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Generic-NFT: A Generic Non-Fungible Token Architecture for Flexible Value Transfer in Web3

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Abstract

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I. Introduction

The development of user-centric Web3 is still in its infancy. To solve the current situation where Internet giants monopolize the power to use user data, Web3 needs to establish a decentralized identifier (DID) to link user data with it in the form of DID documents [1]. Do user assets need to be similarly decentralized representation in Web3? The answer is yes. User assets are mainly divided into cash and physical assets with a certain market value. For the average individual in modern society, the value of physical assets they hold is often much greater than that of cash assets. Blockchain cryptocurrencies, or Fungible Tokens (FTs), can represent cash assets in a decentralized manner, and FTs have basically achieved cross-chain value exchange. However, most physical assets in the real world are illiquid, and important assets require centralized corroboration. For example, the confirmation of real estate needs to rely on the registration of the housing authority. In order to decentralize the representation of physical assets, Non-Fungible Token (NFT) came into being [2]. It is a unique data unit stored on the blockchain, which has better liquidity and can be traded efficiently and atomically. Through cryptographic confirmation, no one can forge assets.

NFTs have been widely adopted in various crucial Web3 systems such as decentralized gaming industry, online events, collectibles trading, and the Metaverse [3]. NFTs aim to enable the value mapping of users' physical assets (such as houses, cars, collectibles, and even DIY images and game props) as their unique identifiers. Users can customize the value of NFT based on digital attributes such as the rarity and liquidity of physical assets, and trade them freely. For example, on the Opensea NFT marketplace, users are free to mint NFTs and trade NFTs using Ethereum.

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Different NFT ecosystems are developed based on divergent blockchain smart contracts, protocols, and standards. Currently, the mainstream NFT systems are developed with Ethereum as the underlying blockchain, and some are developed based on other public blockchains such as Polygon and permissioned blockchains such as Ant Chain. NFT protocols include Ethereum Request for Comments 721 (ERC-721), ERC-998, ERC-1155, Ethereum Improvement Proposals 1948 (EIP-1948), EOSIO.NFT, and others.

The lack of generic blockchain infrastructure and unified development standards have resulted in the fragmented NFT ecosystems, which brings the following two problems. On the one hand, the current NFT system is tightly coupled to its underlying blockchain platform, with different NFTs linked to their unique blockchain addresses as evidence of their persistent correlation. This makes the current NFT transactions only between different users of a specific blockchain, and different NFT ecosystems are isolated. At the same time, the usability of NFTs is severely challenged by the performance of the underlying blockchain. Complex operations and high congestion result in expensive transaction fees and long confirmation latency that limit the widespread adoption of NFTs. On the other hand, differences between platforms bring about untrustworthy value mapping of physical assets and a lack of governance. How to convince the buyer that the physical assets associated with the NFT on other platforms are tangible. How to regulate and govern the diverse NFT trading ecology. In addition, generic incentive and penalty mechanisms are challenging to design.

There is no doubt that an adaptive and scalable NFT architecture is necessary for sustainable Web3 economic development. Some NFT trading marketplaces, such as Opensea, Binance NFT, and Crypto.com NFT, have been launched to be compatible with different underlying blockchains and protocols to realize NFT heterogeneous transactions. These platforms mainly focus on designing user-oriented graphical interfaces for NFT release, display and trading based on a single core underlying blockchain. At the same time, they are gradually adapted by developers to provide support for a few cross-chain NFT transactions. However, due to their inherent strong coupling to the supporting blockchain infrastructure, different platforms may not be compatible with each other. In addition, users who want to mint/trade NFTs must be familiar with the corresponding blockchain-related knowledge and protocol specifications for each platform, which leads to high learning

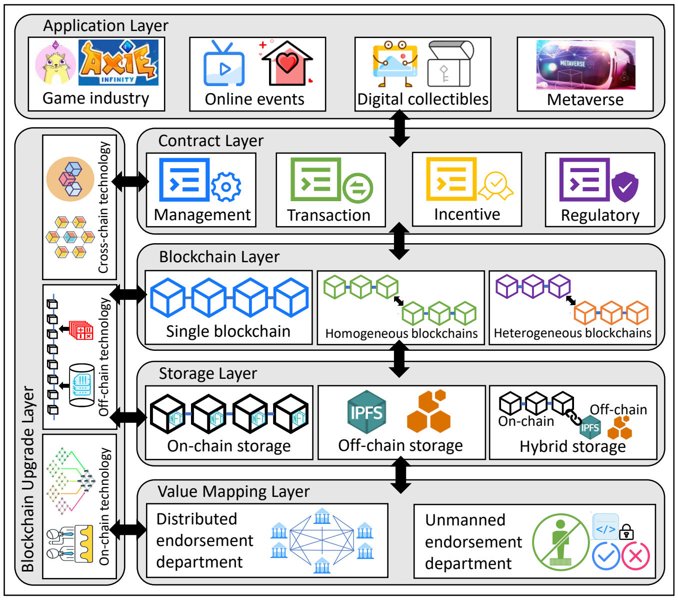


Fig. 1. Illustration of the proposed architecture in Web3.

costs for non-professionals.

In context, this paper proposes a generic NFT architecture, called Generic-NFT, which is suitable for all types of NFTs for heterogeneous cross-chain high-performance flexible value transfer. Figure 1 illustrates the Generic-NFT architecture, which enables generic capabilities in two dimensions. Horizontally, Generic-NFT bridges the isolated NFT ecosystem by integrating asset value mapping, multimodal distributed storage, blockchain, and smart contract technologies. The Storage layer includes on-chain, off-chain, and hybrid storage. The data mapping layer includes two modes of distributed and unmanned endorsement departments. The blockchain layer includes single, homogeneous and heterogeneous blockchains. The contract layer includes management, transaction, incentive, and regulatory contract interfaces. The application layer includes various Web3 systems. Vertically, using adaptive scalable technology to “upgrade” the underlying blockchain of Web3 to provide high usability for Generic-NFT [4]. On-chain scalable technology includes consensus mechanism improvements and sharding mechanisms. Off-chain scalable technology includes state channel and off-chain computing mechanisms. Cross-chain scalable technology includes relay-based and relay-free cross-chain mechanisms.

In the rest of this article, we first analyze the traditional NFT trading platform architecture, and the design directions of the existing architecture. We then introduce the Generic-NFT architecture and potential solutions. This article provides a cross-platform NFT transaction case to demonstrate the benefits of Generic-NFT. Finally, we conclude this paper.

II. NFT: Challenges and Opportunities

A. State of the Art

Figure 2 illustrates the traditional NFT transaction architecture. This architecture logically consists of three layers: the blockchain layer, the server layer, and the client layer. The blockchain layer provides persistent ledger storage through mainnet nodes, and smart contracts provide the server layer

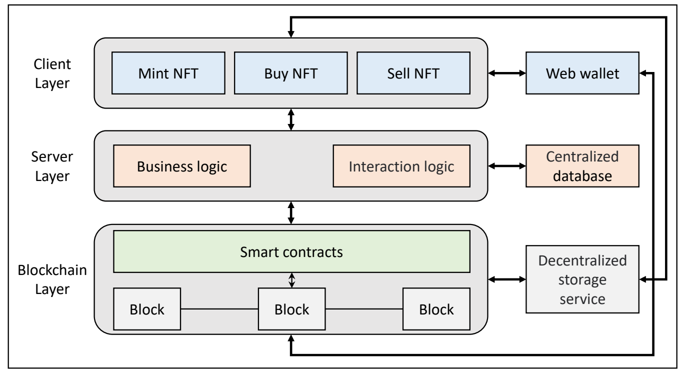


Fig. 2. Traditional three-layer NFT architecture.

with the ability to read and write on-chain data. Distributed storage solutions such as IPFS and Swarm earn blockchain-incentivized FTs by providing NFTs to clients for distributed storage services. The server layer implements the business and interaction logic required by the client layer, and centrally stores data that does not need to be recorded on-chain. Web browser user interfaces such as minting, buying, and selling NFTs are provided to users by the client layer. Each client connects to the blockchain through a web wallet such as MetaMask and uses it to sign client transactions.

The general approach to developing an NFT trading system is comprehensively designing these three layers according to specific NFT item requirements. More specifically, developers first select a suitable underlying blockchain as the infrastructure to provide persistent on-chain storage, then designs smart contracts to interface with the platform business for on-chain data, and finally design the platform back-end logic and front-end interactive interface to implement various types of NFT transaction functions.

B. Open Problems

While developing a trading platform based on the above three-layer NFT architecture seems straightforward, it has several issues that hinder sustainable development. We summarize these issues as follows.

Vulnerability with Physical Asset Value Mapping: The blockchain layer can persistently store data mapped from NFT entity assets to the blockchain, such as hash identifiers, providing tamper-evident data once on the chain. The blockchain layer can persistently store the data mapped from NFT physical assets to the blockchain, such as hash identifiers, providing the property that the on-chain data cannot be tampered with. However, the authenticity and trustworthiness of the on-chain data are closely related to the operations during the uploading process. How to ensure that the data in the on-chain operation will not be “replaced” by attackers, i.e., how to prove to the participants that this NFT represents the physical asset promised by its owner. For example, real estate, essentially a centralized physical asset, is characterized on-chain in the form of NFT. The value mapping process must rely on the endorsement of a centralized agency such as the housing authority, so how to ensure that the endorsement process of the housing authority is authentic and credible. In addition, the current distributed storage services that NFTs rely on are vulnerable. For example, using IPFS to store NFT raw data, there is no guarantee that the data will be replicated to all nodes. If the only storage node is offline, or the NFT points to the wrong file address, it is easy to cause data to be unavailable [2], [5].

Difficulty with Blockchain Infrastructure Compatibility: On the one hand, it is horizontal cross-chain compatibility. For different types of NFT physical assets, we need to establish different storage and transaction frameworks, which means that different underlying blockchain infrastructures must be compatible. For example, if a user mints an NFT on an NFT trading platform, he can only sell/buy NFT within the platform ecosystem, and cannot transfer NFT cross-chains. On the other hand, it is vertical backward update compatibility. At present, the most common type of NFT is static NFT. Since static NFT cannot be dynamically upgraded, its metadata state cannot be changed after being minted. These NFTs can only be collected and exchanged in their current form, and cannot meet scenarios that require access to continuously updated external data, such as game equipment and NBA top shot player data updates. Therefore, the industry has launched a dynamic NFT (dNFT) that provides dynamic features. Each dNFT contains a smart contract that can be triggered based on external conditions, resulting in changes to the dNFT metadata. However, after the smart contract is deployed to the public blockchain, the contract code itself also has the problem that it cannot be updated, so the backward update compatibility of NFT is a direction worth exploring.

Diverse Application Usability Challenges: Diverse Application Usability Challenges: NFT applications are tightly coupled with their underlying blockchain platforms, resulting in the usability of NFTs, such as user satisfaction with transaction speed and operating fees, which are limited by the current performance bottlenecks of public blockchains, complex operations of NFT transactions and blockchain high congestion limits the wide application of NFTs. In addition, the NFT ecosystem lacks cross-platform governance, and diversified applications have various security risks. For example, in the current NFT wash trading, the owner of an NFT transfers his/her NFT between two different addresses in the public blockchain, thereby raise its value, attract future buyers, and affecting the fairness of NFT transactions. This paper argues that a fair and transparent trading environment is also part of the usability of NFTs. However, there is currently a lack of clear regulations and regulatory means for the legitimacy of participants' operations.

C. Future Trends

With the development of blockchain technology and more and more Web3 applications, the industry and academia need to establish a generic architecture to solve the above-mentioned main problems. There are some clear trends in the design of NFT architecture, which we summarize below.

Ubiquitous automated value mapping: If the physical assets are likened to the capillary ends, its value mapping is the data source that supplies blood to the entire NFT system. Since multiple NFTs based on different blockchain infrastructures coexist in the ecosystem, the design of the new architecture should support ubiquitous value mapping and be compatible with these different NFT protocols and standards. For example, Wang et al. [6] proposed a blockchain network-enabled satellite-based Internet of Things (BNS-IoT) sharding scalable scheme, which provides ubiquitous high-performance blockchain coverage. This also provides an opportunity for Web3 to access the blockchain for ubiquitous value mapping.

In addition to ubiquitous mapping, there is also a trend toward automated access. It should provide a configurable and programmable interface to intelligently perform NFT value mapping operations with the support of trusted hardware through unmanned automated management. For example, Liu et al. [7] used the Trusted Execution Environment (TEE) to provide trusted automatic upload of off-chain environmental data to the blockchain, and its transmission latency meets the usability requirements.

Fusion of flexible NFT storage and universal cross-chain: Flexible off-chain data storage provides the ability to reasonably manage metadata mapped to various types of physical assets. Universal cross-chain further enhances the value transfer capability of massive physical assets [8]–[10]. The fusion of NFT storage and cross-chain creates a unified core that can string together the logic of Web3. As an element that connects the real world and cyber world, the core provides a pool of value with various combined operations that help hide the complexity and heterogeneity of the underlying infrastructure. This trend suggests that NFT architecture should build a core of connectivity for southbound value mapping and interoperability between northbound applications.

The key to unifying the northbound NFT market environment is the reusability of core programs and composite interfaces. This means that a generic connectivity core needs to provide open source, programmable, interoperable, scalable, and pluggable applications for different stakeholders. Meanwhile, the NFT market environment should be an abstract model independent of a specific platform, decomposing the overall business into multiple microservices, each of which can be developed, deployed, and run independently. Microservices are loosely coupled, and problems with a single service will not affect the entire system [11]. This model enables developers to customize and reuse existing microservices to construct composite services according to their needs, thereby significantly reducing development and maintenance costs. Therefore, scalable microservice resources should be one of the built-in features of modern NFT architecture.

There are many opportunities to standardize southbound value mapping to make it easier for service providers and consumers to work with the NFT ecosystem. From a conceptual model perspective, the core of a value mapping environment is dissemination and exchange. The value of dissemination should have a variety of mapping methods, content presentation modes, and content operation and maintenance capabilities. The exchange of value to generate liquidity is the key to the economic system, which requires the ability to provide value carriers, identity authentication, exchange mechanisms, incentive mechanisms, and rights protection. Therefore, supporting the interoperability of different underlying blockchain systems remains a significant obstacle to realizing large-scale

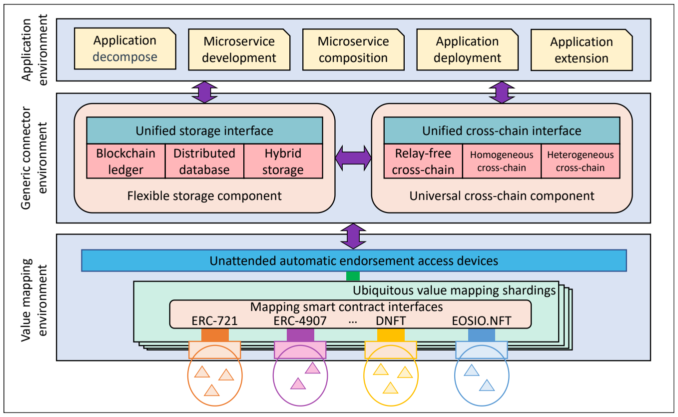


Fig. 3. Generic-NFT architecture.

Web3 applications. Metaverse Standards Forum (MSF), Open Metaverse Alliance of Web3 (OMA3), and other standardization organizations composed of large enterprises in many industries are leading the standardization process of Web3. In addition, NFT platforms such as Opensea, Solsea, and Rarible are also striving to provide unified open APIs to simplify the development of NFT applications. The overall direction is to design architecture based on oracles and cross-chain bridges to achieve unified NFT value mapping and circulation through progressive integration protocols and standards. However, the extensibility development process of these platforms is rather slow, and the fundamental reason is that a generic loosely coupled scalable architecture was not built at the beginning of the platform design.

III. Generic-NFT: Architecture Overview

In this paper, we propose a Web3 generic NFT architecture called Generic-NFT. As shown in Figure 3, Generic-NFT consists of three environments, the application environment and the value mapping environment connected through a generic connector environment.

Value Mapping Environment: This environment is first proposed to support different types of physical assets for value mapping with different NFT standards. According to the mapping types, value mapping services for massive off-chain assets are provided using sharding technology. The mapping smart contract interfaces of different shardings parse the mapping inputs of different standards, then transform them into a universal and scalable format to send to the unattended automatic endorsement access devices for metadata verification, endorsement, and upload of value mapping. Only validated physical assets can be further stored and value circulated. Automated endorsement is securely executed inside a programmable black box, where a multi-dimensional verification approach judges the correctness and integrity of mapping inputs to physical assets. Therefore, consumers can map their physical assets indiscriminately without worrying about the design specifications of the platform.

Generic Connector Environment: This environment bridges the value mapping environment and the application environment. The connector has a flexible storage component and a universal cross-chain component. The storage component provides three optional ways to store physical assets from the southbound environment, storing them in separate resource pools according to category and consumer security requirements. Blockchain ledger storage has the highest level of security but requires high fees and slow storage speeds for users. Distributed database storage refers to an IPFS-like model of off-chain storage, which requires proof of existence to verify the integrity of the data. Hybrid storage refers to off-chain storage of original asset data and on-chain storage of metadata. The cross-chain component links the data of the storage component, and provides a relay-free universal cross-chain transaction functionality, including the cross-chain of homogeneous and heterogeneous resources. Universality ensures that the assets traded can be based on any underlying blockchain to support the economic flow of the entire NFT architecture. In addition, cross-chain components provide high-availability value transfer support by integrating adaptive blockchain technologies.

Application Environment: Since the generic connector environment hides the underlying differences, this environment supports the custom connection logic for NFT service platforms, application decomposition based on requirements, microservice development and combination, application deployment, and even application extension. Therefore, this environment builds a unified NFT service ecosystem for Web3. As the environment supports the reuse of microservices, different stakeholders can share the provided microservice programs, and for complex business logic, they can also quickly build value-added functions on top of existing applications.

IV. Design Principles and Implementation Solutions

The previous section introduced a generic architecture, Generic-NFT, which supports the coordination of value mapping and application development through a generic connector. In this section, we illustrate how to instantiate such an architecture. To this end, design principles are presented as the architecture's building blocks, and implementation solutions are given.

A. Value Mapping Environment Design

Principle 1: Enabling ubiquitous and automated access for physical assets: The value mapping environment is southbound of the Generic-NFT architecture, aiming to interact with physical asset owners directly. On the traditional Web2, the real environment data is transmitted from data acquisition devices to data gateways aggregated to the Internet through a set of unified standards such as Ethernet. Compared with the traditional Internet, the design of the Web3 value mapping environment is more difficult due to the heterogeneity of physical assets. In addition, the mapped data in Generic-NFT should be parsable, manageable, and verifiable. Since the mapping layer abstracts the physical assets, end-owners can freely and automatically map off-chain assets in the Generic-NFT architecture.

As an initial solution to the above problem, we first designed the ubiquitous value mapping shardings. The mapping shardings are multimodal mapping smart contract interfaces consisting of a set of front-end and back-end ports divided according to mapping types. The front-end port supports different NFT protocols, including ERC-721, ERC-4907, DNFT, and EOSIO.NFT, and the back-end port connects to unmanned automated endorsement access devices. To achieve the first objective, mapping contracts are deployed at BNS-IoT to provide value mapping interfaces to participants. Thus physical asset owners can communicate directly with our mapping interface via the clients. Other service-oriented communications, such as Starlink, can be plugged into the Generic-NFT architecture for mapping interface communications. In addition, mapping interfaces for different shardings can be further placed in different locations for large-scale deployment.

For the second objective, endorsement access devices are used for the automatic validation, endorsement, and uploading of value mapping data. On the one hand, the integrity of the mapping data is verified by deploying endorsement smart contracts in the TEE-enabled devices. On the other hand, the trusted oracle services are accessed to verify the authenticity and correctness of the mapping data. After the multidimensional verification is passed, the endorsement access device endorses the mapping process and finally uploads the asset metadata in a generic format parsed and transformed by the mapping interface to the connector environment.

B. Generic Connector Environment Design

The generic connector is a bridge between the southbound and northbound environments and is designed to achieve two objectives: flexible storage and universal cross-chain.

Principle 2: Provide a unified framework for data storage and management of heterogeneous physical assets: The storage component is designed to interact with the southbound value mapping environment. As the volume of mapped data grows rapidly, the data storage component needs to store massive amounts of physical asset data at high throughput. Asset data is mapped from different sources with different protocols, and the storage component classifies, stores, and manages it transparently by category and security level.

Tong et al. [12] proposed a hybrid blockchain distributed transparent storage architecture. They also provided different privacy-preserving storage policies for different data security levels and designed a parallel transaction processing mechanism to enhance the throughput of access transactions. In addition, a reputation-based practical byzantine-fault-tolerance (R-PBFT) consensus protocol is designed based on the data owner's reputation to enhance fault tolerance. Thus we propose an approach to decide where to store mapped data and provide flexible adaptively and high throughput data management [13].

Principle 3: Provide universal cross-chain to support Internet of Everything transactions: The cross-chain component is designed to interact with the northbound application environment, which should be designed to support universality to enhance connectivity to disparate heterogeneous asset data and applications.

To achieve the objectives, Generic-NFT supports the following three features. First, the relay-free of NFT cross-chain transaction provides the feasibility of the Web3 Internet of Everything vision. Because the relay-based model of cross-chain is built on trust in the intermediary and requires complex adaptation by relays, its generality is poor. Web3's Internet of Everything should be trustless or trust based on cryptography. To achieve this vision, appropriate system improvements to existing blockchains are necessary to support a cross-chain model of sidechains based on cryptographic techniques such as zero-knowledge proofs. This cross-chain component supports homogeneous and heterogeneous interoperability between northbound and southbound environments. Second, the economic liquidity brought by generic cross-chains further creates trading incentives for NFT minters and promotes the enthusiasm of participants within the ecosystem. Finally, improve transaction performance by integrating adaptive blockchain scalability technologies, such as sharding according to different domains and batch processing of NFT transactions using state channel technology. The high usability of the cross-chain component further supports Web3 massive interoperability and ensures the stability of economic flows.

C. Application Environment Design

Principle 4: Provide a complete ecosystem for Web3 application development and maintenance: The application environment is located northbound of the Generic-NFT architecture and provides applications for multiple stakeholders such as service providers, consumers, software providers, and hardware providers. As more and more off-chain assets are mapped to Generic-NFT, the application environment should support the entire application lifecycle, including development, deployment, extension, and maintenance.

Microservices are service-oriented architectures commonly used with container technology. Building an ecosystem for service composition-oriented applications is a general approach to achieving the design objectives of the application environment [14]. On the one hand, the ecosystem provides atomic services, independent processes, isolated deployment, and decentralized service governance for all applications. Applications can be service componentized by business decomposition, and systems can be developed rapidly by component combination. Business-unique service components can be deployed independently, making the overall system structure clear and flexible. Complex applications are also composed of multiple loosely coupled microservices and can be extended with functional modules on demand. On the other hand, multiple stakeholders can request shared developed microservice applications from the ecosystem in an open-source/paid manner, enabling rapid construction of value-added applications. In addition, microservices' decentralized service governance goal fits with the Web3 Distributed Autonomous Organization (DAO) concept. As part of the maintenance of the Web3 application ecosystem, the governance of the application involves multiple stakeholders. DAO members agree on governance decisions through grassroots voting, and then governance rules are developed using smart contracts and open source coding to form an automated distributed governance mechanism.

V. Case Study and Validation

A. Selected Scenario

To further illustrate the advantages of Generic-NFT, we conduct a case study and analysis in this section. Figure 4 presents

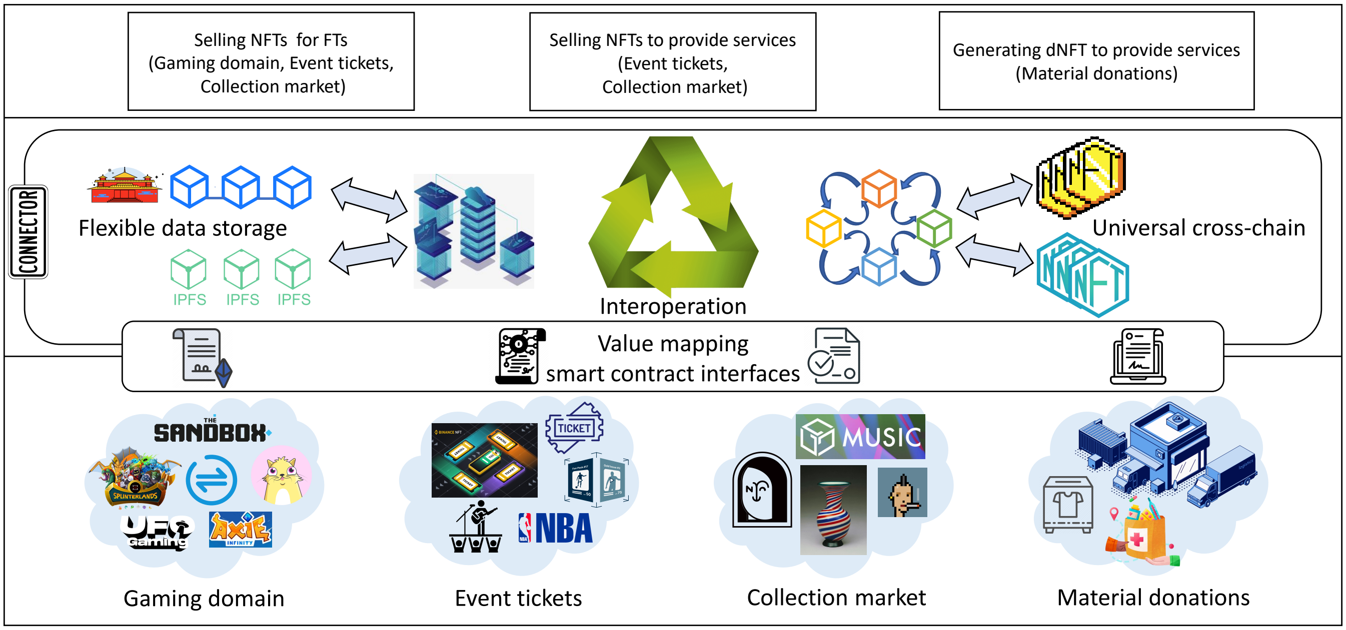


Fig. 4. Implementation of multiple NFT systems with Generic-NFT architecture.

selected scenarios for deploying four practical NFT systems in our Generic-NFT architecture: gaming domains, event tickets, collection market, and material donations.

In the above scenarios, these four systems perform essentially the same processing flow: (i) The physical or electronic assets are input for value mapping through the mapping smart contract interfaces. (ii) The applications are designed according to the business logic required by the scenarios. (iii) A generic connector connects the above two parts for flexible storage and management of value-mapped data and assets, and provides high-throughput cross-chain transaction support.

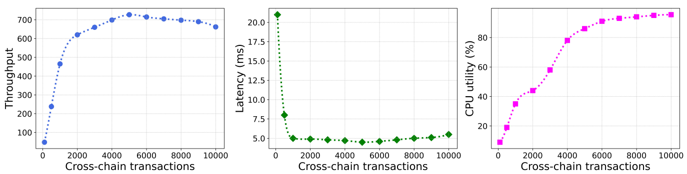
B. Architecture Validation

Value Mapping: We consider deploying these systems to illustrate ubiquitous automated access. Equipment trading systems in the gaming industry reflect the need for players to circulate the value of their props. Different blockchain games may be developed following different NFT protocols, such as CryptoKitties using the ERC-721 standard, and each CryptoKitty is unique. War of Crypto, which uses the ERC-1155 standard, can create repetitive items such as "potions" in batches. By accessing the value mapping shardings classified according to the standards in games, players can directly select the props they own for value mapping. The mapped data is further transmitted to an automated endorsement access device, which can easily verify the integrity, authenticity, and correctness using a trusted oracle, as the game prop information of the palyer is publicly available on the underlying blockchain. After successful verification, the physical asset mapping process is uniformly endorsed and uploaded to the connector environment.

Then we consider another system for material donations, in which the donations are spread worldwide. With the communication services provided by BNS-IoT or Starlink, it is even possible to connect to value mapping shardings in remote regions. The material value mapping process is similar to the above, with the difference that the automated endorsement access device needs to be built in the logistics center. After the donation materials are automatically scanned in the logistics center, the data is transferred to the endorsement device for verification. After verification and endorsement, the dynamic NFT of the material is generated, and the logistics center delivers the material according to the donation destination. The material dNFT is dynamically updated according to the logistics information to ensure the transparency and openness of the material logistics and transportation.

Flexible Data Storage: We consider the collection market system. In this case, the digital collections (e.g., electronic paintings, music files) and physical collections (e.g., physical paintings, antiques) should be stored. Digital collections can be stored in the blockchain ledger according to the capacity size and the owner's security requirements, or original data stored in the distributed database with on-chain storage of the hash root to prove data integrity. Physical collections, on the other hand, are stored in a hybrid way, with a small amount of metadata (e.g., collection certificates, account history) stored on-chain and physical collections stored in off-chain trusted institutions such as museums.

Universal Cross-chain Transactions: With cryptography and computer science development, the vision of the Internet of Everything as Web3 is gradually becoming a reality. A relay-free cross-chain model based on cryptography as the foundation of trust is the key to realizing the universal cross-chain, and its core is to abandon the traditional intermediary trust architecture. For example, considering the concert ticket selling scenario, where the traditional ticketing model relies on a centralized institution, and the problem of reselling and fraud has always been the norm for traditional ticketing. NFT tickets utilize blockchain cryptography to revolutionize the ability to resell tickets in the ticket market, giving control back to the venue and the artist. In addition, dNFT tickets can change based on whether the ticket is activated or not, and can trigger incentives to fans based on live events, such as food tokens and souvenirs, increasing fan participation and loyalty. It can



(a) Average throughput (b) Average latency (c) CPU utility

Fig. 5. Performance envaluation of Generic-NFT.

be seen that NFT cross-chain transactions also need to evolve towards relay-free.

Application Lifecycle: The application environment supports the entire application lifecycle, including microservice development, composition, reuse, deployment, and maintenance. Selling NFTs for FTs is the most common microservice that multiple systems can share in gaming, ticketing, and collectibles. In addition, the microservices composition can provide value-added applications. For example, the microservices that generate dNFTs are combined with ticketing services to provide dynamic applications during the event.

From these scenarios, we can conclude that the most intuitive advantages of our architecture include the following aspects: (i) The unified Gnenric-NFT architecture can support the value mapping of massive physical assets for multiple NFT systems. (ii) Physical assets can be flexibly stored and freely traded. (iii) Multiple systems can be rapidly deployed from existing systems to share microservice applications on Generic-NFT.

C. Performance Envaluation

We have conducted simulation experiments to evaluate the performance of our proposed Generic-NFT architecture. Our Generic-NFT runs on two machines based on a 6-core 12-thread i7-10500 CPU, 16 GB RAM, and 480 GB SSD. We use Docker containerization technology to build two independent Hyperledger Fabric and FISCO BCOS permissioned blockchain clusters. We consider the NFT transfer scenario, and implement NFTs application development of various physical assets (such as authorized patents, music, and digital paintings) based on the two permissioned blockchains. A generic side-chain based relay-free cross-chain model has been implemented for users of different blockchains to cross-chain trade different NFTs.

Figure 5 shows the results of our evaluation of cross-chain transaction throughput, latency, and CPU utilization. Figure 5(a) shows the average throughput curve of initiating 10,000 cross-chain NFT transactions. The throughput reaches a maximum average of 727 transactions/second when the test transaction volume reaches 5,000, after which the throughput reaches a bottleneck and stabilizes. Figure 5(b) shows that as the number of transactions increases to 1,000, the latency drops rapidly and stabilizes at about 5ms. Figure 5(c) shows that CPU occupancy peaks when the number of transactions reaches 6,000, with an average CPU occupancy of 66%. Thus, Generic-NFT can ensure the usability of the trading system in large-scale scenarios.

VI. Conclusion

This paper introduces a generic NFT architecture, called Generic-NFT, that lowers the barriers to the evolution of Web3 towards a decentralized Internet of Everything vision. Specifically, the architecture leverages generic connectors as a bridge between physical assets and application services. In this architecture, the public can easily and freely map the value of physical assets, and developers can quickly customize NFT applications. Generic-NFT consists of four parts: value mapping, endorsement access, storage, and transfer, and provides the ubiquitous mapping smart contract interfaces. As a result, this architecture unifies heterogeneous physical assets into a complete value interconnection ecosystem, facilitating entity control and management in the physical world, enriching decentralized applications in the network world, and providing hybrid storage and universal cross-chain for flexible interoperability between the two worlds.

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