

Taiyi: A Peer-to-Peer Network for Decentralized Autonomous Worlds

Abstract

This paper proposes and formally defines the "Taiyi Network," a high-performance peer-to-peer network protocol implemented in C++, designed specifically to host persistent, Decentralized Autonomous Worlds (DAW). The Taiyi Network aims to provide a robust and efficient infrastructure for complex, participant-driven virtual ecosystems, such as its first experimental application, the MUD game "The Great Nuo World."

This paper will elaborate on its core technical contributions, which collectively serve the philosophical vision of "Cultivating Truth into Reality." Its core technologies include:

Siming Tiandao Consensus: A variant of Delegated Proof-of-Stake (DPOS) optimized for low-latency MUD interactions, designed to support high-frequency, low-latency state updates.

Law of Conservation of Qi: A self-consistent economic engine implemented at the protocol layer. This model introduces the "Feigang" mechanism, which converts network resource consumption (represented as "QI" or Gas) 1:1 into direct, non-transferable rewards for the creators of effective application logic (Smart Game Scripts, SGS). This design constitutes a novel "Proof-of-Utility" incentive paradigm, fundamentally addressing the incentive misalignment and economic unsustainability issues faced by first-generation decentralized games (GameFi 1.0).

Programmable Non-Fungible Assets (NFA): The atomic units that constitute these autonomous worlds (including characters, items, and even regions). NFAs deeply bind their logic (SGS) with their state on-chain, turning them into dynamic agents capable of autonomous behavior.

Based on the aforementioned technical primitives, this paper will focus on introducing and arguing for the "Story Universe" concept. This system is defined as an emergent narrative system driven jointly by autonomous agents (including human

users and Artificial Intelligence agents as first-class citizens), programmable physical laws (SGS), and self-consistent economic laws (Conservation of Qi).

This paper aims to provide a complete technical and economic blueprint for building a new generation of digital worlds with inherent economic closure, sustainable incentive mechanisms, and persistent "Physical Reality."

1. Introduction

1.1. Limitations of Centralized Virtual Worlds

The architecture of traditional online games and virtual worlds is, by its nature, centralized. All game data, asset records, and logic execution rely on server clusters controlled by a single entity. This model presents inherent limitations:

- First, players lack true ownership of their assets. The items, characters, and currency that users acquire through time and resource investment in the game are essentially just entries in a centralized database. Their ownership and final interpretation rights belong to the operator. Once the servers are shut down or the terms of service change, players' digital property may be permanently lost, lacking any guarantee of persistence.
- Second, the world's rules are opaque and can be unilaterally altered. The game's core economic parameters, physical laws, and interaction logic are secretly formulated by developers and can be adjusted at any time. Players are in a position of information and power asymmetry.
- Finally, the value system is closed. The value generated by in-game economic activities is difficult to circulate or recognize outside the game's ecosystem, limiting its economic potential. This model alienates player behavior into a form of labor within a closed system, i.e., "playbour," the value of which is unilaterally captured by the platform.

1.2. Challenges of First-Generation Decentralized Games (GameFi 1.0)

In response to the centralized model, the first generation of blockchain-based games (GameFi 1.0) emerged, centered on the "Play-to-Earn" concept. By introducing Non-Fungible Tokens (NFTs) and Fungible Tokens (FTs), these games achieved verifiable

ownership of game assets for players for the first time. However, this early paradigm quickly exposed its deep-seated structural problems.

On a technical level, most projects were built on general-purpose computing platforms like the Ethereum Virtual Machine (EVM). The EVM was designed for general-purpose decentralized applications. Its architecture (e.g., 256-bit word size, stack-based operations) presents significant performance bottlenecks and high transaction costs (Gas fees) for complex games requiring high-frequency, low-latency state updates. This severely damages the core game experience, making complex gameplay difficult to implement on-chain.

On an economic level, their models are often unsustainable. To attract users, projects commonly use high-inflation token emissions to reward player behavior. However, these models lack effective value-sinking scenarios to absorb the newly issued tokens. As a result, participants' primary motivation shifts from game enjoyment to speculative arbitrage. The failure of this model lies in it being merely "Play-to-Earn," where the act of "playing" itself becomes labor for value extraction, leading to hyperinflation. Once the influx of new users slows, the system, facing continuous selling pressure on the token, enters a "death spiral" of hyperinflation, causing asset values to collapse and players to leave en masse. These failures demonstrate that merely putting assets on-chain, without building a self-consistent, closed-loop value economy, cannot support a persistent virtual world. The Taiyi Network's "Proof-of-Utility" economic model (detailed in Chapter 5) is a direct response to this specific failure.

1.3. The New Paradigm: Cultivating Truth into Reality

The Taiyi Network aims to propose a new solution, its core philosophy summarized as "Cultivating Truth into Reality." This concept holds that a virtual world composed purely of information can, through specific technical architecture and rule design, attain a "Physical Reality" analogous to the physical world.

This "Physical Reality" does not refer to a crude imitation of the physical world, but rather to its possession of the following four core attributes:

- **Immutable History:** All events and state transitions are permanently recorded on a traceable, undeniable causal chain (i.e., the blockchain).

- **Transparent and Enforced Laws:** The world's operating rules are published in code (C++ consensus and SGS scripts) and enforced by the decentralized network, free from the subjective interference of any single entity.
- **Verifiable Ownership:** The ownership of assets (NFAs and FTs) within the world is clear, exclusive, and freely disposable.
- **Self-Consistent Internal Economy:** The world's value system can self-sustain, self-regulate, and effectively incentivize creative activities beneficial to the ecosystem (detailed in Chapter 5).

To achieve this vision, general-purpose blockchain platforms and their advocated "Universal Composability" paradigm present a fundamental conflict. A "real" world pursuing internal logical consistency cannot tolerate external, unpredictable protocols arbitrarily interfering with its core state (e.g., an external DeFi protocol locking or destroying the game world's core NFA resources). Such external intervention would undermine the uniformity of its "physical laws." Therefore, building a customized blockchain (the Taiyi Network) architecturally isolated and designed specifically to carry this vision is not merely a technical optimization, but a philosophical necessity.

1.4. Contributions of This Paper

This paper aims to provide a comprehensive, formal technical and economic exposition of the Taiyi Network protocol. Its core contributions include:

- **A C++/Lua high-performance architecture optimized for DAW:** Formally defining the Taiyi Network's underlying state machine, DPOS consensus, and the theoretical basis for its choice of a customized Lua virtual machine.
- **A "Proof-of-Utility" economic engine based on "Conservation of Qi":** Detailing the economic model of YANG, QI, and Feigang, and the mathematical principles of "Cultivation," arguing how it solves the incentive problems of GameFi 1.0.
- **A formal definition of the "Story Universe" as an emergent narrative system:** In Chapter 8, this paper will systematically demonstrate

how the various components of the Taiyi Network (autonomous agents, SGS physics, economic laws, regional sovereignty) work in concert to form a "Story Universe" or Complex Adaptive System (CAS).

2. The Three Realms Model: A Conceptual Framework

To systematically describe the structure and operating principles of the Taiyi Network, this paper introduces the "Three Realms Model," derived from its worldview setting, as a formal conceptual framework. This model deconstructs the entire system into three interacting but functionally distinct domains, clearly revealing the relationships between users, logic, and state.

2.1. Formal Ontology of the System

The ontology of the Taiyi Network can be defined by the following three realms:

- **The Primordial Spirit Realm (元神界):** This realm is defined as the set of all **Accounts** in the network. Each account represents a conscious entity capable of interacting with the network, be it a human user or an AI Agent. The Primordial Spirit Realm is the source for initiating state transitions and exercising asset ownership, corresponding to the system's user and authentication layer.
- **The Dao Realm (道界):** This realm is defined as the set of all **Logic** (rules) in the network. It comprises two levels: first, the C++ underlying protocols hard-coded into the node client, which form the immutable "physical laws" of the universe; second, the dynamic rules expressed through Smart Game Scripts (SGS), which can be created and evolved by users—these are the "divine abilities" and "laws" of the universe.
- **The Chaos Realm (混沌界):** This realm is defined as the **Global State** of the network at any given moment, encompassing the sum of all assets. This includes Fungible Tokens (FT) represented by "QI" and "YANG" (Longevity), as well as the Programmable Non-Fungible Assets (NFA) that make up all things in the world. The Chaos Realm is the object upon which the laws of the Dao Realm act and the stage where the entities of the Primordial Spirit Realm interact, corresponding to the system's state and asset layer.

2.2. Structural Isomorphism: Mapping from Worldview to System Architecture

The essence of the Taiyi Network's design is not merely applying a fantasy story as a superficial skin, but achieving a **Structural Isomorphism** from its core worldview concepts to its system technical components. This deep mapping is a deliberate design pattern intended to enhance the system's **Comprehensibility** and internal logical **Cohesion**. By mapping complex technical concepts (like "Validator Node," "Gas," "Smart Contract") to intuitive worldview concepts (like "Siming," "True Qi," "Tiandao"), the architecture lowers the cognitive barrier for developers and users and reinforces the world's internal logic.

The following table (Table 1) illustrates this critical mapping relationship. It integrates all of the project's core documentation and serves as the "Rosetta Stone" for understanding the Taiyi Network protocol.

Table 1: Isomorphic Mapping from Worldview to Architecture

Worldview Concept	Taiyi Network Component (Technical Implementation)	Function / Role
司命 (Siming)	DPOS Witness Node (siming_plugin)	Validate transactions, produce blocks (Target ~3 sec / "Breath"), maintain network consensus.
因果天道 (Causal Tiandao)	Blockchain (Hash-linked block structure)	The immutable, ordered ledger recording all state transitions.
天道 (Tiandao)	Smart Game Script (SGS) / Consensus Rules	Enforceable Lua or C++ logic that dictates world laws and asset behaviors.

Worldview Concept	Taiyi Network Component (Technical Implementation)	Function / Role
元神/神魂 (Primordial Spirit)	Account (account_object)	The identity layer for users (human or AI), used to own assets and initiate transactions.
阳寿 (YANG)	Base Currency (FT)	The primary unit of account, store of value, and staking asset, with an inflationary model.
真气/先天一炁 (QI)	Network Fuel (FT / Gas)	The resource consumed to execute computation (call SGS) on the network.
非罡 (Feigang)	Account-bound Incentive Voucher (Non-token)	Converted from consumed QI, non-transferable, used to reward SGS creators.
法宝/万物 (Treasures/All Things)	Programmable NFA (nfa_object)	Atomic, stateful, SGS-logic-bearing assets in the world.
修真 (Cultivation)	Probabilistic Mining	The underlying algorithm for user NFAs to acquire QI from a global reward pool.
息 (Breath)	Block Time	The network's target block production time, approximately 3 seconds.

The importance of this correspondence table is that it elevates the project's narrative from a mere "theme" to a core design principle. It clearly demonstrates to a technical audience that the seemingly esoteric terms have precise functional counterparts, making the entire system more intuitive and internally consistent. This "translation" from the philosophical layer to the technical layer is the foundation for the credibility

of the project's deep integration claims and is what fundamentally distinguishes it from other blockchain games.

3. Network Architecture and Consensus

The Taiyi Network is designed as a high-performance, deterministic state machine, with its underlying architecture optimized to support large-scale, high-concurrency autonomous worlds. This section will delve into its core C++ architecture, consensus mechanism, and transaction processing flow.

3.1. Core Architecture: A C++ State Machine

Through structural analysis of the `taiyi` core codebase¹⁴, the system can be identified as an account-model-based deterministic state machine. Its core logic is primarily located in the `libraries/chain` directory.

At the center of the system is a `database` class, which manages the blockchain's global state. All on-chain objects, such as `account_object` (accounts), `nfa_object` (NFA assets), etc., are instantiated and state-managed through this database. The `database` class encapsulates access to the underlying data storage and provides critical methods for applying transactions, managing undo states, and interacting with on-chain objects, ensuring the atomicity and consistency of state transitions.

The choice of C++ as the core implementation language is based on its exceptional performance, fine-grained memory control, and ability to be deeply optimized for game logic. The overall architecture draws on design ideas from mature C++ blockchain frameworks like Steem, but replaces its core social logic with the specific logic required to serve MUD games and autonomous worlds. This provides a level of performance and customization that general-purpose platforms like EVM cannot offer.

3.2. Siming Tiandao Consensus (DPOS)

To achieve the high throughput and low latency required for game applications while maintaining a degree of decentralization, the Taiyi Network adopts Delegated Proof-of-Stake (DPOS) as its consensus mechanism, named "Siming Tiandao Consensus."

The core of this mechanism is the election of a fixed number (planned maximum of 21) of block producers, known as "Siming." Any account holding network stake (represented by QI or YANG) can vote ("pay homage") to elect trusted nodes to become "Siming." The elected "Siming" produce blocks according to a deterministic, periodically rotating schedule. This design greatly reduces the network communication overhead required to reach consensus, thereby enabling very short block intervals.

The Taiyi Network's target block time is set to approximately 3 seconds, referred to in the worldview as "one breath" (a breath). This design decision is crucial for MUDs and similar games that require frequent interaction. High-frequency, low-risk operations in MUD games, such as moving, looking, or talking, cannot tolerate block confirmation delays of tens of seconds or even minutes. A 3-second "breath" confirmation time ensures that most of the player's operations can receive on-chain confirmation and state updates in a short time, providing a smooth, real-time gaming experience.

The core component responsible for implementing this logic is the `siming_plugin`, which manages the block production scheduling loop, transaction validation, and block signing, serving as the direct code-level embodiment of the "Siming" concept.

3.3. Transaction Lifecycle: Operations and Evaluators

Every state transition in the Taiyi Network is triggered by a Transaction. A transaction contains one or more Operations. Every atomic action in the system, such as transferring funds, creating an NFA, or calling an SGS, is defined as a specific operation type.

The definitions for operations are located in the `libraries/protocol/include/taiyi/protocol/operations.hpp` file¹⁴. For each operation type, there is a corresponding Evaluator class to handle its logic. The role of the evaluator is to verify that all preconditions for the operation are met (e.g., does the initiating account have sufficient balance, does it have the necessary permissions?), and after validation, to apply the operation to the database state, i.e., modify the relevant on-chain objects.

This "Operation-Evaluator" design pattern separates the definition of behavior from the execution of behavior, making the system logic clear, extensible, and maintainable. The implementation template for evaluators is defined in `libraries/chain/include/taiyi/chain/evaluator.hpp`, ensuring that all state transitions follow strict, deterministic rules¹⁴.

4. Tiandao: Smart Game Scripts (SGS) and the Lua Virtual Machine

If the C++ architecture is the skeleton of the Taiyi Network, then the Smart Game Scripts (SGS) and their execution environment—the Lua Virtual Machine—are what give this world its rules and soul. In the Taiyi Network, smart contracts are personified as "Tiandao" (Heavenly Laws). They are code written in the Lua language, executed within the node's built-in virtual machine, and are responsible for defining and driving all the dynamic logic of the game world.

4.1. Theoretical Basis for a Customized Virtual Machine

The Taiyi Network's choice to integrate a Lua VM, rather than adopting general-purpose solutions like EVM or WASM, is based on a profound design philosophy that goes beyond mere performance considerations. While general-purpose VMs are powerful, their design goal is universality, which for building an autonomous world with a strong worldview and high internal logical consistency, becomes a constraint.

The core reasons for choosing Lua are:

- **Lowering the Barrier to Creation:** The Lua language is concise, easy to learn, and has decades of application history and a huge developer base in the game development field. This significantly flattens the learning curve for content creators (including game designers and even advanced players) and is the technical prerequisite for realizing the "Building is Playing" concept.
- **Improving Execution Efficiency:** The Lua VM is renowned for its lightweight nature, efficiency, and seamless integration with C++. This allows the Taiyi Network to build a highly optimized execution environment, embedding core game rules (like movement, basic interactions) directly into the C++ consensus layer as underlying operational functions for upper-level

SGS to call, thus achieving execution efficiency far superior to general-purpose VMs.

- **Ensuring Worldview Cohesion:** As discussed in section 1.3, the Taiyi Network is philosophically cautious about "universal composability." By providing a VM with a limited interface, designed specifically for game logic, the Taiyi Network can ensure that all on-chain logic serves its core worldview. This avoids the logical confusion and stylistic conflicts that universal composability might bring, thereby protecting the virtual world's immersion and "Physical Reality."

The following table (Table 2) compares the key differences between Taiyi Network's customized architecture and a general-purpose EVM-based architecture for game applications.

Table 2: Comparison of Taiyi Network and EVM Game Architectures

Feature	Taiyi Network (C++/Lua)	EVM-Based Architecture (Solidity)
VM Focus	Dedicated operations for game logic & state	General-purpose computation
Primary Language	Lua (Native to game scripting)	Solidity (Native to finance & logic)
Performance Model	Optimized for low-latency, high-frequency state updates	Optimized for security & general computation, often a bottleneck for games
Gas/Fee Model	QI consumption directly rewards utility creators (Feigang)	Fees primarily reward validators/miners
Composability	Internally curated (Ensures world integrity)	Universal and permissionless (Promotes ecosystem integration)

Feature	Taiyi Network (C++/Lua)	EVM-Based Architecture (Solidity)
State Management	Native C++ objects for core game entities	General key-value storage, inefficient for complex game objects

4.2. The Taiyi Lua Virtual Machine

The Taiyi Network node integrates a specially configured Lua virtual machine, which serves as the sandbox execution environment for all SGS14. This VM is tightly coupled with the C++ underlying layer and has the following key features:

- **Resource Metering:** The VM can accurately meter every instruction and memory allocation during SGS execution. This fine-grained resource tracking is fundamental to accurately calculating QI (Gas) consumption, ensuring fair use of network resources and resistance to DoS attacks.
- **Secure Sandbox:** SGS runs in a restricted environment, unable to access the node's file system, network, or other external resources, ensuring that user-submitted code does not pose a threat to the node itself.
- **State Interface:** The VM provides a set of efficient APIs that allow SGS to safely read and modify the Taiyi Network's blockchain state (i.e., call the C++ database class), such as querying account balances or reading/writing NFA properties.

4.3. SGS Execution Model

The lifecycle of an SGS follows a clear model, with all examples available in the `taiyi-contracts` codebase¹⁵:

- **Deployment:** Any account can submit Lua code as transaction data to the network. The network validates and stores this code, assigning it a unique contract name.
- **Binding:** A deployed SGS can be bound to an NFA, serving as that NFA's behavioral logic. An NFA can bind multiple SGS to define its complex behaviors.

- **Execution:** When a user calls a function of an NFA via a transaction, the Taiyi Network node loads the SGS code bound to that NFA into its Lua VM and executes the corresponding function. The execution process consumes the caller's QI, and the "Feigang" generated is rewarded to the SGS's creator.

5. Law of Conservation of Qi: A Self-Consistent Economic Engine

The Taiyi Network's economic model is built around a core principle—the "Law of Conservation of Qi." This is not a strict law of physics, but rather a set of economic protocols designed to build a self-consistent, sustainable, and value-creation-incentivizing economy. The core of this model is to transform the consumption of network computing resources (Gas) into direct rewards for the creators of high-quality application logic (SGS).

5.1. Formal Definitions: YANG, QI, and Feigang

The "Law of Conservation of Qi" can be formally described by the following axioms:

- **QI is the fundamental energy of the system:** All meaningful state transitions require the consumption of QI.
- **The consumption of QI is a transfer of value, not annihilation:** Consumed QI is transferred in an equal amount to the creator of the SGS called in that consumption event, in the form of "Feigang."
- **The generation of QI stems from systemic inflation and participant investment:** New QI enters circulation through a probabilistic mining process called "Cultivation," and its reward pool is funded by the inflation of the base token, YANG.
- **The material world is transformed from QI:** Basic resources (FTs) in the game world cannot be created from nothing; they must be generated by consuming QI, establishing a fundamental value backing for QI.

The Taiyi economy is composed of three core assets:

- **YANG:** The base currency and staking asset. YANG adopts an inflationary model, with an annualized inflation rate starting at 10% and linearly decreasing to 1% over 20 years. 90% of newly issued YANG is used to fund the

ecosystem (primarily as the source of the global "Cultivation Reward Pool"), and 10% is used to reward "Siming" nodes.

- **QI:** The network fuel (Gas) and core energy. All SGS executions must consume QI.
- **Feigang:** It must be explicitly clarified: **Feigang is not a tradable token.** It is an **account-bound, non-transferable** incentive voucher, with its value measured in QI. The **sole source** of Feigang is the QI consumed by SGS execution, and its **sole use** is that the holder can, at any time, convert it 1:1 back into usable QI **in their own account.**

This design solves the incentive problems faced by many content platforms and GameFi projects at the protocol level. It no longer relies on subjective voting or speculation-driven mining, but instead establishes an objective value-discovery mechanism based on "Proof-of-Utility." The value of an SGS is directly measured by how much QI market participants are willing to consume for it. This design, which transforms network operating costs (Gas fees) into the core value-creation engine of the ecosystem, is the most profound innovation of the Taiyi economic model.

5.2. QI Generation: The Mathematical Principle of Cultivation

The main source of QI is the in-game "Cultivation" behavior, with its rewards coming from the global cultivation reward pool funded by YANG inflation. The underlying mechanism of cultivation is a "Probabilistic Mining" algorithm.

According to the protocol definition, when one or more NFAs participate in a cultivation activity and it concludes after a duration t , the QI reward R obtained is determined by the following formula:

$$R = \lambda \sum_{n=1}^N k_n \times P \times \frac{t}{T}$$

Where:

- R is the final amount of QI reward obtained.
- λ is the cultivation efficiency coefficient, determined by the "cultivation method" (a series of SGS) used, representing the efficiency differences of various methods.

- N is the number of NFAs (e.g., characters, treasures) participating in this cultivation.
- k_n is the amount of "true qi" locked by the n -th NFA participating in the cultivation. This represents the capital invested by the participant.
- P is a deterministic probability sample value in the $[0, 1.0]$ range, calculated at the end of cultivation, introducing randomness.
- t is the effective duration of this cultivation.
- T is a system-defined maximum cultivation time window (e.g., 24 hours), used to normalize the weight of time investment.

This formula clearly shows that QI output is positively correlated with the capital invested by participants ($\sum k_n$), the time invested (t), and the strategy chosen (λ).

The QI obtained from cultivation is not created from thin air; it comes from the global cultivation reward pool funded by YANG inflation.

5.3. QI Consumption and the Feigang Incentive Mechanism

This is the core of the economic model. When any account executes an SGS and consumes an amount C_{QI} of QI, the protocol automatically performs the following two atomic operations:

1. Deduct C_{QI} of QI from the executor's account.
2. Add an equal amount of "Feigang" to the account of the SGS's creator.

"Feigang" is a special form of QI. It has a numerical value but is not a tradable token. It cannot be transferred between accounts. Its only function is that the holder can convert it 1:1 back into usable QI in their own account at any time. This mechanism ensures that rewards are precisely targeted and avoids the introduction of another speculative token.

This is also the most profound innovation of the Taiyi economic model, constructing a novel "Proof-of-Utility" paradigm. This mechanism **reroutes** the network's operating costs (Gas fees), transforming them from mere consumption (or rewards for validators only) into a direct incentive for the ecosystem's core value creators.

This solves the incentive misalignment problem of GameFi 1.0 and the incentive quantification problem of Web3 content platforms. The value of an SGS is no longer

determined by subjective voting but is **objectively** measured by how much QI market participants are willing to consume for it.

The formal process of this mechanism is as follows:

3. Account A initiates a transaction, calling SGS S on NFA X .
4. The Taiyi Lua VM precisely calculates the execution cost of SGS S as C_{QI} .
5. The protocol deducts C_{QI} of QI from Account A's balance.
6. The protocol adds C_{QI} to the **Feigang** balance of the creator of SGS S (Account B).

5.4. The Complete Economic Cycle and Value Anchor

The entire economic system forms an elegant closed loop:

- **Macro-Injection:** 90% of YANG's annual inflation is used to fund the ecosystem, forming the source of the global cultivation reward pool.
- **Energy Generation:** Players obtain QI from the reward pool through "Cultivation" (investing capital, time, and strategy).
- **Value Discovery & Consumption:** Players consume QI to run high-quality SGS to gain game experiences or functionality.
- **Creator Incentive:** The consumed QI is converted into Feigang, directly rewarding the SGS creators.
- **Value Outflow:** SGS creators convert Feigang back into QI, which can be used to pay for their own consumption or realize value through an exchange mechanism with YANG.
- **Value Anchor:** The value of QI is not entirely dependent on speculation. It has fundamental, intrinsic consumption scenarios and a value basis: QI is the **only** way to convert into basic material resources (gold, food, wood, cloth, medicine) through specific mechanisms (like the "Refining Heaven Pagoda" NFA). These basic materials are necessary to build and maintain the game world, thus providing an ultimate value anchor for QI.

This cycle tightly links the network's macroeconomic policy (inflation), micro-user behavior (cultivation and consumption), and content creation (SGS development), aiming to build a self-regulating, self-incentivizing, and sustainable digital economy.

6. Programmable Non-Fungible Assets (NFA): The Atomic Units of the Autonomous World

The core world-building block of the Taiyi Network is the Programmable Non-Fungible Asset (NFA). This concept is a significant extension of the standard NFT, deeply integrating the asset's ownership certificate with its intrinsic behavioral logic, turning every on-chain entity into a potential autonomous agent.

6.1. From NFT to NFA: Binding On-Chain State and Logic

Standard NFTs (like ERC-721) primarily solve the problems of digital asset uniqueness and ownership verification. However, they are typically static; their properties and functions depend on the interpretation and execution of external centralized servers. In contrast, NFAs in the Taiyi Network have the following core features:

- **On-Chain Binding of State and Logic:** An NFA not only records its owner and metadata but, more importantly, it directly binds one or more SGS on-chain. These SGS define the NFA's complete properties, state, and executable behavioral functions.
- **Autonomous Behavior Capability:** Because SGS can include logic designed to execute periodically (e.g., the `heart_beat` function in `liantianta.lua`), NFAs can achieve autonomous behavior without external triggers.

This means the NFA's logic is endogenous, transparent, and enforced by blockchain consensus, freeing it from dependence on external servers.

6.2. The "Primordial Spirit Access" Protocol

This is the most revolutionary feature of the Taiyi Network's NFA design, known in the worldview as "Primordial Spirit Access" ("Shenhun Jieru") or "Possession" ("Duoshe"). This protocol is **not limited** to character NFAs but applies to **all** NFAs. The protocol dictates that since all NFAs adhere to a unified underlying interface standard, any account ("Primordial Spirit") can "access" any NFA it owns and operate from that NFA's perspective.

The significance of this design far exceeds traditional role-playing. It fundamentally dissolves the "player-character" (subject-object) duality. The Account is formally defined as a pure, bodiless **consciousness** or **Agency**. The NFA, then, is the **Vessel** this consciousness can inhabit, regardless of whether that vessel is a character, a sword, a tree, or a piece of land.

When a player accesses a sword NFA, they can execute the "parry" or "release sword qi" skills defined by the sword's SGS. This mechanism allows participants to explore "what is the experience of being a tree?", creating unprecedented possibilities for digital "presence" and narrative experience.

6.3. Open Access and AI Agents

The Taiyi Network, by design, sets no entry barriers for accessors. This means that Artificial Intelligence (AI) agents can become first-class citizens in the network, just like human players. An AI can freely create an account, control a private key via algorithms, and thus own and operate NFAs.

The combination of AI agents and programmable NFAs creates a "dual-autonomy" system:

- **SGS-defined Autonomy:** The NFA has pre-programmed autonomous logic defined by its SGS (like `heart_beat`).
- **AI-defined Autonomy:** The NFA can be "accessed" and controlled by an AI agent with autonomous decision-making capabilities.

Combined with the "Primordial Spirit Access" protocol, the roles of AI agents can become extremely diverse and complex:

- It can play a normal character NFA, teaming up, trading, and competing with other players.
- It can operate a production NFA (like the "Refining Heaven Pagoda"), autonomously deciding production strategy based on market prices.
- It can even control a regional NFA, acting as a city lord, responsible for urban planning, taxation, and management.

This combination will give rise to extremely high Emergent Complexity. For example, an AI agent could own and "access" a Zone NFA, playing the role of a rational,

autonomous "City Lord." This AI lord could dynamically adjust its region's SGS permissions (see Chapter 7) or adjust tax rates based on market conditions to achieve its programmed goals (e.g., maximizing its region's QI revenue), thereby creating a dynamic socio-economic environment far beyond what any human script could design.

This complete openness to AI aims to build a virtual ecosystem that is truly human-machine symbiotic and co-evolving. The behavior of AIs will bring immense complexity and unpredictability to the world, making "The Great Nuo World" more like a real, self-organizing society than a stage with pre-set scripts by developers.

7. Dynamic Autonomy and Local Sovereignty: The Zone Permission Control Mechanism for Tiandao

7.1. The Permission Paradox: Conflict Between Permissionless Innovation and State Integrity

The Taiyi Network aims to build a vibrant ecosystem. To ensure the vitality of the ecosystem and the emergence of creativity, its core relies on the **Permissionless** innovation of SGS. Any account can freely create new "Tiandao" (SGS) to define new world rules and asset behaviors.

However, this complete openness introduces a core governance paradox: a malicious or poorly designed SGS (e.g., one intended for economic attack or to break the game's narrative integrity) could have a catastrophic impact on the system. If anyone can introduce chaotic "laws" at any time, how can the "Physical Reality" of this world be maintained?

The Taiyi Network uses the "Feigang" reward mechanism to incentivize excellent SGS creators. This mechanism directly converts computing resource consumption (QI) into rewards for creators, forming a "Proof-of-Utility" economic loop. However, relying solely on positive incentive mechanisms is insufficient to counter deliberate sabotage. Malicious or poorly designed SGS could cause disastrous impacts on specific local Zones. For example, a destructive SGS might exploit underlying protocol vulnerabilities or execute extremely resource-intensive operations to launch speculative attacks on a region and all associated NFAs running within it, leading to

the destruction of the game's narrative and fairness. Malicious actors might gain meager rewards by creating SGS that purely consume QI. Therefore, to maintain the "Physical Reality" of the Decentralized Autonomous World (DAW), hard punishment and prohibition mechanisms must be introduced.

7.2. The Zone as a Boundary of Autonomous Sovereignty

The Taiyi Network's solution is to **delegate** governance power to the local level, rather than relying on global, centralized review. The system introduces the Zone as an entity that exercises **Local Sovereignty**.

A Zone is itself a Programmable Non-Fungible Asset (NFA), and its owner is granted protocol-level permission control over the execution of SGS within its territory.

The Zone NFA acts as a local "City Lord" or "Landlord." By empowering the Zone owner with the ability to set execution permissions for SGS entering its boundaries, the Zone's SGS permission mechanism achieves **dynamic, local, and immediate** rule enforcement on the local environment without modifying the underlying C++ consensus protocol. This delegation model enhances the system's anti-fragility. The base layer's global consensus (Sining nodes) is responsible for maintaining fundamental security and state consistency, while the **content responsibility** for SGS running within a specific region is delegated to the Zone NFA's owner or the account holding its Active permission. This layered governance model improves the system's response speed to local crises (such as economic attacks on a specific region or the game as a whole), ensuring the stability and order of the local environment.

7.3. Formal Definition and Interface of Zone Permissions

The Zone's state object is extended to store a permission list for SGS. Only accounts holding the Zone NFA's `owner` or `active` permission can initiate governance operations.

The core governance interfaces include:

- `set_contract_permission`: Explicitly set the permission status of an SGS in the Zone's permission map (PROHIBITED or ALLOWED).
- `remove_contract_permission`: Remove an explicit setting for an SGS, reverting it to the default state.

- `set_ref_prohibited_contract_zone`: Set a reference zone from which to inherit its prohibition list.

The following table (Table 3) summarizes the functions of these core interfaces.

Table 3: Core Zone Permission Management Interfaces and Their Roles

Interface Function (Lua API)	Function Description	Required Permission	Effect on Zone State
<code>set_contract_permission</code>	Sets the explicit permission (allowed or prohibited) for a specific SGS in this zone.	Owner or Active	Creates/updates an SGS permission record in the Zone state object.
<code>remove_contract_permission</code>	Removes the explicit permission setting for a specific SGS.	Owner or Active	Deletes the SGS permission record from the Zone state object, reverting to default or reference rule.
<code>set_ref_prohibited_contract_zone</code>	References this zone's prohibition list to another zone's prohibition list.	Owner or Active	Updates the <code>ref_prohibited_zone_id</code> field in the Zone state object.

7.4. Collaborative Zone Governance: The Blacklist Reference Model

In a permissionless ecosystem, the number of potentially malicious or poor-quality SGS can grow rapidly. Requiring every newly created Zone NFA to repeatedly invest resources in maintaining an exhaustive blacklist against thousands of undesirable or destructive SGS would constitute a massive operational burden. This redundant labor reduces governance efficiency and slows down the creation and secure

deployment of new zones. To solve this scalability challenge, the Taiyi Network introduces a zone reference mechanism, allowing one Zone to inherit the prohibition list of other established, trusted Zones, thus achieving effective sharing of governance resources.

Through the `set_ref_prohibited_contract_zone` interface, this mechanism allows a Zone A to *reference* the prohibition list of another (usually more mature and trustworthy) Zone B. Zone A does not store a copy of Zone B's list; instead, it dynamically queries Zone B's state during each SGS permission check. For example, the code sample `niuxincun.lua` uses this interface to reference another Zone's prohibition list, reflecting inter-zone collaborative governance¹⁵.

This design creates an **Emergent Trust Network**. The reference mechanism essentially creates a trust network. Small or nascent zones can delegate security and compliance responsibilities to large, well-managed, reputable zones. This allows security standards to propagate from the top down, solving the scalability problem of a permissionless system. Furthermore, this structure promotes governance specialization. Certain core Zones (e.g., the `daliang` Zone) may evolve into de facto "security auditing bodies" or "standards-setters," their quality of governance itself becoming a quantifiable on-chain value and reputation.

To ensure the final say of local sovereignty, the priority for permission judgment is strictly defined as: **Local Override > Reference Prohibition > Global Default (i.e., Allowed)**.

7.5. Contribution of the Governance Mechanism to the Economic Engine

The Zone permission mechanism is critical to maintaining the long-term stability of the "Law of Conservation of Qi."

By prohibiting malicious SGS (e.g., those designed purely for "Feigang-farming" with no actual utility), the Zone NFA owner ensures that the QI consumed within their territory is used for **genuinely effective**, non-destructive state transitions.

This greatly protects the **Signal-to-Noise Ratio** of the Feigang incentive mechanism. It ensures that the Feigang rewards obtained by SGS creators truly originate from QI consumption generated by SGS that are recognized by the market

(i.e., Zone owners and users) as beneficial to the ecosystem. Thus, this governance capability allows the "Proof-of-Utility" economic model to be closed.

Furthermore, this verifiable security (Good Governance) increases the value of the Zone NFA itself. A well-governed Zone has lower environmental risk and is more suitable for high-value economic activities (like running complex SGS). This provides a direct economic incentive for the Zone NFA owner to actively fulfill their governance duties as "City Lord."

8. The Story Universe: An Emergent Narrative System Driven by AI, NFAs, and Economic Laws

This chapter aims to respond to the project's core philosophy by systematically synthesizing the aforementioned technical and economic components to formally define how the Taiyi Network operates as a "Story Universe."

8.1. Definition of "Story Universe": Beyond Static Lore

A "Story Universe" is not a static background story (Lore) pre-written by developers. Instead, this paper formally defines the "Story Universe" as a **Complex Adaptive System (CAS)**.

In this system, the "Narrative" itself is the **Emergent State Transitions** recorded by the system on an immutable ledger (the Taiyi blockchain). This chapter will deconstruct the four core pillars of this system's emergence: the Actors (The Who), the Physics (The How), the Economy (The Why), and the Territory (The Where).

8.2. The Actors of the Narrative: Human Players and AI Agents as First-Class Citizens (The "Who")

Building on the discussions in Chapter 2 (Primordial Spirit Realm) and Chapter 6 (AI Agents), the narrative in this system is jointly driven by two types of Autonomous Agents with equal status:

- **Human Agents:** Interacting with the network through their **account** (Primordial Spirit).
- **Artificial Intelligence Agents:** Interacting with the network through their **account** (Primordial Spirit).

The actions of these agents (manifested as signed Operations) are the fundamental drivers of the narrative's unfolding.

8.3. The Physics of the Narrative: SGS as Programmable "Physical Laws" (The "How")

Building on the discussion in Chapter 4 (SGS & Lua VM), the "Tiandao" (SGS) constitute the **Programmable Physics** of this universe. They define the "How" of the narrative's unfolding.

SGS define what is possible, what is impossible, and the cost (QI consumption) and consequence (state change) of all actions. Therefore, every "story" (e.g., "a character uses a 'Yantong Stone' to create another character") is, at the protocol level, a **Computation** (the execution of an SGS). It consumes "energy" (QI) and, according to the established "physical laws" (SGS code), transforms an initial state into an irreversible final state.

8.4. The Economy of the Narrative: Proof-of-Utility Driven by "Conservation of Qi" (The "Why")

Building on the discussion in Chapter 5 (Law of Conservation of Qi), the agents' actions are **not** random; they are **incentivized** and **constrained** by uniform economic laws. This economic law provides the fundamental motivation (The "Why") for all agents' actions.

The "Law of Conservation of Qi" ensures:

- **Motivation to Survive/Act:** Agents must acquire QI through "Cultivation" (Formula 5.2) to pay the price of "action" (executing SGS).
- **Motivation to Create/Contribute:** Agents must create **useful** "physical laws" (i.e., high-quality SGS) to receive rewards through the "Feigang" mechanism, thereby acquiring more QI.

Therefore, the "Proof-of-Utility" mechanism is itself the universe's **Core Plot Engine**. It economically guarantees that the "Story Universe" will spontaneously be filled with conflict, innovation, cooperation, and competition, as all agents compete under a common framework to acquire energy (QI) and create utility (SGS). An AI

agent's "character arc" might be its on-chain verifiable, rational pursuit of maximizing its Feigang income.

8.5. The Territory of the Narrative: Zone NFAs as Sovereign Stages (The "Where")

Building on the discussion in Chapter 7 (Zone NFA), the "Where" the narrative takes place is not homogeneous. Each Zone NFA is a **Sovereign Stage**. The owner of this stage (e.g., a "City Lord"), through the SGS permission mechanism, plays the role of a "local narrative director," defining the **local narrative rules** of that stage (e.g., setting "PVP is prohibited here" or "Magic is nullified here" via `set_contract_permission`).

This mechanism allows for the generation of **Emergent Cultures**. A Zone NFA strictly managed by an AI City Lord with a comprehensive blacklist will spontaneously generate narratives about "order," "law," and "civilization." Conversely, a completely permissionless Zone NFA will generate narratives about "chaos," "frontiers," and "danger."

8.6. The Experience of the Narrative: "Primordial Spirit Access" and Emergent Presence (The "Feeling")

Building on the discussion in Chapter 6 ("Primordial Spirit Access"), the "Feeling" of the narrative is **Panoramic** and **Democratized**. The "Primordial Spirit Access" and "Possession" protocol allows any agent (Primordial Spirit) to experience and drive the narrative from the perspective of **any** NFA it owns.

In summary, the "Story Universe" is the holistic emergent property of the Taiyi Network's architecture. It is a universe where the narrative's **Actors** (Human/AI), **Physics** (SGS), **Economy** (QI/Feigang), and **Territory** (Zones) are all programmable, autonomous, and co-evolving on-chain. And the "Story" itself is the verifiable, immutable record of this collaborative evolution (i.e., the Taiyi blockchain itself).

9. Experimental Implementation: The Great Nuo World

To validate and demonstrate the capabilities of the Taiyi Network protocol, a MUD (Multi-User Dungeon) game called "The Great Nuo World" is being developed as its first experimental application. This section will illustrate the practical operation of the Taiyi protocol (especially the "Story Universe" described in Chapter 8) by analyzing the code logic and interaction flow of its core mechanics.

9.1. Code Logic Analysis of Core World-Building Mechanics

By analyzing the SGS functions in the `taiyi-contracts` repository¹⁵, we can deconstruct the concrete implementation of the "physical laws" in the "Story Universe."

9.1.1. Resource Generation: Logic of `liantianta.lua`

The "Refining Heaven Pagoda" (`liantianta`) is a typical autonomous production NFA. The core logic of its SGS (`liantianta.lua`) is as follows:

- **State Variables:** The SGS reads and writes key state variables via an API, such as `nfa.owner` (the owner's account) and `nfa.qi` (the amount of chaotic qi stored).
- **Autonomous Behavior (`heart_beat` function):** This function is designed to be called periodically and automatically by the Taiyi Network protocol. Its internal logic checks the `nfa.qi` stock. If the stock is above a threshold, it executes the conversion logic: consuming a certain amount of qi and adding a corresponding amount of basic resource FTs (e.g., "gold" and "food") to the `nfa`. The conversion ratio is a fundamental rule hard-coded in the underlying (C++) layer. If `qi` is insufficient, the function does nothing.
- **Active Activation (`active` function):** This function allows the NFA's `owner` to manually trigger a resource conversion process by sending a transaction, or to reactivate it after the `heart_beat` has stopped due to lack of energy.

This SGS clearly demonstrates how a programmable NFA operates as an **autonomous economic agent** in the world. It follows the "physical laws" defined by its internal SGS (conversion rate) and continuously transforms energy (QI) into matter (FTs).

9.1.2. Entity Creation: Logic of `yantongshi.lua`

The "Yantong Stone" (`yantongshi`) demonstrates how an NFA can act as a "factory" to create other NFAs. The core of its SGS (`yantongshi.lua`)¹⁵ is the `born_actor` function:

- **Core Functionality:** The `born_actor` function allows the owner of the "Yantong Stone" to birth a new character NFA within the Zone NFA where the stone is located.
- **Parameterized Creation:** The function accepts multiple parameters, such as `sex` (gender), `sxq` (sexual orientation), and `prop` (a table containing initial attribute point distribution, e.g., strength, constitution, etc.). This indicates the creation process is highly customizable.
- **Interaction with Underlying Protocol:** The function's internal logic calls native functions of the Taiyi Network (exposed to the VM via the Lua C-API). First, it calls an internal function like `__create_actor`, which is responsible for creating a new, basic NFA object in the blockchain state and returning its unique ID. Next, it calls `__upgrade_actor_contract` to set the newly created character NFA's core contract to a standard character behavior SGS (e.g., `contract.actor.normal`). Finally, it sets the new character NFA's initial attribute values based on the passed `prop` parameter.

This example reveals the powerful world-building capabilities of SGS: they can not only change their own state but also interact with the underlying protocol to instantiate and configure entirely new, complex on-chain objects. This allows the world's evolution and expansion to be driven completely by in-game logic and assets.

9.2. On-Chain Interaction Tracing: Lifecycle of a MUD Command

Below, we trace the complete lifecycle of a simple player command, `start_cultivation`, based on actual interaction logs from the `ndanuo` MUD client. This demonstrates the coordinated operation of the "Story Universe's" four pillars (Actor, Physics, Economy, Territory).

1. **Input (Actor):** The player (Primordial Spirit) inputs the command `start_cultivation` in the `ndanuo` MUD client.

2. **Transaction Construction (Actor -> Physics):** The client parses this command and constructs a Taiyi Network transaction. The transaction contains an Operation targeting the character NFA the player is currently "accessing," calling the `start_cultivation` function in its core contract. The transaction is signed with the player's account private key.
3. **Network Consensus:** The transaction is broadcast to the Taiyi Network. A rotating "Siming" node includes this transaction in its block proposal. After DPOS consensus, the block is finalized, taking approximately 3 seconds ("one breath").
4. **State Change (Physics -> Narrative):** When the transaction is executed, the character NFA's `start_cultivation` function runs in the Lua VM. This SGS (physical law) modifies the character NFA's internal state, for example, setting an `is_cultivating` flag to `true` and recording the start timestamp.
5. **Economic Impact (QI Consumption) (Economy):** The Lua VM calculates the amount of QI required based on the computational complexity of the `start_cultivation` function (e.g., 0.01 QI). This amount of QI is deducted from the player's account balance.
6. **Economic Impact (Feigang Reward) (Economy -> Physics):** The consumed 0.01 QI is immediately converted into 0.01 Feigang and credited to the account of the creator of that character's core SGS (the contract to which `start_cultivation` belongs).
7. **Client Response (Narrative):** The `ndanuo` client, upon listening to the successful transaction confirmation event, displays a success message to the player, such as: "You begin to breathe the vital energy of the world and have entered a state of cultivation."

9.3. Simulation: Autonomous Economic Activity of an AI Agent

Imagine an AI agent (Primordial Spirit) that owns a "Refining Heaven Pagoda" NFA. The AI's program logic could periodically query the real-time market prices of basic resource FTs (gold, food, wood, cloth, medicine) on the Taiyi chain, provided by some "oracle" SGS.

When the AI detects that the price of "FOOD" is highest, it autonomously constructs and broadcasts a transaction. This transaction calls its "Refining Heaven Pagoda" NFA's `active` function, passing parameters to specify that all stored `qi` should be converted into "FOOD." After the transaction succeeds, the AI's account is credited with a large amount of "FOOD" FT, which it can then sell on the in-game decentralized market for a profit.

This process is fully automated and perfectly demonstrates the "Story Universe" described in Chapter 8: an autonomous **Actor** (AI agent) utilizes programmable **Physics** (`liantianta.lua`) and follows **Economic** incentives (profit margin) to take action on-chain. All its actions are immutably recorded as part of the "Narrative."

10. Conclusion

The Taiyi Network proposes a comprehensive protocol for building persistent, decentralized autonomous worlds. Through a profound reflection on the limitations of existing centralized virtual worlds and first-generation blockchain games (GameFi 1.0), the Taiyi Network has made a series of fundamental innovations in its architecture, consensus, economic model, and core asset primitives.

Its core contributions lie in:

- **A high-performance, customized architecture born for gaming:** By adopting C++ and DPOS consensus (~3 sec "breath") and integrating a Lua VM optimized for game logic, the Taiyi Network aims to fundamentally solve the performance bottlenecks of general-purpose blockchains in hosting complex, high-frequency interactive worlds.
- **A self-consistent, "Proof-of-Utility" economic model:** The innovative "Law of Conservation of Qi" and the "Feigang" mechanism convert network resource consumption (Gas/QI) directly into objective, non-transferable rewards for the creators of valuable application logic (SGS). This builds a self-incentivizing, self-regulating economic closed loop, offering a new paradigm for solving the "creator economy" problem in the Web3 space.
- **A paradigm-shifting asset and interaction primitive:** The Programmable NFA and its unique "Primordial Spirit Access" (Possession)

protocol elevate on-chain assets from static ownership certificates to dynamic agents with endogenous logic and autonomous behavior.

- **An emergent "Story Universe":** As argued in Chapter 8, by combining autonomous agents (human and AI), programmable physics (SGS), a self-consistent economy (Conservation of Qi), and local sovereignty (Zone NFA), the Taiyi Network constructs a "Story Universe" as a complex adaptive system, where the narrative is the co-evolved, immutable on-chain record of all participants.

These components work in concert to serve the grand vision of "Cultivating Truth into Reality." The Taiyi Network is not just a technical framework but a philosophical experiment in digital "Physical Reality." It demonstrates that through ingenious protocol design, a world composed purely of information can possess an immutable history, enforced laws, verifiable ownership, and a sustainable internal economy. This represents a solid step forward in building digital existences that are meaningful and hold lasting value.

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