested event and determines a corresponding action needs to be taken on a destination chain (e.g., executing the second leg of a cross-chain swap initiated via Analog GMP), Chronicle Nodes act as relayers. They retrieve the finalized instructions (e.g., a GMP payload) from the Timechain and securely submit the corresponding transaction to the destination chain, often using the TSS-controlled gateway account to authorize the execution.

- **Sharding**: To manage the complexity and scale of interacting with numerous external blockchains, the network of Chronicle Nodes is partitioned into shards. Each shard comprises a subset of Chronicle Nodes specifically assigned to monitor and interact with one or more particular external chains. The Timechain manages the registration of these shards, assigns Chronicle Nodes to them (potentially based on stake or other criteria), and handles administrative tasks like key rotation for each shard's TSS keys. This sharding mechanism allows Analog to parallelize cross-chain operations, enhancing scalability and ensuring that the workload for monitoring diverse networks is distributed efficiently across the Chronicle Node set.

Initially, Chronicle Node services will be operated by Analog Labs to ensure stability and reliability during the mainnet launch phase. However, the architecture is designed for progressive decentralization. The long-term vision involves transitioning to a trust-minimized model where any entity meeting the required hardware specifications and staking a sufficient amount of $ANLOG tokens can operate a Chronicle Node, participate in shards, and earn rewards for contributing to the network's cross-chain capabilities.

2.2.3 Timechain EVM: Native Solidity Execution Environment

A pivotal enhancement to the Analog architecture is the integration of the **Timechain EVM**, providing an embedded Ethereum Virtual Machine execution environment directly within the Timechain's runtime. This capability significantly expands Analog's functionality and developer appeal.

2.2.3.1 Rationale & Strategic Importance

The primary motivation for incorporating an EVM environment is to facilitate the seamless deployment and execution of smart contracts written in Solidity—the most widely used smart contract language—natively on the Timechain. This eliminates the need for developers to rely on external execution environments or complex bridging mechanisms for EVM-based logic, thereby reducing operational overhead and potential points of failure.

By embedding EVM capabilities, Timechain becomes significantly more interoperable with the vast existing ecosystem of Ethereum tooling and infrastructure. Developers can leverage familiar tools like Remix IDE, Hardhat, Foundry, libraries such as Ethers.js or Web3.js, and wallets like MetaMask to build, deploy, and interact with contracts on the Timechain. This dramatically lowers the barrier to entry for the large global pool of Solidity developers, enabling them to easily bring existing applications to the Analog ecosystem or build new ones that leverage Analog's unique cross-chain features.

Furthermore, native EVM execution allows smart contracts deployed on the Timechain to directly interact with Substrate's underlying primitives and other runtime modules via specialized precompiles. This enables powerful hybrid applications that combine the familiarity of Solidity with the unique capabilities of the Timechain, such as its native token ($ANLOG), governance mechanisms, or the core interoperability protocols like Analog GMP.

2.2.3.2 Technical Implementation: PolkaVM and Pallet-Revive

The Timechain EVM is realized through the integration of two key technologies developed by Parity Technologies for the Polkadot ecosystem: **PolkaVM** and **pallet-revive**.

- **PolkaVM**: This is the virtual machine chosen to execute EVM-compatible bytecode within the Timechain runtime. Unlike the traditional stack-based EVM used by Ethereum, PolkaVM is a modern VM based on the **RISC-V** instruction set architecture. **RISC-V** is a register-based architecture, which generally allows for more efficient translation to underlying hardware instructions compared to stack machines. PolkaVM specifically uses a 64-bit word size, contrasting with the EVM's 256-bit word size. While Solidity often deals with 256-bit integers (which still require emulation on PolkaVM when compiled from YUL), the native 64-bit operations for other computations can be significantly faster on standard hardware. PolkaVM is designed with several key goals relevant to blockchain execution[5]:
    - **Security**: Sandboxed execution to prevent contracts from interfering with the host system.

- **Performance**: Aiming for execution speeds competitive with or exceeding state-of-the-art WebAssembly (Wasm) VMs and traditional EVMs.
- **Efficiency**: Fast compilation times (near O(n)) and low memory overhead per VM instance.
- **Determinism**: Guaranteeing identical outputs for identical inputs and code, essential for blockchain consensus.
- **Gas Metering**: Support for accurate and deterministic resource accounting.
- **LLVM Compatibility:** PolkaVM integrates with the LLVM compiler infrastructure, opening the possibility for future support of smart contracts written in languages like Rust or C++ that can compile to RISC-V via LLVM, although the initial focus via pallet-revive is Solidity.

- **Pallet-Revive:** This is the Substrate FRAME pallet that integrates PolkaVM into the Timechain runtime and provides the necessary logic to handle EVM-style transactions and contract execution. pallet-revive is described as a heavily modified fork of pallet-contracts (Substrate's native Wasm smart contract pallet), specifically adapted for RISC-V execution via PolkaVM and aiming for closer compatibility with Ethereum's behavior and tooling.

The typical workflow for deploying and executing Solidity contracts via pallet-revive involves several steps:

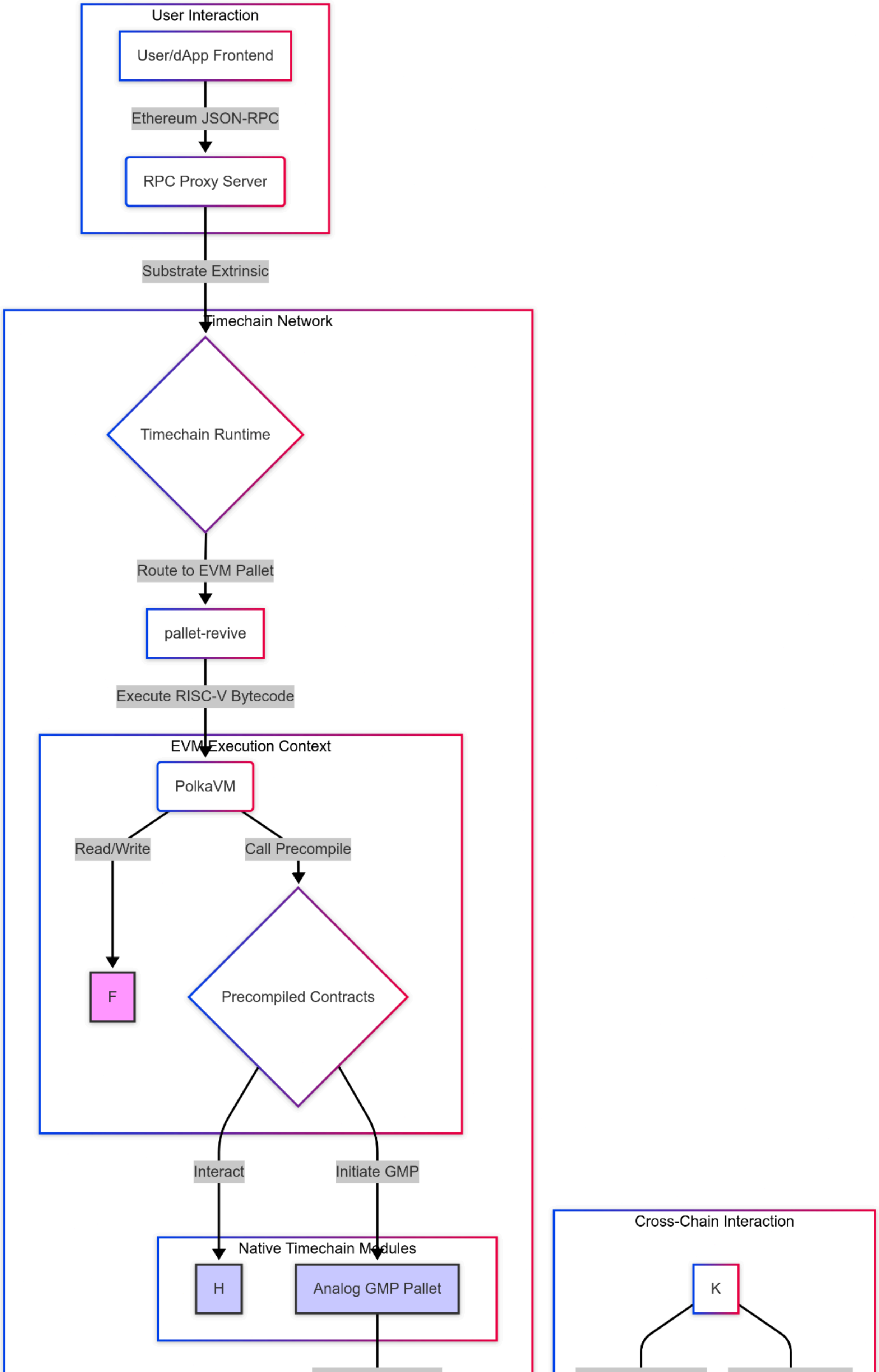
1. Developers write smart contracts in Solidity.
2. The standard Solidity compiler (**solc**) compiles the Solidity code into YUL (Yet Another Intermediate Language), an intermediate representation used by Solidity. Using YUL provides stability, as it is less prone to change than the high-level Solidity syntax itself.
3. A specialized compiler, named **revive**, takes the YUL output and recompiles it into RISC-V bytecode specifically targeted for execution on PolkaVM.
4. This RISC-V bytecode is deployed to the Timechain.

5. When a transaction calls a contract, pallet-revive loads the RISC-V bytecode and instructs PolkaVM to execute it within the sandboxed runtime environment.

- **RPC Compatibility:** To ensure seamless interaction with existing Ethereum wallets and frontend tools (like MetaMask, Remix, Ethers.js), an **Ethereum JSON-RPC proxy server** is typically deployed alongside Timechain nodes.8 This proxy intercepts standard Ethereum RPC requests, translates them into Substrate extrinsics (transactions) that pallet-revive can understand, and submits them to the Timechain. It also translates responses back into the format expected by Ethereum tools. This abstraction layer allows users and developers to interact with the Timechain EVM using familiar interfaces without needing to understand the underlying Substrate specifics.
- **Runtime Configuration:** Integrating pallet-revive requires careful configuration within the Timechain runtime. This includes defining parameters such as:
  - Gas pricing models and transaction fee mechanisms compatible with EVM expectations.
  - Storage limits and costs for the contract state.
  - Block gas limits to prevent denial-of-service attacks.
  - Mapping between Substrate's native account format (e.g., AccountId32) and Ethereum's address format (H160). pallet-revive aims to use Ethereum-native types like U256 for balances and H256 for hashes internally, where possible to enhance compatibility.
- **Implementation of precompiles:** These are special contracts deployed at known addresses that allow EVM contracts to call native Timechain runtime functions (Substrate pallets), which are not part of the standard EVM specification. Precompiles would be necessary, for example, for an EVM contract to interact with the $ANLOG token, participate in governance, trigger an Analog GMP message, or query data from Analog Watch.

2.2.3.3 Integrated Workflow

The following diagram illustrates the typical flow of interaction involving the Timechain EVM, native Timechain components, and the Analog GMP protocol:


User Interaction
User/dApp Frontend
Ethereum JSON-RPC
RPC Proxy Server
Substrate Extrinsic
Timechain Network
Timechain Runtime
Route to EVM Pallet
pallet-revive
Execute RISC-V Bytecode
EVM Execution Context
PolkaVM
Read/Write
Call Precompile
F
Precompiled Contracts
Interact
Initiate GMP
Native Timechain Modules
H
Analog GMP Pallet
Cross-Chain Interaction
K

Workflow Description:

1. A user or dApp initiates an action via standard Ethereum JSON-RPC calls (e.g., sending a transaction using MetaMask).
2. The RPC Proxy Server intercepts this call, translates it into a Substrate-compatible extrinsic, and submits it to a Timechain node.
3. The Timechain Runtime receives the extrinsic and routes it to the pallet-revive module.
4. pallet-revive identifies the target contract and instructs PolkaVM to execute the corresponding RISC-V bytecode.
5. During execution within PolkaVM, the contract can:
    a. Read from or write to its own persistent EVM-style storage, which is managed by pallet-revive within the Timechain's overall state.
    b. Call precompiled contracts deployed at special addresses.
6. Precompiled contracts act as bridges to native Timechain functionality:
    a. They might interact with standard Substrate pallets, such as the Balances pallet to manage ANLOG tokens or a Staking pallet.
    b. Crucially, a precompile can allow the EVM contract to interact with the Analog GMP pallet, initiating a cross-chain message request.
7. If a GMP message is initiated, the GMP pallet records the details of the request immutably on the Timechain ledger, acting as the Accountability Layer.
8. Chronicle Nodes, constantly monitoring the Timechain, detect the finalized GMP event.
9. The assigned Chronicle Node shard validates the request (potentially involving TSS) and relays the message to the target external blockchain, typically by submitting a transaction to the appropriate Gateway Smart Contract (GSC) on that chain, authorized via TSS.

2.3 Key Features & Benefits

The Timechain, enhanced with its integrated EVM, offers a compelling set of features and benefits:

- **Enhanced Security:** Multi-layered security approach combining NPoS consensus with economic incentives/slashing, TSS for robust cross-chain interactions involving decentralized Chronicle Nodes, secure sandboxing and gas metering within the Timechain EVM, and the underlying security features of the Substrate framework.
- **Scalability and Performance:** Designed for high throughput, leveraging Substrate's efficient architecture, parallelized cross-chain operations via sharded Chronicle Nodes, and the potential for high-performance smart contract execution via the PolkaVM-based Timechain EVM. Transaction batching and other optimizations further contribute to efficiency.
- **Seamless Interoperability:** Core design principle realized through Analog GMP, Analog Watch, and Analog Automation, enabling communication and data flow between diverse networks. The Timechain EVM extends this by allowing Solidity contracts to natively participate in and trigger cross-chain workflows.
- **EVM Compatibility:** Native support for Solidity smart contracts via PolkaVM and pallet-revive, enabling developers to utilize familiar Ethereum tools (RPC, Wallets, IDEs, libraries) and easily migrate existing dApps or build new ones within the Analog ecosystem.
- **Developer Experience:** A unified platform offering interoperability primitives, verifiable data, automation tools, and a familiar EVM environment under one roof, aiming to streamline dApp development for multi-chain applications.
- **On-Chain Governance:** Decentralized governance mechanisms allow ANLOG token holders to propose and vote on protocol upgrades, parameter adjustments, and treasury allocations, ensuring the network evolves according to community consensus.
- **Flexibility and Upgradeability:** Built on Substrate, the Timechain benefits from modularity and forkless runtime upgrades, allowing for the seamless introduction of new features, performance improvements, and security patches over time.

2.4 Validator Network

The integration of the Timechain EVM does not fundamentally alter the core roles of the validator network but reinforces their importance within the expanded ecosystem.

- **Time Nodes:** Their primary responsibility remains the security and finalization of the Timechain state through participation in the NPoS consensus protocol. They validate all transactions, including those originating from or interacting with the Timechain EVM, ensuring the integrity of the entire ledger. Their role is foundational to the trust and security of all applications built on Analog, including EVM-based dApps.
- **Chronicle Nodes:** Their dual roles in attestation (monitoring external chains via Connectors and validating events using TSS) and relaying (forwarding messages like GMP payloads from the Timechain to destination chains) remain critical. The Timechain EVM enhances the source of potential cross-chain requests, as EVM contracts can now initiate GMP calls via precompiles. Chronicle Nodes are essential for executing these EVM-initiated cross-chain actions securely and reliably. As the network decentralizes, the requirement for Chronicle Nodes to stake $ANLOG becomes crucial, ensuring their economic alignment with the network's health and the security of the cross-chain operations they facilitate.

Note that at the launch of the mainnet, Analog will operate Chronicle Node services as a centralized entity. However, as Analog progresses on its roadmap, the goal is to transition to a trust-minimized infrastructure, allowing anyone to join and offer Chronicle Node services to the network. For more details, check out the Tokenomics paper[6].

3.0 Analog Tech Stack & Product Suite

3.1 Unified Infrastructure Overview

Analog provides a cohesive technology stack designed to abstract the complexities of the multi-chain landscape, enabling developers to build sophisticated decentralized applications that operate seamlessly across network boundaries. This stack is composed of several integrated layers, as illustrated in Figure 1 (from the Original Timepaper).

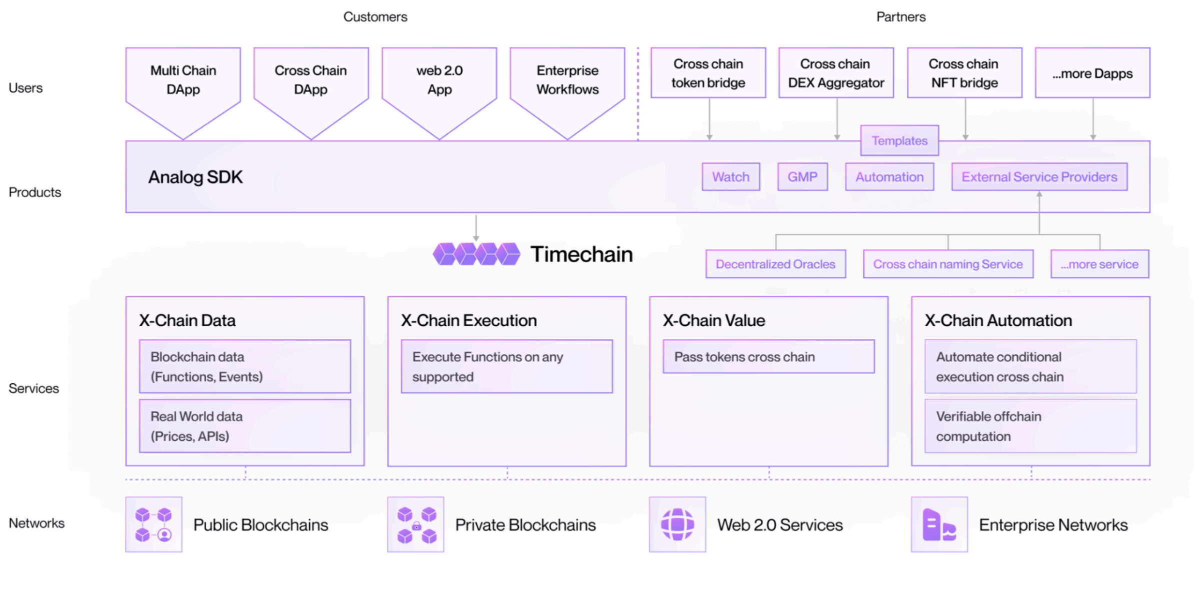


Figure 1: Analog Tech stack

- **Networks**: Analog is architected to connect a diverse range of networks. Initial integration efforts prioritize major public Layer 1 and Layer 2 blockchains, including Ethereum, Polygon, Astar, and BNB Chain. The architecture is designed for extensibility, with future plans encompassing integration with other public chains, private/consortium blockchains, enterprise systems, and potentially even traditional Web2 services, bridging disparate data and value silos.
- **Services**: Built upon the network connectivity layer, Analog offers a suite of core services focused on enabling seamless data and liquidity flow across chains. These services include:
    - **Cross-chain Data:** Providing access to indexed and verifiable data from connected networks (via Analog Watch).
    - **Cross-chain Execution:** Enabling smart contracts on one chain to trigger actions on another (via Analog GMP).

    - **Cross-chain Value Transfer:** Facilitating the movement of assets across different blockchains securely and efficiently (underpinned by GMP).
    - **Cross-chain Automation:** Allowing for the scheduling and execution of complex, conditional tasks across multiple chains (via Analog Automation). This integrated approach contrasts with specialized solutions that may focus on only one or two of these services, requiring developers to piece together multiple protocols.
- **Timechain**: As detailed in Section 2.0, the Timechain serves as the sovereign core of the Analog network. It provides the settlement layer, the security guarantees (NPoS, TSS coordination), the central Accountability Layer for all cross-chain activities, and now, the native execution environment for EVM smart contracts (Timechain EVM).
- **Products**: Leveraging the underlying services and the Timechain, Analog offers a growing suite of products accessible via easy-to-use SDKs and toolkits. These include foundational infrastructure products like Analog GMP, Analog Watch, and Analog Automation, as well as application-layer products specifically designed to attract and unify liquidity, such as Zenswap, Firestarter, and Analog Staking.
- **Unified API:** A single GraphQL endpoint provides developers with a streamlined interface for querying data from smart contracts across any supported chain, simplifying data access and integration for multi-chain dApps.

This layered architecture aims to provide a one-stop solution for developers building in the multi-chain era, allowing them to focus on application logic rather than low-level interoperability and infrastructure challenges.

3.2 Core Interoperability Services

The foundation of Analog's value proposition lies in its robust and secure core interoperability services, enabled by the Timechain and the Chronicle Node network.

3.2.1 Analog GMP (General Message Passing)

Analog GMP is the cornerstone protocol enabling communication and arbitrary function execution between smart contracts deployed on different blockchains. It embodies the concept of "cross-chain smart contract execution calls[7]", aiming to standardize inter-chain interactions much like TCP/IP standardized communication on the internet.

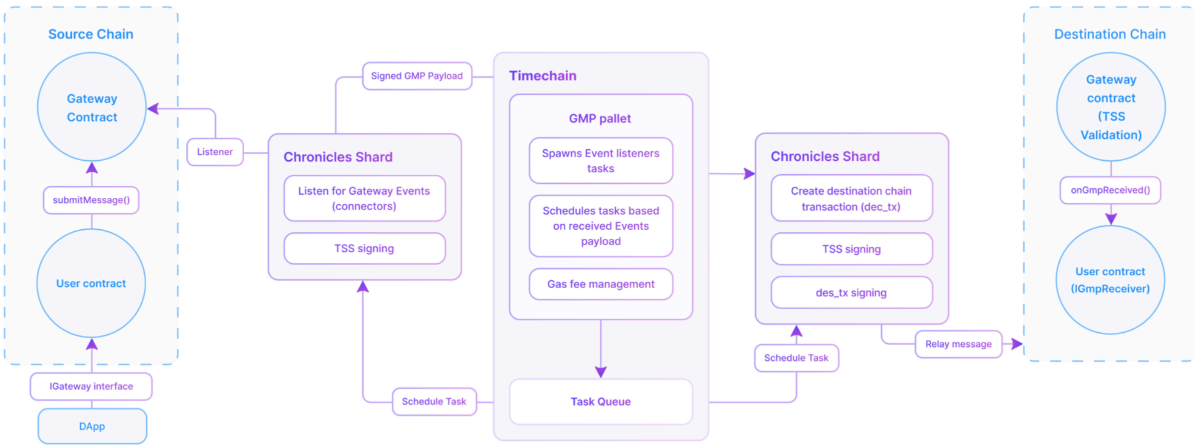


Figure 2: High-level illustration of GMP protocol

- **Architecture**: GMP relies on components deployed both on-chain and off-chain:
  - **On-Chain:**
    - **Gateway Smart Contracts (GSCs):** Deployed by Analog on each supported external chain, these contracts serve as the entry and exit points for GMP messages. Application contracts interact with their local GSC to send messages, and GSCs on the destination chain receive messages relayed by Chronicle Nodes to trigger execution.
    - **Application Smart Contracts (ASCs):** These are the user-deployed contracts (dApps) that utilize GMP to communicate with their counterparts on other chains.
    - **Time Nodes:** Secure the Timechain where GMP messages are recorded and processed.
  - **Off-Chain:**

        - **Chronicle Nodes:** Monitor GSCs on source chains for outgoing message events (e.g., GmpCreated), attest to their validity using TSS, submit the attestation to the Timechain, observe finalized GMP instructions on the Timechain, and relay them to the GSC on the destination chain for execution. They utilize Connectors to interface with specific blockchains.
        - **Shards**: Groups of Chronicle Nodes responsible for specific external chains, enabling parallel processing and scalability. Two shards are typically involved in a GMP transaction: a source shard for attestation and a destination shard for relaying/execution.
        - **Threshold Signature Schemes (TSS):** Used by Chronicle Node shards to securely attest to source chain events and potentially authorize execution on destination chains via GSCs.
    - **Transaction Lifecycle:** A typical GMP call involves:
        1. A user interacts with an ASC on Chain X.
        2. The ASC calls a function (e.g., submitMessage()) on the GSC on Chain X, providing the message payload and destination details.
        3. The GSC emits an event (e.g., GmpCreated).
        4. The source shard Chronicle Nodes observe and validate this event using TSS.
        5. The validated event is submitted to the Timechain.
        6. The Timechain processes the event, records it as a finalized GMP message, and makes it available for the destination shard.
        7. The destination shard Chronicle Nodes retrieve the message. One node (Signer) relays the message by calling an execution function (e.g., execute()) on the GSC on Chain Y.
        8. The GSC on Chain Y verifies the message (implicitly trusting the Timechain's finality and the relaying Chronicle Node's

authorization, often backed by TSS) and calls the target function (e.g., onGmpReceived) on the destination ASC.

9. The destination ASC executes its logic. Events confirming execution (e.g., GmpExecuted) may be emitted.
10. The Timechain may track the final status of the cross-chain transaction.

- **Use Cases:**
  - GMP enables a wide array of cross-chain applications, including unified domain name services spanning multiple chains, cross-chain NFT marketplaces where assets can be utilized seamlessly across networks, cross-chain DEXs that tap into liquidity pools on different chains (like Zenswap), cross-chain lending platforms allowing collateral on one chain to back loans on another, and sophisticated cross-chain liquidation protocols.

The integration of the Timechain EVM elevates the importance of GMP. Solidity contracts deployed on the Timechain can now leverage GMP (via precompiles) to interact with contracts and assets on any external chain supported by Analog. Furthermore, the new liquidity-focused applications, *Zenswap* and *Firestarter*, fundamentally rely on GMP's secure and reliable transport layer to execute their core cross-chain functions (swaps, asset transfers, capital aggregation). The security, performance, and cost-efficiency of GMP are therefore critical enablers for the entire expanded Analog ecosystem.

3.2.2 Analog Watch (Verifiable Data Indexing)

Analog Watch addresses the challenge of accessing reliable and verifiable data from multiple blockchains. It functions as a cross-chain data indexing and querying solution, aggregating data from networks like Ethereum, Astar, and Polygon, curating it, and making it available to developers via a unified API.

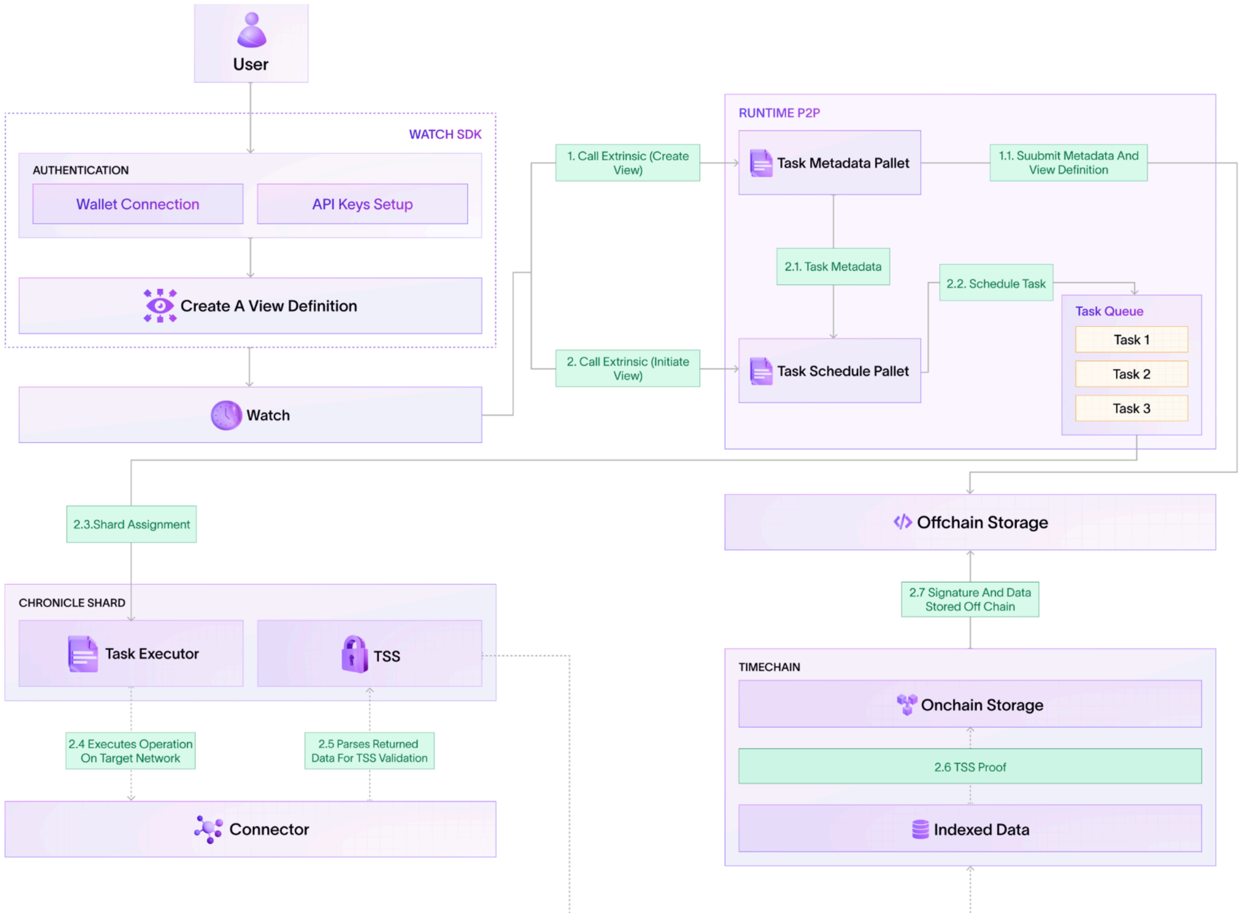


Figure 3: Analog Watch

- **Design**: Analog Watch offers two operational modes:
  - ***Hosted Service (Current):*** A centralized service provided by Analog Labs. Users can define "Views" —specifications describing how data from certain smart contracts should be indexed—via a user-friendly portal. Analog Labs runs the infrastructure to ingest data block-by-block according to these View definitions and serves it via a GraphQL endpoint. Views need to be sponsored (e.g., by Data Collectors or the Data Designer) to remain active and queryable, with sponsorship metadata tracked on the Timechain. This mode offers ease of use and zero cost for querying currently.
  - **On-Demand Data Validation Service (Future):** A planned trust-minimized approach designed to provide cryptographic guarantees

about the validity of queried data. In this mode, View metadata is stored on the Timechain. The Timechain schedules indexing tasks ("Timegraph tasks"), which are assigned to the relevant Chronicle Node shard. As new blocks are discovered on the source chain, Chronicle Nodes fetch the relevant data, sign it, and use TSS to produce an aggregated signature (TSS Data Hash) if a supermajority agrees on the data's validity. This hash is stored on the Timechain, serving as a commitment. While the actual data might be stored off-chain (e.g., in a Postgres database) for efficient querying, users can submit specific queries for on-chain validation against the stored TSS Data Hash, receiving a cryptographically signed response from the Chronicle Node shard.

- **Tokenomics**: The economic model involves View sponsorship and potentially future roles for Data Providers and Validators within the decentralized On-Demand service, likely involving $ANLOG token staking or payments.

The planned On-Demand Data Validation Service represents a significant advancement. By leveraging the same secure and decentralized Chronicle Node network and TSS mechanism used for GMP, Analog Watch can provide a high degree of trust for cross-chain data. This is particularly crucial for DeFi applications, RWA tokenization platforms like Firestarter (which might require verifiable off-chain data feeds linked to asset performance or valuation), and other use cases where data integrity is paramount. Providing cryptographically verifiable data, attested to by the staked validator set, distinguishes Analog Watch from simpler indexing solutions and makes it a vital component for building reliable applications within the Analog ecosystem.

3.2.3 Analog Automation

Analog Automation[8] is designed to enable the scheduling and execution of arbitrary tasks across multiple blockchains based on predefined conditions or triggers. It aims to automate complex workflows that might involve interactions across different chains, potentially triggered by time-based schedules, specific on-chain events detected by Analog Watch, or calls from smart contracts (including those on the Timechain EVM). Analog Automation complements GMP and Watch by providing the "action" layer for sophisticated, automated cross-chain strategies, further reducing manual intervention and enabling more complex dApp logic.

3.3 Liquidity Unification Products

Building upon the core interoperability infrastructure, Analog is introducing a suite of application-layer products specifically designed to attract, unify, and efficiently manage liquidity across the fragmented Web3 ecosystem. These products leverage the Timechain, GMP, and potentially Watch and Automation to deliver powerful financial primitives.

3.3.1 Zenswap: Cross-Chain DEX

Zenswap is Analog's native decentralized exchange, engineered for fast, secure, and cost-effective asset swaps across multiple supported blockchains.

- **Overview**: Zenswap utilizes Analog GMP to seamlessly route swap transactions and liquidity between different chains. Its core function is to optimize transaction paths and tap into aggregated liquidity pools across networks, aiming to minimize slippage and fees for users while driving cross-chain volume through the Analog network. It serves as a primary engine for attracting TVL and demonstrating the practical benefits of Analog's interoperability.
- **LP Revenue Streams:** Liquidity Providers (LPs) are incentivized through multiple revenue streams:
    - *Swap Fees:* A proportional share of the 0.3% fee levied on all trades within the pools they contribute to.
    - *$ANLOG Token Rewards:* Direct incentives paid in Analog's native $ANLOG token, allocated from a dedicated portion of the token supply, potentially with bonuses tied to pool trading volume.
    - *ZSWAP Token Rewards:* Incentives paid in Zenswap's own native governance/utility token ($ZSWAP), distributed based on liquidity provision.

3.3.2 Firestarter: RWA Tokenization Launchpad

Firestarter[9] is a pioneering platform built on Analog, designed to bridge the gap between illiquid Real-World Assets (RWAs) and the liquidity of decentralized finance (DeFi).

- **Overview**: Firestarter facilitates the tokenization of assets like real estate, small business equity, or infrastructure projects, transforming them into tradable digital tokens on the Timechain. By leveraging Analog's infrastructure, it aims to democratize access to traditionally exclusive investment opportunities and unlock the value tied up in RWAs.
- **Key Features**:
    - *Tokenization*: Assets are legally structured and linked to on-chain tokens via smart contracts (potentially deployed on Timechain EVM), ensuring clear ownership rights and enabling automated distribution of income (e.g., rental yields, profit shares) to token holders.
    - *Bonding Curves:* Utilizes automated market maker mechanisms with bonding curves for continuous price discovery and liquidity. Token prices adjust algorithmically based on buy and sell pressure, rewarding early investors and ensuring assets remain tradable.
    - *DeFi Integration*: Tokenized RWAs become composable DeFi assets. Holders can earn yield from the underlying asset's income, and potentially use their RWA tokens as collateral for loans within the Analog ecosystem or potentially on external chains (via GMP).
    - *Cross-Chain Access:* Leverages Analog GMP to attract investment capital from various blockchains (e.g., Ethereum, Polygon) into RWA projects launched on Firestarter, broadening the potential investor base.

3.3.3 Analog Staking: Liquid Cross-Chain Staking

Analog Staking introduces an innovative mechanism that allows ANLOG token holders to participate in securing the Timechain network via NPoS while maintaining liquidity and accessing additional yield opportunities across the multi-chain DeFi landscape.

- **Overview**: When users stake their ANLOG tokens (delegating them to Time Nodes to secure the network), they receive a liquid staking derivative token, stANLOG, in return. This stANLOG token represents their staked position but remains freely transferable and usable within DeFi protocols, both on the Timechain itself and, via Analog GMP, on external supported blockchains.
- **Value Proposition:**
    - **Dual Yield:** Stakers earn rewards from two primary sources simultaneously: protocol-level staking rewards (inflation and transaction fees) for securing the Timechain, and potential yields generated by deploying their liquid stANLOG tokens in DeFi applications.
    - **Capital Efficiency:** Unlike traditional staking, where assets are locked and illiquid, stANLOG allows users to earn staking rewards while actively using the value of their staked assets elsewhere, maximizing capital utility.
    - **Cross-Chain Flexibility:** Through Analog GMP, stANLOG can be bridged to other networks (e.g., as wANLOG on Ethereum), allowing stakers to access potentially higher-yielding DeFi opportunities on established ecosystems while still contributing to Timechain security.
    - **Governance Rights:** Staked ANLOG (represented by stANLOG) retains governance rights, allowing holders to participate in proposals concerning protocol upgrades, parameter changes (like inflation rates), and treasury management.
- **Yield Structure:** Stakers accrue yield from multiple sources:
    - *Inflationary Rewards*: A base annual inflation rate of 8% on the total ANLOG supply is distributed to stakers. An additional 2% initial emissions pool may boost rewards for early participants. The actual APY received from inflation is inversely correlated with the total percentage of ANLOG supply being staked (e.g., potentially 50-60% APY at very low participation rates, decreasing towards the base rate as participation rises).
    - *Network Transaction Fees*: A share of the fees collected from transactions processed on the Timechain (including those from Timechain EVM contract interactions) is distributed to stakers (estimated ~2% APY).

- *External DeFi Yields:* Additional yield can be earned by deploying stANLOG in DeFi protocols:
  - On Analog: Lending pools, liquidity provision on Zenswap (estimated ~3% APY).
  - Cross-Chain: Bridging stANLOG (e.g., to wANLOG on Ethereum) and utilizing it in external lending or restaking protocols (potentially higher yields, ~10%+ APY, subject to external market conditions and risks). A small bridging rebate (e.g., 0.1%) may incentivize cross-chain deployment.

4.0 Tokenomics

See [6] for more details about Analog Tokenomics.

5.0 Conclusion

Analog presents a significantly evolved vision and architecture, moving beyond its initial focus on pure interoperability to address the critical, intertwined challenges of cross-chain communication and liquidity fragmentation in the modern Web3 ecosystem. The Timechain, as a sovereign Substrate-based network secured by NPoS, provides a robust foundation, offering flexibility, security, and inherent adaptability through its modular design and forkless upgradeability.

The integration of the Timechain EVM via PolkaVM and pallet-revive represents a pivotal technical advancement. It strategically positions Analog to capture the vast developer pool familiar with Solidity and Ethereum tooling, while aiming for superior performance and closer EVM compatibility compared to legacy solutions. This native EVM environment, combined with Analog's core interoperability services (GMP, Watch, Automation), creates a powerful platform for building sophisticated hybrid applications that leverage the strengths of both the EVM and the underlying Substrate framework.

Furthermore, the introduction of dedicated liquidity applications—Zenswap (cross-chain DEX), Firestarter (RWA launchpad), and Analog Staking (liquid staking)—marks a strategic shift towards actively cultivating economic activity and unifying TVL. These products are not merely built on Analog; they are deeply integrated with its core infrastructure and tokenomics. The ANLOG token evolves into a central economic engine, directly incentivizing liquidity provision, network security, and participation across the application layer, creating potent feedback loops designed to drive ecosystem growth.

By tackling both the technical complexities of secure cross-chain interaction (via TSS and GMP) and the economic challenge of siloed liquidity (via Zenswap, Firestarter, and stANLOG), Analog offers a comprehensive solution tailored to the needs of the contemporary multi-chain world. Its architecture, combining established consensus mechanisms with cutting-edge VM technology and innovative application design, positions Analog as a key infrastructure provider aiming to unlock the full potential of a truly interconnected and liquid decentralized future. The successful execution of its roadmap, particularly the deployment of its liquidity suite and the progressive decentralization of its validator network, will be crucial in realizing this ambitious vision.

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