

Art
Blockchain
Network

The White Paper

Soon to be the norm, infrastructure for art.

Startrail The White Paper

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01

Startrail's Vision

The Startrail is an infrastructure supporting the development of the fine arts ecosystem by furthering its trust and credibility. It is designed and managed by starbahn, Inc, but will run operations through the Startrail Consortium, an organization soon to be established in order to assure public trust.

This project began in 2006 when we first announced our central concept, which is to create a standard and universal infrastructure for art using technology.

We initiated our idea to create a platform where exposure and chances are readily available to fresh artists, and to have their contributions to the community continually reward them over the years. We envisioned a system where content creators and owners received royalty-type revenues when their work is distributed or re-distributed, creating a mechanism that helps to control the sale and resale prices to benefit all parties.

Currently, there are many trading channels available when distributing artwork, ranging from small individual sales to large entities making multiple simultaneous transactions. There are also many processes by other parties involved in the ecosystem, such as exhibition curators, critics and appraisers, all of whom come with their own set of professional skills and services.

As the art business is global, the amount of exposure and circulation a piece of artwork experiences ranges anywhere from being seen by a small community, to being known universally and cherished throughout the ages. In order to trace transactional chronologies for these artworks, secure their values on the market, and allow for their owners to be able to retroactively collect revenues generated through royalties or usage (or remove common hurdles such as those mentioned), a system that connects all the stakeholders involved must be put in place. Yet, the realization of a set of rules that accommodates this level of diversity yields different needs and produces opposing opinions, including arguments against revenue generated and collected during secondary distribution, based on the notion that it lowers the liquidity of the secondary market. There are as many needs as there are roles and stakeholders within the art ecosystem, with those discussed so far being only a sliver of the pie, and addressing them all presents itself as one of the biggest challenges.

Ten years have passed since these challenges were first identified, and since then, blockchain technology has emerged,

opening up possibilities for the future of this project. If blockchain is used, every stakeholder could share information within the industry, while maintaining privacy for customers and individual organizations. On top of this, by customizing distribution and valuation methods per user, works of art created by artists with different audiences can all be handled on the same platform for a long time. By using blockchain, artists both unknown and famous have the opportunity of being connected to transactions with both local and major galleries and auction houses, or any other party that handles or would want to handle art pieces. The amount of revenue each party receives could be set arbitrarily, and according to local laws, and large scale artists could have their marketing and management teams tend to their accounts on their behalf. This platform built on blockchain can be designed to find the optimal distribution solution for each user while responding to the changing environment in real time, and involves all stakeholders involved in the art market, such as curators and appraisers as well.

Startrail was designed to maximize the possibilities of using blockchain networks and initially began as a system to distribute revenue to artists on the network. As a result of expanding this system to serve more roles, Startrail became a sophisticated platform that linked related stakeholders throughout the transaction cycle of each piece of artwork, all the way to managing copyright and distribution. The initial product is built by startbahn, but the operation of the platform itself would be decentralized via the Startrail Consortium. The entire project aims to create a "sustainable and indispensable infrastructure for the entire art ecosystem that will remain, regardless of whether the starbahn team and early operators are no longer involved."

The art market has become more present in society since the emergence of modern technology culture, with the last 250 years establishing it as a significant aspect of the global economy. We hope to contribute to this unique system, and add value to it through our technological creations.

We at Startrail believe that our proposed network is the best solution to the art market at the moment, but also that it is only the first step in becoming what is possible through the use of blockchain. As technology continues to progress, we hope that the network will continue to update and expand with new players and business sectors within our industry.

We pledge to do our very best to get the most potential out of blockchain technology and to better manage a decentralized infrastructure aimed at further developing all sectors of the art market.

With sincerity,

Taihei SHII, Founder of Startrail and CEO of Startbahn, Inc.

02

Overview

The art industry has grown extensively since the creation and inclusion of an online market. With that, the rising concentration of counterfeit artworks available on the market has become a severe problem. Not only does this saturation of fake artworks lower the credibility of institutions and make appraising artworks difficult, but it also makes tracking and managing copyright ownership close to impossible in the secondary market. The fault causing this phenomenon lies within the current art distribution system, as the systems in place fail to manage the components that make art pieces credible and gives it provenance, or the chronology of every ownership, custody, and location (such as the origin) of a piece of art or objects.

Startrail is an infrastructure made for the art ecosystem. The network uses blockchain technology to flexibly manage the custody and history of the artworks in the system and also manages and records the history of its circulation (if applicable). Startrail is built to be forward and backward compatible, as well as scalable on a global level. Creating records for a piece of artwork begins by registering it with Startrail. Upon registration, Startrail generates a certificate of authenticity for the registered artwork called an Startrail certificate. The Startrail certificate serves multiple functions. Not only can the Startrail certificate prove the authenticity of the artwork, but it can also serve as credentials for the creator or contributor, with all the relevant information time-stamped during transactions that involve this artwork.

The Startrail certificate can also utilize the information it contains for copyright and edition management, if the artwork is available for reproduction (including being referenced and credited by other artists), and also automatically collects royalty-like revenues called Creator Contribution Returns^{*1}. This automation is made possible through an automatic contract execution program, Smart Contracts^{*2}, made available on the blockchain.

The same automation also matches Artists (i.e., content creators) and Handlers (i.e., any party that handles artworks, such as galleries and other business entities) based on the information they provide, and the Startrail Certificate retains details of transactions. Furthermore, in addition to information management, because the network uses blockchain technology, it continuously adapts to market changes and technological developments as time passes,

always aiming to build a global and comprehensive infrastructure through doing so. The network also aims to realize gradability and interoperability with other projects and systems that may become relevant in the future. (Section 4)

Startrail uses public blockchains to ensure the reliability of technical information and the security of a decentralized system. Information on the public blockchain is almost all public information and, therefore, privacy may be a concern. However, Startrail addresses this by selecting information to be written on the blockchain, linking it with off-chain storage, and allowing a user to own multiple wallets through one Startrail account. In addition, the issue of descriptive data reliability that arises at the interface between the blockchain and the real world is also subject to debate. Startrail addresses this through the implementation of proper authentication, elimination of malicious users through our governance, and establishing a method for describing the artwork in digital data on the blockchain. (Section 4)

The Ethereum blockchain used by Startrail combines publicity (as described above) with automatic contract execution and is a public chain that is commonly used around the world. The ERC721 standard provided by the OpenZeppelin SDK allows it to have connectivity with other projects and wallets. In addition to this, Startrail has adopted mechanisms to reduce GAS charges^{*3} by implementing mechanisms that allow the platform to cover GAS charges and appropriately switch data storage methods to reduce costs. As a security measure, Startrail has also properly considered and introduced access rights and secret key management. (Section 5)

Finally, Startrail differs from other blockchain applications in the art industry by not only making it easier to manage transaction history but also by setting rules for publishing and distributing works and providing participants with options to receive rewards. Other differences include Startrail adopting governance based on governance tokens, enabling information updates based on consensus-building (Section 7), and interoperating projects within the same Ethereum network and other blockchains using gateway companies^{*4} (Section 6). startbahn as the development entity has created this infrastructure with the belief that the most necessary part of the entire process is respect for the art ecosystem and creating new value within it, all while preserving the brand and reliability of the industry.

Notes

- * 1 4.3.4
- * 2 5.1
- * 3 4.3.4
- * 4 Section 6

03

Problem Statements

Clare McAndrew (2019) stated that in 2018, global revenue from the art market reached 67.4 billion dollars, 6% higher than the previous year. This market continues to grow, as well as demand for art sold online. On the other hand, the market still suffers from such problems as counterfeiting, as the Fine Arts Expert Institute (FAEI)*⁵ pointed out, in 2014, that roughly half of the artworks in circulation may be counterfeits. Saturation of counterfeit pieces not only deteriorates the reliability of the art market, but also makes copyright management extremely difficult in the secondary

market. Given that a variety of precedents have addressed this problem by leveraging the tamper-proofness of blockchain technologies, we believe it is integral to creating a network that satisfies all involved stakeholders in the art ecosystem and is compatible with other blockchain-based projects.

3.1 Proof of Authenticity and Provenance

Despite the fact that accurate records on authenticity and provenance are the basis of reliability in the art market, the circulation of counterfeits in art trading remains a serious problem. The main reason for this credibility problem lies in the transactions, as they are still dependent on paper certificates. Paper certificates have no uniform standards nor adhere to industry-wide management methods, and are also easy to forge and tamper. As these paper certificates cannot be adequately verified as authentic, specialists who can determine the source and history of each artwork must take the time to evaluate each piece. In addition to this current reality, Startrail's goals move in conjunction with the growth and change of the art market. Sales in the global art market have increased 6% compared to the previous year raking in \$67.4 billion, with the number of consummated transactions hitting an all-time high since 2008

(McAndrew, 2019) [6]. These numbers demonstrate the sheer volume of artwork transactions that need to be managed, as well as the complication of their source and history per transaction, foreshadowing that the use of traditional methods to accurately organize and manage these pieces will become increasingly difficult as the industry grows. The impact of technological development regarding this situation cannot be overlooked either, as the improvement of duplication technology and artwork distributed in replicable formats (such as digital artwork) require appropriate management methods tailored to these formats. For these reasons, we believe that proof of authenticity and provenance are imperative elements that Startrail should address in order to maintain and improve the reliability of the art market.

3.2 Compatibility with New Distribution Management Systems

Proof of authenticity and provenance can contribute not only to the reliability of the art market based on the current system. For example, the resale right (a system where the artist who created the sold art receives a portion of the sale each time the work is resold in the secondary market) is a current topic of discussion. One point made by those opposed to the resale right system criticizes how high the cost of monitoring transaction records (including provenance information) is when this system is in place (Ginsburgh, 2005). The concept of Fractional Ownership, a system where a single piece of art can be owned and traded by divided interests, is also up for similar debate, with debated aspects revolving around the methods of securing the source and provenance of

each piece. If a management system has built-in records of origin and provenance for each piece of art, currently hard to enforce rules and regulations (due to administrative costs such as copyright and individual transaction rules, or those mentioned above) would become practical. A management system that revolves around securing the origin and provenance for each piece on the market does not yet currently exist, yet realizing this system would lead to the creation of unprecedented transparency and visibility in the art market, shoring up the culture we all live within. In preparation for such a future, it will be necessary to develop an infrastructure that includes a design compatible with new distribution management systems.

3.3 System Updatability and Interoperability

While the concept of creating an arts business management platform based on the authenticity and provenance of artworks is important, the idea itself is by no means new. Online platforms for art management and trading with similar objectives have been actively developed since the early 2010s. Hiscox, 2015; Hiscox, 2016; Hiscox, 2017)*⁵. Like Startrail, some of these other platforms also utilize blockchain technology to prevent forgery and falsification of the available information. While these trends are generally positive for the industry as a whole, Startrail has identified the following challenges in these current platforms.

The first challenge identified is that not all the proposed platforms are designed specifically for the structure of the art market. The art ecosystem is uniquely shaped by the very nature of what it does: value the transacted artworks based on the context of their histories as artworks. It makes it challenging to streamline transactions because of this often subjective variable factor. This variable factor extends to the intentions and incentives of the different parties involved in the art ecosystem as well. So for this platform to become the industry standard, it is integral to create an infrastructure that appeals to and serves the interests of all parties.

The second challenge identified is that the platforms currently available as solutions are not standardized in any way. Having each

platform be unique and non-compatible would mean that specific pieces of art or artists would only be available on one or a few platforms, resulting in the users registering in multiple platforms. As inconvenient as it would be not having artworks available across platforms, the more significant issue is that the online art market could become concentrated in specific platforms.

Under these circumstances, upgradeability and interoperability is indispensable for Startrail. The former allows for appropriate changes to registration formats and rules attached to authenticity and provenance, in accordance with the incentive of each player in the art market and the rise of new technologies, and the latter allows for record transfer across platforms that have similar functions.

In this section, we stated three problems that Startrail hopes to solve. Proof of authenticity and provenance increases the reliability of the art market, the compatibility with new distribution management systems realizes various applications based on security, and the system upgradeability and interoperability encourages the natural introduction of Startrail to the current art market. As an infrastructure, Startrail will benefit various aspects of the art market, such as facilitating the entry of new collectors and financial institutions into the market and updating the existing record-keeping methods for public collections in institutions.

Notes

* 5 http://artdaily.com/index.asp?int_sec=11&int_new=73562#.XU5OLJP7QWq (Accessed August 9, 2019) Deloitte reported in 2017 that 81% of art dealers and 83% of asset managers unknowingly dealt counterfeit work, or work with unclear sources and provenances. These numbers illustrate the biggest single reason why credibility of the art market is questioned.

* 6 According to Hiscox(2018, 2019) the year-on-year growth rate of the online art market has been declining in recent years

04

About the Startrail

4.1 Solutions provided by Startrail

This section outlines the solutions that were introduced in Section 3 via Startrail through its three main characteristics (to be described below) that are used to make Startrail a pillar of reliability and development for the art ecosystem.

① Proof of Authenticity and Provenance

A piece of art registered on the Startrail has an Startrail certificate issued on the blockchain containing the information and guidelines for handling the artwork attached to it (4.2.2), allowing the owner of the work to prove their ownership, as well as its authenticity and provenance (4.3.1).

② Integration of New Distribution Management Systems

Issuing Startrail Certificates make management of pieces and their copyright possible, even when the pieces are on the secondary market. Institutions and businesses that handle art and provide services for the arts are referred to as Handlers^{*7}, and can have Handler Registration Forms issued in their name (4.2.3). Handler Registration Forms contain all the details that concern each registered Handler, for e.g., the services they provide, the rules

and regulations when using their services, and the details that stem from each of those interactions. Matching the handling rules defined on Startrail Certificate and the rules defined on the Handler Registration Forms allows the Handler to handle the work and manage the services related to the artwork, along with the Handler's own unique conditions regarding the wishes of the artists (4.3.2).

Rulesets (if there are multiple rules) identified on the Startrail Certificate will continue to be passed along to each successor owner during transfer of ownership, and the piece would retain all past information pertaining to it. In addition, rulesets are editable upon mutual agreement between the artist and the current owner. Using this, revenue^{*8} from transactions can be distributed fairly to the original artist (4.3.4), and fractional ownership becomes more transparent and potentially more lucrative among those who participate (6.3).

③ Updatability and Interoperability of the Infrastructural System

Startrail's infrastructure proves ownership and provenance without having to rely purely on any single party. By adopting a governance system based on the wants and needs of the participants, the system is as flexible as it is efficient. With the goal of connecting

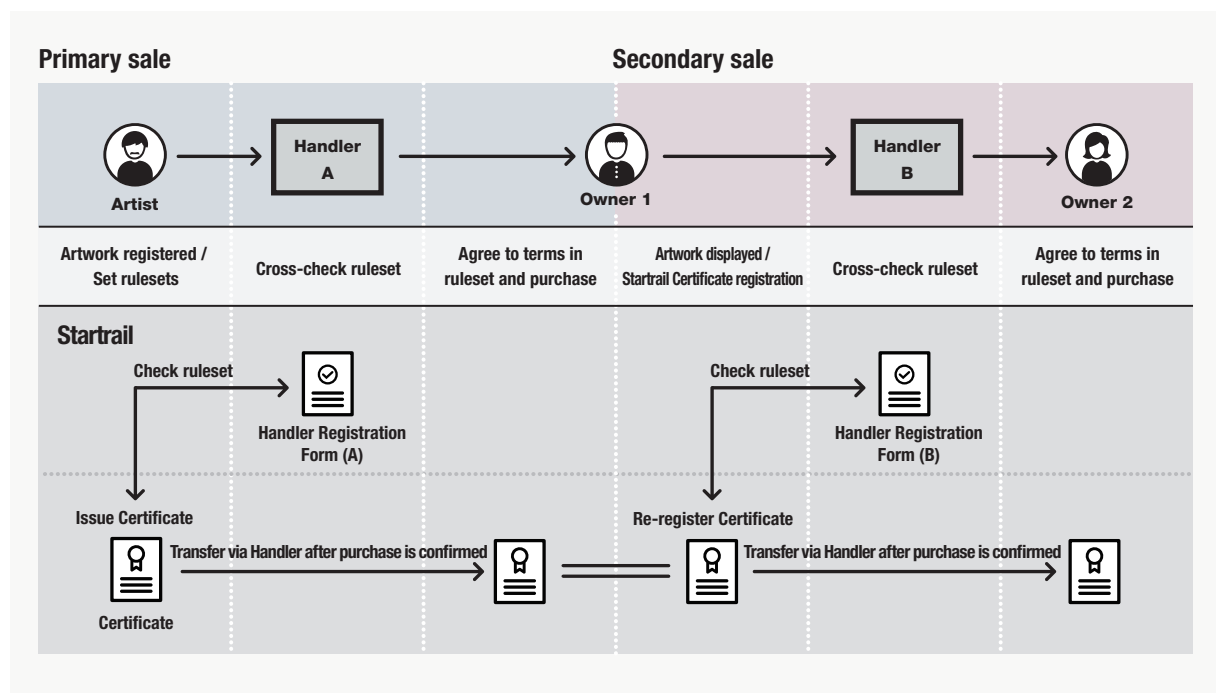


Figure 1: Startrail as a whole

international users in the marketplace, Startrail attempts to cultivate a welcoming community, as well as become interoperable with other services that offer similar services created on the blockchain, which becomes convenient when fractional ownership situations happen across platforms.

Startrail believes that its design should emphasize not only the rules or needs based on specific participants, but to keep all stakeholders in mind while maintaining the highest degree of freedom regarding the setting of contractual conditions and terms. Its infrastructure is designed to be as transparent as much as tamper-resistant.

4.2 | How Startrail Works

4.2.1. Defining the Structure and Terminology

The Structure of Startrail

The following diagram illustrates how Startrail is structured

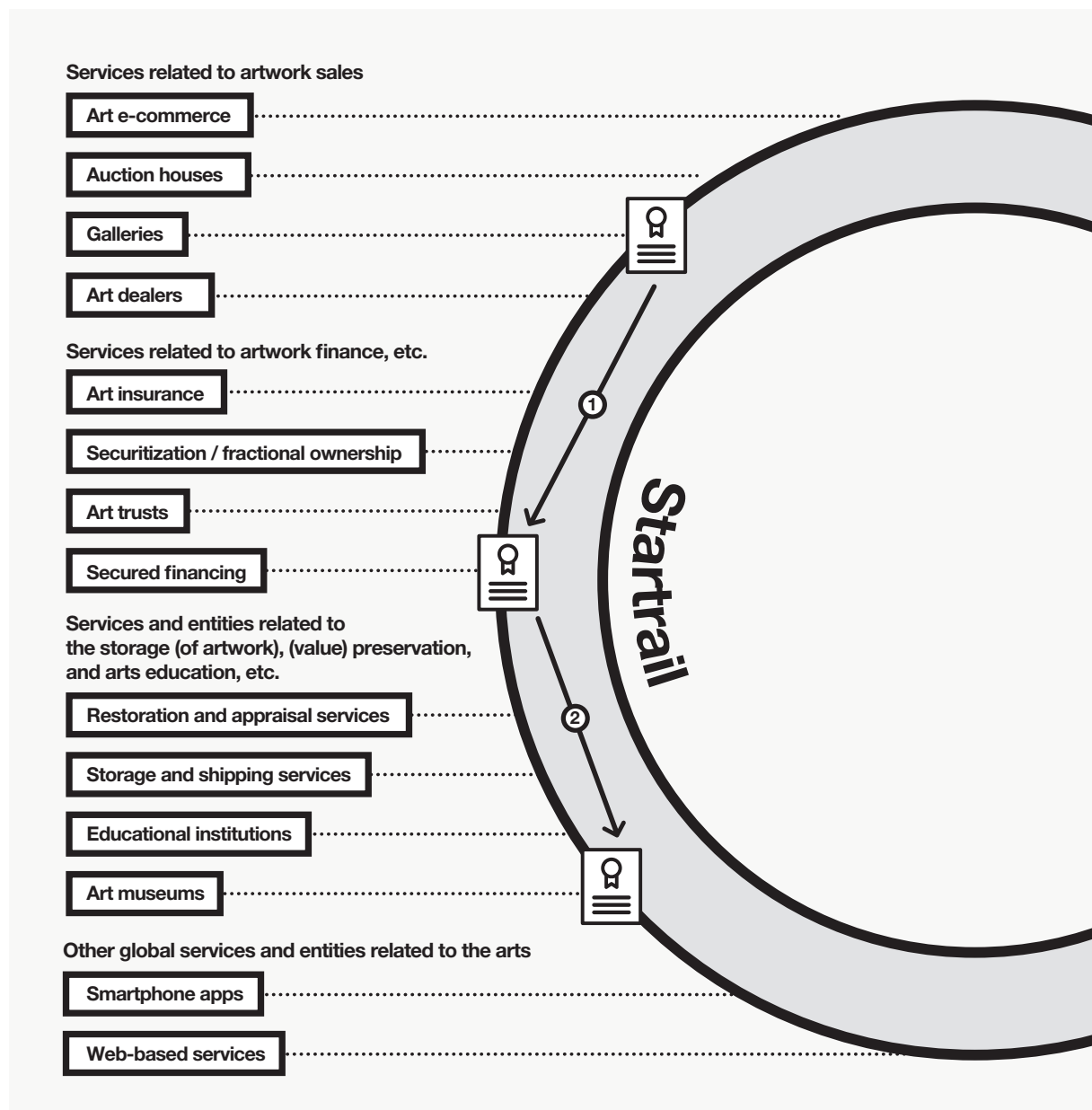


Figure 2: How Startrail is organized

Definition of terms

The following table defines terms used within Startrail

Table 1: Terms Used to Explain Startrail

Startrail	— The network for artwork registration, provenance management, distribution / copyright management support, revenue sharing of artwork
Startrail participants	— Participants who use Startrail for various reasons, generalized into three groups A, B and C below.
A. Platform	— Participants who are authorized by the Startrail Consortium, and can connect directly to Startrail and deploy (create) various Handlers (that handle artworks).
A'. Handler(s)	— Participants who provide art related functions within the Startrail ecosystem. These participants play roles such as transferring work certificates and adding information to it. Each Handler has a Handler Registration Form issued to them on the network (described later). <ul style="list-style-type: none"> - Parties and individuals involved in the buying and selling of art, such as galleries, websites, art dealers and auction houses - Parties and individuals involved in the history or criticism of art such as museums, academic institutions, restoration and appraisal services - Businesses involved in art finance, such as non-life insurance companies that handle art insurance, art trust companies, financial institutions that provide art collateral loans, investment-related companies, etc.
B. Artist(s)	— Participants who register their work with Startrail as the creator of the artwork, and who also holds the copyright to it and sets the rules for copyright licenses on the Startrail Certificate generated for such artwork. They would also be the right holder for any revenue gained via resale of their work. The artist may be the principal, or an agent commissioned by the artist (such as a managing gallery).
C. Owner(s)	— Businesses and individuals who buy, own and sell art. The current owner of the work is regarded as the “Owner”, and if it is yet unsold and belongs to the artist, the artist is the “Owner”.

4.2.2. Issuing Startrail Certificates

Startrail will issue an Startrail Certificate, namely a certificate issued to each piece of artwork registered to the network. Each Startrail Certificate contains two categories of information:

Artwork data and Related account data. The sections below describe the information included in each Startrail Certificate.

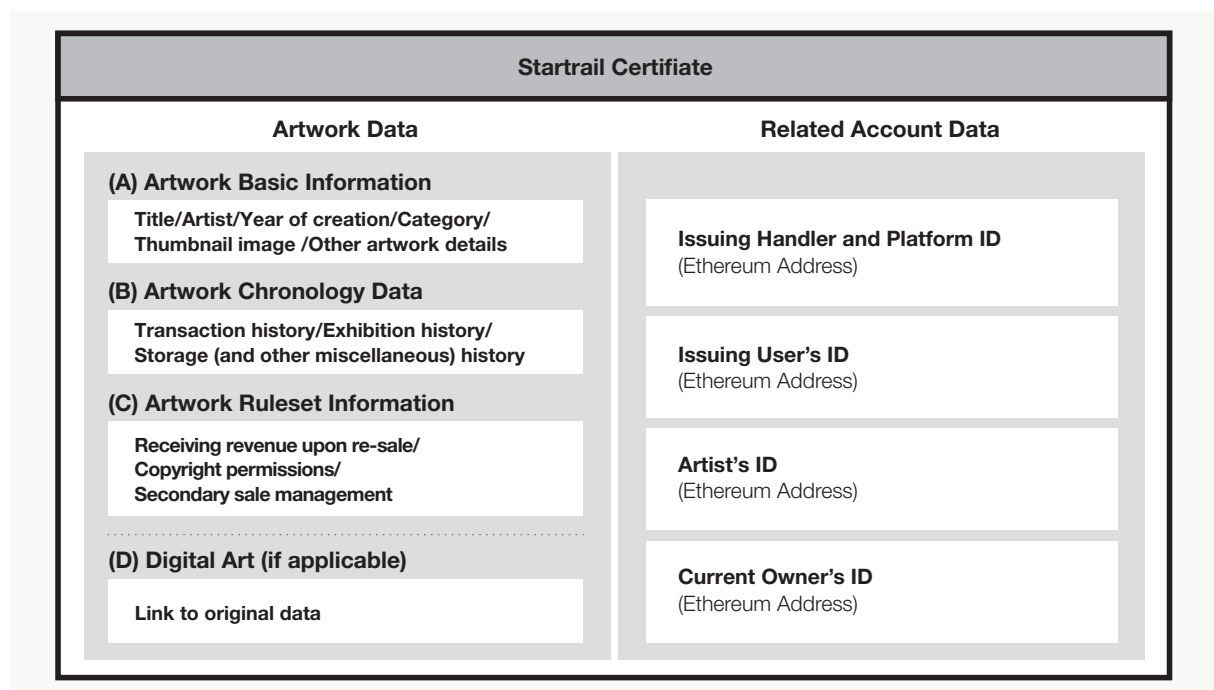


Figure 3: Details included in the Startrail Certificates

Art Work Data

A. Basic Information

The Startrail Certificate contains basic information about each artwork, such as the title, artist's name, year of creation, and mediums used in the piece⁹. There could also be links to digital data (such as images, spectrum data, other data useful in determining authenticity) [9] that would be useful when the artwork is sold. Information that would fall under "basic information" would be content that is static and would not need to be modified after the piece is sold (unless the original artist adds language support or further details).

B. Artwork Chronology Data

Each artwork will have its history and origin recorded, including its entire transaction histories, such as the date and time, Handlers involved, and transaction type (primary, secondary, offline, etc.), transaction location, and the ID of the current and previous owners. Any awards or restorations that the artwork receives would be put in this category as well. If there are previous paper certificates or information provided (for e.g., for works already traded in the secondary market), such records will be linked as non-public information after converting them into electronic files.


Timestamp	Handler	Category	Location	Owner	Certificate 	...
2018.10.22	Gallery A	sales	New york	0x7fc...B97e300	www.abc.jp/xpdf	...
2019.3.21	Auction B	sales	Tokyo	0x8b...Cb8b533	www.abc.jp/xpdf	...
2019.6.5	Museum C	exhibition	Tokyo	0x8b...Cb8b533	www.abc.jp/xpdf	...

Figure 4: Provenance data recorded for each artwork

C. Ruleset Information

Each registered artwork would contain rulesets regulating the artwork. Information pertaining to the rulesets would be recorded as well, including any and all arrangements established by the artist or their agent for secondary sales. Such information may

include copyright licensing granted to the next owner of the artwork. Distribution and copyright management is contained in each ruleset as shown in the following diagram.

Startrail Certificate						
Re-sale revenue upon secondary sale <table border="1"> <tr> <td>Not required</td> </tr> <tr> <td>X% Required</td> </tr> <tr> <td>Artist will not receive (even if generated)</td> </tr> </table>	Not required	X% Required	Artist will not receive (even if generated)	Copyright permissions by Owner <table border="1"> <tr> <td> Artist (or verified agent) can customize For-profit / non-profit (Educational or research usage / Archival usage/Free exhibitions, etc.) Limitations for certain uses (Political/Religious / Certain other themes, etc) Reproduction (Formats) Exhibitions Modifications / Modification / Adaptation (Categories for works based of original artwork / Formats) Transfers / Loans (Fee or no fee, etc.) </td> </tr> <tr> <td> Settings can be filled out as a group (for e.g., using regulations such as Creative Commons (6 level) standards) </td> </tr> </table>	Artist (or verified agent) can customize For-profit / non-profit (Educational or research usage / Archival usage/Free exhibitions, etc.) Limitations for certain uses (Political/Religious / Certain other themes, etc) Reproduction (Formats) Exhibitions Modifications / Modification / Adaptation (Categories for works based of original artwork / Formats) Transfers / Loans (Fee or no fee, etc.)	Settings can be filled out as a group (for e.g., using regulations such as Creative Commons (6 level) standards)
Not required						
X% Required						
Artist will not receive (even if generated)						
Artist (or verified agent) can customize For-profit / non-profit (Educational or research usage / Archival usage/Free exhibitions, etc.) Limitations for certain uses (Political/Religious / Certain other themes, etc) Reproduction (Formats) Exhibitions Modifications / Modification / Adaptation (Categories for works based of original artwork / Formats) Transfers / Loans (Fee or no fee, etc.)						
Settings can be filled out as a group (for e.g., using regulations such as Creative Commons (6 level) standards)						
Sale Settings <table border="1"> <tr> <td> ales exclusions for certain countries and geographic locations Exclusions for certain services Resale blackout period </td> </tr> </table>	ales exclusions for certain countries and geographic locations Exclusions for certain services Resale blackout period					
ales exclusions for certain countries and geographic locations Exclusions for certain services Resale blackout period						

Figure 5: Examples of terms that can be set through the ruleset section of the Startrail Certificate

D. Link to Original Data

The Startrail Certificate proves the ownership of a physical work of art, but in a digital transaction, ownership on the blockchain is noted and managed by linking. The IPFS (Interplanetary File System), a distributed storage mechanism, would be used and has already been verified for practical use, and is in the process of being confirmed to operate with Startrail in the future.

Data Linked to the Account

Each Startrail Certificate contains the Ethereum address of the Startrail participant associated with it, with the address being the contract address^{*10} of the Handler or the Platform, as well as the address of an externally owned account (EOA) address used for certificate delivery. The EOA address would include the EOA address of the certificate issuer, the creator of the work (or its representative), and all owners from past to present. Some of these fields are optional to include.

These Startrail participants' Ethereum addresses manage information such as the user who entered the information, which users can receive refunds or revenue (if they are entitled to receive such compensation), and which users can revise or approve rulesets associated with it.

Issuing Certificates

There are two types of Startrail Certificates issued via blockchain. Ideally, the original artist would be the initial person to register their artwork to Startrail, but if not, an agent or proxy could also register the artwork to have an Startrail Certificate issued for the piece.

The registration of a previously unsold artwork by the party that provided it would be considered the "Primary Issue" of the Startrail Certificate. It is ideal for the original artist to be the individual linked via their Ethereum address to the Certificate in order for them to ruleset for copyright licensing and royalties, as well as proving to those viewing it as the authentic artwork created by the Ethereum address holding artist.

The other way to register pieces would be to register already circulating existing artworks before their registration with Startrail. These pieces are "secondary distributions" because they are pre-owned by individuals and distributors before their registration on Startrail. They would be registered by an owner or Handler, who would have an Startrail Certificate issued as a "Secondary Issue" because of their prior sale. Secondary Issue artworks are not linked to the original creator of the artwork (unlike an artwork that received a Primary Issued Startrail Certificate), and therefore are not tied to an Ethereum address, making its authenticity unprovable as well as ruleset information unavailable^{*11}.

Secondary issuing could quickly come into play in the present, as auction houses can issue such Certificates for secondary sales. Art museums could also register owned artwork and issue Startrail Certificates for custody and in-house organization. As it becomes increasingly essential to archive digital work as part of our cultural heritage, this certificate system could become useful for archiving pieces in museums and other institutions. The system could also aid in maintaining pieces that belong to individuals and public and private organizations. Owners of multiple collections could also use Startrail as an organizational tool for their private collections.

4.2.3. Handle Registration Forms

Each Handler who wishes to connect to the rulesets and artwork within Startrail is required to complete a Handler Registration Form. This form would be the equivalent to a Primary or Secondary Issue Startrail Certificate, containing the necessary information about the Handler instead of an artwork. Handlers could set their policies regarding royalties as well as requirements on the artwork they are looking to purchase.

Like artists including rulesets in their Startrail Certificate when registering their artwork, each Handler would be able to include their own rulesets regarding information such as the type of artwork

they are looking for, as well as policies regarding revenue returns (copyright and royalties) of the artworks they choose to handle. Startrail would then be able to match the information on the Startrail Certificate and Handler Registration form and connect the artists and the Handlers according to the rulesets each party registered when having their credentials issued. By doing so, artists would be able to find Handlers specifically interested in the work they have to offer, and Handlers receive artworks filtered to fit their prerequisites. Startrail includes features, including this matching feature, that benefits both artists and stakeholders because Startrail aims to fulfill the needs of all parties involved.

Startrail Certificate	Handler Registration Form
Artwork Basic Information (A) Title / Artist / Year of creation / Category / Thumbnail image Other artwork details, etc.	Basic Handler Information (a) Doing business as (DBA) Name / Handler name / Operator / Nationality / Category / License information, etc.
Artwork Chronology Data (B) Transaction history / Exhibition history / Storage (and other miscellaneous) history	Handler History (b) Editing history re: Handler information / Records of ruleset changes, etc.
Artwork Ruleset Information (C) Receiving revenue upon re-sale / Copyright permissions / Secondary sale management	Handler Ruleset Information (c) Whether re-sale revenue required, other terms and conditions for the handled artwork

Figure 6: Information included in the Handler Registration Form (compared to the Startrail Certificate)

Handler Registration Form

The Handler Registration Form has elements a, b and c.

a. Basic Handler Information

Basic Handler information is basic information registered about each Handler on Startrail, such as their location and the person responsible for their operations.

b. Handler History

Handler history contains the history of each Handler's records, such as edits in their rulesets.

c. Handler Ruleset Information

Handler ruleset information contains policies and rulesets regarding

the business operation and work handled by each Handler. Aside from the terms of service established by each Handler for their services or operations, these rulesets would be rules for the artwork they handle on Startrail. The ruleset would include what types of artworks each Handler accepts and their handling policies.

More specifically, the Handler rulesets include the presence or absence of royalties for the artworks handled through each Handler's services. Any information on distribution revenues (if they are present), such as the ratio to the transaction amount, along with their conditions, would be included here as well. By collating the contents of A-C (basic information, chronology data and ruleset information), the artworks handled can be controlled^{*12} using Smart Contracts^{*13} (*to be described later).

4.3 Startrail Features

4.3.1. History Management

In terms of preventing the distribution of counterfeit artwork, managing the provenance and chronology of each piece of artwork is critical because the value of an is not only determined by its creator and authenticity, but also by its provenance and transaction history. Aside from this history, its recorded exhibition history and conservation (if any) may influence its valuation as well.

Startrail includes all of this historical information for each piece registered on the network. By doing so, artwork information that was previously disparate would be organized and indexed on the blockchain, reliably proving the authenticity of each piece and protecting its value.

Works on the secondary market are also often lost to the original creator of the work, as tracking the piece since it is first sold

becomes difficult. Unless the artworks are often publicly shown, or are documented in reliable sources such as a Catalogue Raisonné^{*14}, specific information of how the artwork has passed hands and the events occurring during such transfers can be close to impossible to track by an individual, thus making it harder for artists to track their artworks. By using blockchain, no matter the medium of the artwork, every transaction the artwork has had and every event in its history would be recorded, creating a preservation archive of art and culture available to the public.

This information is all archived in blocks such as transactions, appearances, restorations, management services, and in other groupings that would be organized by an event. Private details of the individuals noted in the blockchain would be unavailable. Startrail aims to be a reliable source where one can vet their sources.

4.3.2. Managing Distribution and Copyright using Rulesets

Startrail was built to manage copyright and resale rules alongside the certification and ownership of each artwork.

It has proven difficult to manage copyright, especially in complex situations that often arise in the art world such as when parties attempt to gain partial permission of a copyright or permission for partial usage. This is due to the fact that several parties are involved including: the content creator, copyright agent (if any), and copyright owners (if any), along with the individual asking for permission. This complex process is extremely tedious to execute in practice, making it difficult for the artist to receive the benefit of an artwork protected by copyright. On top of that, the secondary resale of the artwork without the resources to facilitate rulesets per contract often fall short due to resource and budgeting reasons.

When issuing a piece through Startrail, the original contract and rulesets included in the Startrail Certificate are continuously valid even after the primary issuer sells their artwork in the secondary market. As so, the primary issuer would never have to recontract for any other transaction when their artwork is resold in the future. This is not only helpful for content creators, but also for owners and distributors, as the primary issuer can set usage regulations to their artwork when their Startrail Certificate is first issued. It enables both those who utilize and create the artwork never to have to seek and make contact, and engage in the negotiation process that previously may have been roadblocks for artists to benefit from their copyright ownership.

Ethereum, the blockchain used to implement Startrail, enables a function called a Smart Contract, which automatically executes contracts. Content can easily be managed and organized through this, such as transferring ownership, automatically calculating royalties based on contract ratio^{*15}, and determining whether an artwork can be registered to a Handler. Not only could Smart Contracts be used to link certificates when they are resold, it could also link editions of artworks as well^{*16}.

Smart Contracts can also manage contracts that involve licenses in real-world situations (i.e., outside of online transactions).

These real-world situations would be applicable to license agreements (of artwork) for exhibitions, modifications of terms or content for pre existing artwork, and the commercial arrangements of them. If all such arrangements can be made through a single platform using blockchain (with all terms and conditions included), it would make the process transparent and trustworthy for all parties involved. Unfortunately, blockchain cannot determine whether the terms of a contract are being followed or not by a party granted usage rights. Still, it is possible to view the license scope and contract contents very clearly, as well as the date and time both parties agreed to their terms. This transparency likely hinders bad faith actors.

Below is the mechanism for the transfer of ownership between two parties, and the original content creator subsequently renewing the rulesets underlying the artwork with its current owner.

1. First, the content creator (or their agent) sets the terms and conditions of the copyright usage license to be granted to the current owner of the artwork within the ruleset section of the Startrail Certificate tied to the artwork.
2. The rules the content creator set are recorded on the blockchain, and when this artwork is sold to a new owner, the certificate issued for the artwork and its copyright license would be transferred to the new owner. The new owner and content creator (i.e., original owner) would have a brand-new contractual relationship regarding the licensing of the sold artwork^{*17}.
3. If the copyright license belongs to another party who is not the original content creator, both the content creator and current holder of the license would have to consent to any changes made to the ruleset.

4.3.3. Startrail Certificates between Related Artworks

Startrail Certificates are issued not only independently, but as a document for cross-referencing and finding related pieces of work on the Startrail network.

For example, the Startrail Certificates could have information linking editions of an artwork, identifying other editions, or that the artwork has licensed materials from a different artwork.

Linking the Startrail Certificates on the blockchain brings the following benefits:

- All editions of an artwork can be treated equally in the case there are underlying copyright revenues, and they could all be managed in one place and authorized in bulk.
- Artworks that are (approved and) based off other works can be officially recognized, and the original work such artwork was based on can receive rightful reproduction fees.
- Issue limits for editions are essential for artists to control the scarcity of their work. Smart Contracts can set the maximum number of edition contracts automatically issued for editioned artwork.

4.3.4. Creator Contribution Returns

The Startrail network introduced Creator Contribution Returns (CCRs), a mechanism that returns profits to the creator of an artwork upon distribution or transfer within the Startrail system. Each time an Startrail Certificate is traded, the original contributor of the artwork can receive a portion of the transaction, with the percentage based on the rules initially set in the ruleset of the Startrail Certificate.

In Europe and some other countries and regions, the right to pursue artist resale rights has already codified into law. On Startrail, regardless of which country the resale occurs, the CCR mechanism is available to any artist who requires it when issuing their Startrail Certificate.

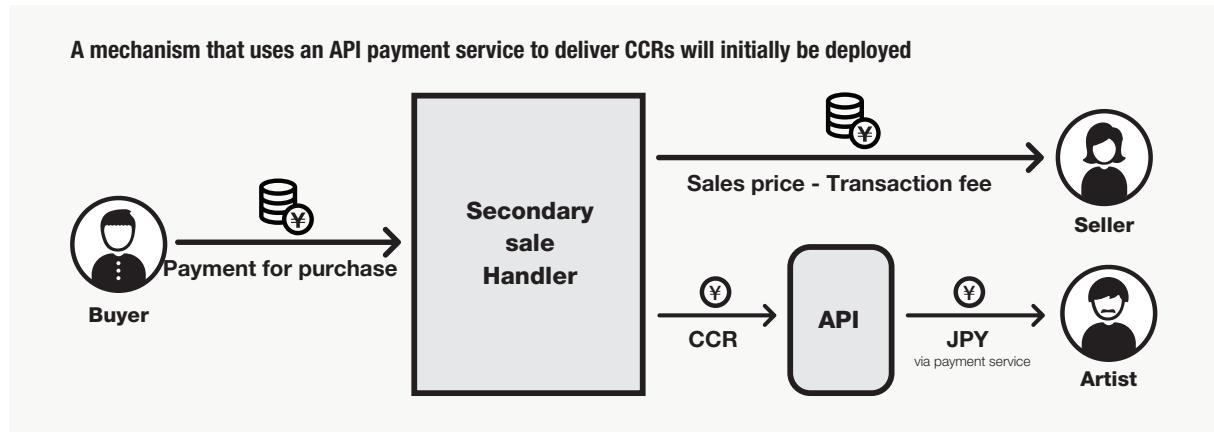


Figure 7: Creator Contribution Returns (CCR) Scheme (off-chain)

The payment of CCR is designed to function off-chain (outside the blockchain) as well as on-chain (on the blockchain).

Off-chain payment is realized via the usage of settlement operators.

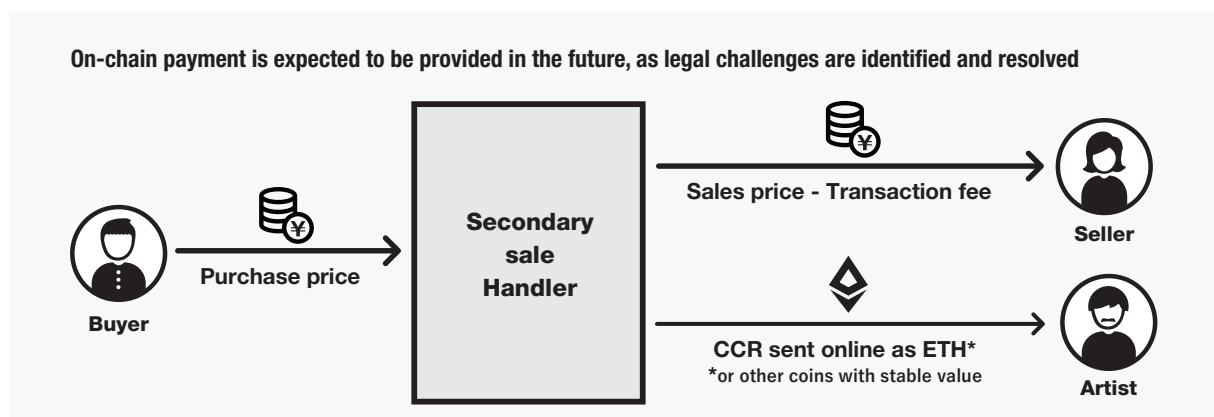


Figure 8: Creator Contribution Returns (CCR) Scheme (on-chain)

On-chain payments are realized through the exchange of legal currency to Ether or other stable value coins, such as Stable Coin. Due to the high volatility of digital coins and the uncertainty of the laws and regulations pertaining to cryptocurrency in different countries, the Startrail network will initially provide off-chain payments and slowly transition to include on-chain payments.

Setting CCRs

When an Startrail Certificate for an artwork is registered, each artist will have the choice of whether to include a clause to receive CCRs and what percentage of return they expect per transaction (excluding taxes such as sales tax and fees such as packing and shipping).

Each Handler can set the CCR rates of the artwork they are looking for (corresponding to the CCR information registered to each Startrail Certificate) under the "CCR Rates" section in the Handler Ruleset portion of their Handler Registration Form. The Handler must set a higher CCR rate than that on the Startrail Certificate of each artwork they handle. Because of this, each Handler would only be allowed to deal with artworks that match their CCR rate settings of their Handler Registration Form.

The CCR mechanism may hinder resales. However, the point of the CCR mechanism is to provide resale rights to artists in countries where such legal rights are unavailable, and also support the preexisting laws and policies regarding artist resale

rights in countries and areas where they are present. Startrail aims to achieve a balance by allowing each stakeholder to freely decide whether they would like to participate, matching aligned stakeholders to interact with each other.

Distribution of CCRs to other Stakeholders

Contributors can set CCRs and other beneficiary rights per registered artwork to others involved with their artwork, such

as their agents and gallery managers, exhibition organizers or institutions. They can even distribute their CCRs to their stakeholders if they wish to do so.

By doing this, artists might more easily obtain funding for production and exhibition. Multiple stakeholders might more efficiently share the risks as well as the benefits.

4.4 | How Transactions Work

Artists, Handlers, and owners construct the Startrail ecosystem. Usual transactions include buying and selling, but also encompass restorationsconservation, storage, and gifting. For ease of explanation, transactional examples will be limited to buying and selling in this Section.

Generic Online Transactions via Handlers

The following would be a typical example of how a primary contributor (artist) makes a sale with a Handler using an online trading service.

1. The primary content contributor (often the original artist) sets the ruleset for their artwork based on the agreement of the Handler's rulesets
2. The buyer agrees to the terms attached to the artwork they are purchasing
3. The buyer acquires the work and pays the transaction fee to the Handler
4. The Startrail Certificate is temporarily moved from the

contributor's account to the Handler's account

5. The contributor or the Handler handling the sold artwork ships the artwork to the buyer
6. The buyer confirms receiving the artwork, the Startrail Certificate for the artwork is transferred to the buyer's account, and the interaction is added to the transaction history on the Handler Registration Form belonging to the Handler
7. The Handler pays the original content creator

The flow described above works similarly between buyers and sellers when the seller is not the primary contributor (artist). Whenever the owner of an artwork submits a piece to sell through a service, it can only be sold through Handlers whose ruleset information on their Handler Registration Form matches the Startrail Certificate of the artwork in question. Upon payment, the seller receives their payment for purchase minus the transaction fee and CCR. This CCR is sent to the primary contributor (artist), and the transaction fee to the service provider who handled the transaction.

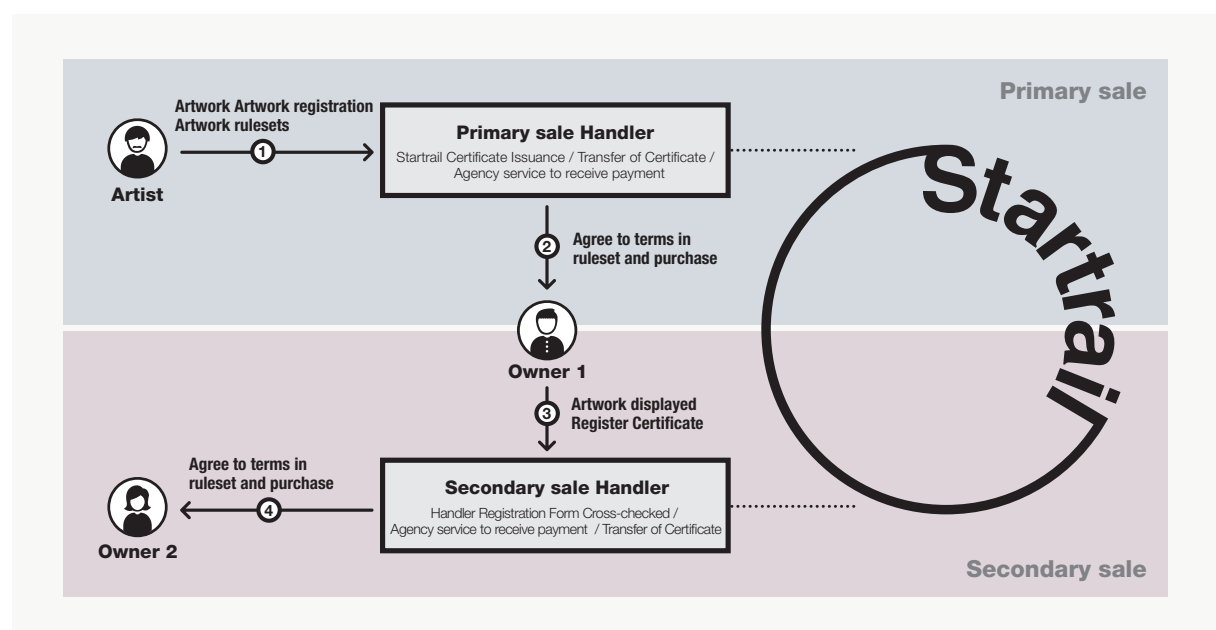


Figure 9: Transaction Flow for Primary and Secondary Sales on Startrail

“startbahn.org^{*18}” is an example of how the trading service on the Startrail network might look. startbahn.org was developed to introduce the features of Startrail and is a platform where artists and stakeholders can connect their art with validated certificates via the issuing of Startrail certificates. Aimed to create a vibrant and transparent art community, the organization showcases artists and galleries. Artists can register to the platform and sell their works by creating an online portfolio page and introduce their artistic practice as well as the artwork they create. The following is the web UI for these pages.

Transactions between Individuals not using a Handler

Transactions between individuals not using a Handler is possible by sending certificates between personal wallets. Startrail proposes using NFC (Near Field Communication) cards, which contain private key information necessary to access the Startrail Certificate of an artwork during such a transaction.



Figure 10: Portfolio Page on startbahn.org

4.5 Interoperability with other blockchain projects

Seamlessly sharing information across the industry to benefit industry stakeholders is a primary objective of Startrail. Therefore, the interoperability of Startrail with other blockchain products has been a significant concern during the creation of the network.

Other blockchain projects include DAppss (distributed applications) that sell content using ERC721^{*19}, in addition to projects that focus on organizing records using blockchain. Use cases and procedures will be discussed in Section 6.

4.6 Privacy Concerns

Privacy is paramount in the art world, especially considering that the price and transaction history of artwork (including, who invested in / owns or has owned the artwork) directly affects value.

Auction price databases are available through many companies

and currently sets one standard for how information is shared and privacy is upheld. Startrail acknowledges the sensitivity and importance of privacy in the art world, and has implemented practices that balance the need to maintain privacy with use geared towards transparency and that do not disrupt current ecosystem standards.

4.6.1. Information Available on Startrail

The information available on Startrail includes “A. Artwork Basic Information” and “B. Artwork Chronology Data”. The title, author, year of production is mandatory information, but providing thumbnail images and other details is voluntary.

Artwork Chronology Data of the artwork such as dates and times of service, and the names of which Handler handled

the artwork are mandatory fields. Importantly, the service provider, service’s country and area, and other information that has to do with the Handler will be automatically included using the information in the Handler Registration Form. On the other hand, additional information such as transaction prices, restoration details, or a link to PDF information files stored off-chain^{*20} are optional fields.

4.6.2. Information Available only to Relevant Parties (Confidential Information)

Ethereum is a public blockchain, and information that is not encrypted on Ethereum is public and can be viewed by anybody.

Limiting access to information on-chain to relevant parties while keeping it shareable can be achieved by either encrypting it or keeping it in external storage (with limited access) and only storing the link to its location on-chain.

The two methods above are made possible by an API linked to Startrail.

However, the information that can be encrypted or stored outside the blockchain would be the optional fields in the historical records (such as provenance details and provenance information from the Artwork Chronology Data section mentioned above).

APIs are provided by Startbahn, Inc. but will later expand to multiple types of APIs provided by other operators who are approved by the Startrail Consortium (also described later).

4.6.3. Allowing the Usage of Multiple Ethereum Addresses

The Ethereum addresses of service providers and artists are uniquely determined on Startrail to authenticate details outlined above. If there are multiple addresses, all of them must be linked to existing individuals and corporations.

General users (such as individuals who are artists or owners) are allowed multiple Ethereum addresses per person, as all

personal assets and transactional histories would be disclosed if they were limited to a single address. Only the owner of the Ethereum addresses and the Handlers of the services they personally registered for and utilize can either see or manage the addresses and users who are linked to the multiple addresses they own. This information would never be publicized on Startrail.

4.7 | Managing Reliability

Startrail is an organization that self-manages through blockchain technology, which has built-in transparency mechanisms and tamper-resistance, and is not governed by any single entity. The reliability of the artwork on Startrail is assured by both the blockchain technology itself, as well as its administration and operation which will be governed by consensus.

As methods to assure the reliability of the artwork on the network, Startrail authenticates the following: that malicious users or businesses did not perform the issuing of the Startrail Certificate or Handler Registration Form, and the Startrail Certificate itself is linked to an actual artwork. By doing so, Startrail introduces a reliable infrastructure that is not under the control of any specific third party.

4.7.1. Authentication of Issued Certificates and Registrations

As described above, Startrail's reliability is based on the security of the authenticated certificates and registrations. The accuracy of the information that is linked to these certificates and registrations is integral to the success of the platform, and such accuracy is heavily dependent on how each party's Ethereum address links to the network.

KYC Identity Verification

The most fundamental building block of Startrail is the artists and Handlers. To keep those involved accountable for their authenticity, Startrail participants are required to have their personal information linked to their Ethereum address via a KYC certification.

KYC for artists is generally done through Handlers but can also be procured directly from the Startrail Consortium. Also, there could be multiple Handlers authenticating a single EOA address.

Anti-Money Laundering Measures

As mentioned in the privacy section, no personal information would be made public. However, anti-money laundering measures will be implemented using blockchain technologies, especially for art transactions and art services based in the EU (European Union). Startrail and KYC (another blockchain service) will create another layer of security to support AML measures.

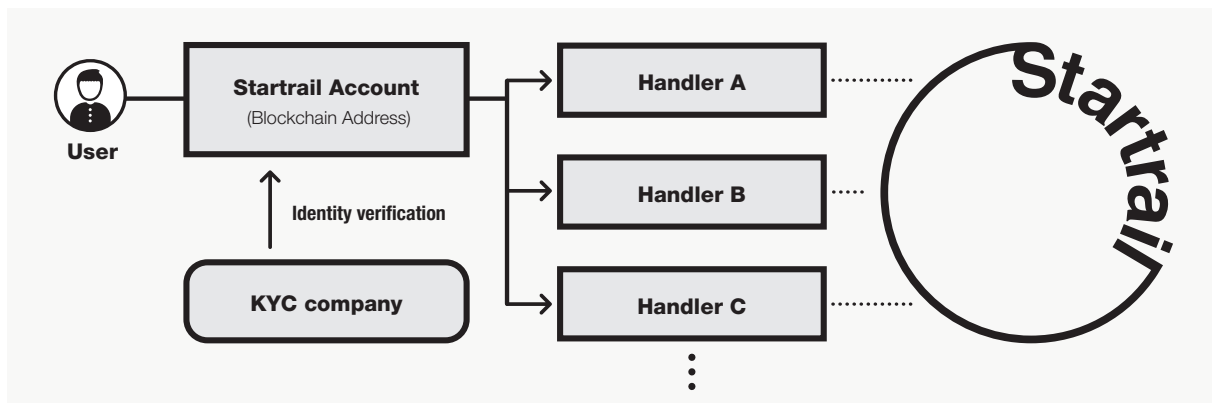


Figure 11: Blockchain Address' KYC Scheme

4.7.2. Matching the Artwork to the Certificate

Matching the actual physical artwork to the issued Startrail Certificate brings questions of how to authenticate the artwork and prove the artwork is related to such Certificate. For example, even with a real Startrail Certificate, one could ship a fake piece of art claiming that the two are paired together unless there are countermeasures to prevent such fraud^{*21}.

Although it is difficult to eliminate the risk of such fraud happening, Startrail addresses this problem by (1) storing the photo data of the artwork on the blockchain and (2) performing governance through the Startrail Consortium.

Solution(1): Photo Data on the Blockchain

Research on digitally documenting physical artwork is already prevalent.

Startrail records information such as shape, color, materials, and mediums when the primary Startrail Certificate is issued for each artwork, and by linking the photo/image data of such artwork to the Certificate on the blockchain, it can be used for future comparisons. In the future, Startrail expects to adapt the digital format of this record-keeping process to the most appropriate technology at the time.

Solution (2): Correction of Information via the Startrail Consortium

There is an undeniable chance that a malicious user could cause a discrepancy between the owner of the Startrail Certificate and the owner of the actual work. In such an event, the Startrail Consortium will leverage its unique governance and be responsible for correcting the information and removing the offender(s)^{*22}.

Notes

- * 7 "Handlers" here include not only auctions and market places, but also NPOs such as museums and educational facilities.
- * 8 A system which returns a portion of the sales revenue to the original artist every time the artwork is resold and changes hands in the secondary. Also referred to as "resale-rights"
- * 9 In the future, Startrail (in terms of information distribution) will be compatible with artwork descriptions and data formats using standard dictionary data such as the Getty Vocabulary Program.
- * 10 Each address issued on the Ethereum blockchain is a unique address issued for each individual Handler on Startrail
- * 11 A Secondary Issue Startrail Certificate can be converted into a Primary Issue Startrail Certificate upon the original artist of the artwork authenticating the registered piece of art. In this case, the owner of the piece could register a ruleset on the Startrail Certificate, but only if the original artist approves the changes at the time of editing.
- * 12 4.3.2
- * 13 Automatic executions of functions for contracts are implemented through Smart Contracts on the Ethereum blockchain, making it possible to execute functions based on the content of the contracts automatically.
- * 14 A catalog summarizing artworks, including information such as year of production and size
- * 15 4.3.4
- * 16 4.3.3
- * 17 A mechanism allowing specific copyright licenses to be traded independently of the artwork ownership is expected to be implemented in the future, particularly for digital art.
- * 18 <https://startbahn.org/>
- * 19 See Section 5
- * 20 Access to linked PDF files also may be restricted given the cloud storage destination.
- * 21 This problem, technically called the "Oracle Issue", is one of the known risks of going outside the blockchain when using blockchain.
- * 22 Section 7

05 Technical Overview

5.1 Ethereum

As mentioned in Section 4, Startrail currently uses a public blockchain (hereinafter referred to as the public chain) called Ethereum (Buterin, 2013; Wood, 2014). Ethereum is a global and openly distributed application building platform that was conceived in 2013 and began operation in 2015. There are several reasons why the Startrail development team chose to use Ethereum.

Ethereum is a public chain. Blockchains can be broadly divided into private chains and public chains. Public chains are accessible to anyone on the Internet and authorized to generate transactions and blocks. In comparison, in private chains transaction approval authority is concentrated on a specific node in a closed community^{*23}. In the art world, it is difficult to design privacy and browsing authority via public chain. However, as many artworks are highly public, and various

stakeholders and organizations are involved in many different ways, Startrail was built on a public chain to implement a public governance system that will never have to rely on a single entity.

Startrail has also adopted Ethereum because of its large number of users compared to other blockchains and the active development of applications (as of October 2019).

However, the trends in the blockchain industry are changing rapidly, and it is always necessary to choose a system that is both backwards and forwards compatible. In the case that the technology platform is no longer suitable, Startrail Governance (Section 7) would move to replace it with a better-suited technology. All information would be migrated to the new blockchain accordingly.

5.2 Design

Overview of Smart Contracts

This section describes smart contracts. In the diagram below, smart contracts are grouped by functions. The function of each part is briefly shown below, and the explanation of each part will be described later if necessary. Startrail design uses a toolkit called OpenZeppelin SDK.

Contracts can be broadly divided into several components. The parts related to Startrail Certificates are called Startrail Tokens. The parts related to the Handler Registration Form is called a Market Contract, and a specific type of Handler that handles trading functions is called a "market". Later, a part related to the endpoint of meta transactions called Relay Contracts will

be described below.

The Startrail Token side functions to issue or transfer certificate tokens that comply with ERC721. Each Handler is deployed as a contract by the platform contract, and handler rules are set in association with each distinguishable contract address. The Relay part that connects them is an endpoint that performs meta transactions on behalf of the end user's transactions and executes functions for both Startrail tokens and market contracts. When transferring ownership of a certificate, on-chain transactions that reflect the handler ruleset enabled through data referenced from the Startrail Certificate (Startrail token) to the Handler (market).

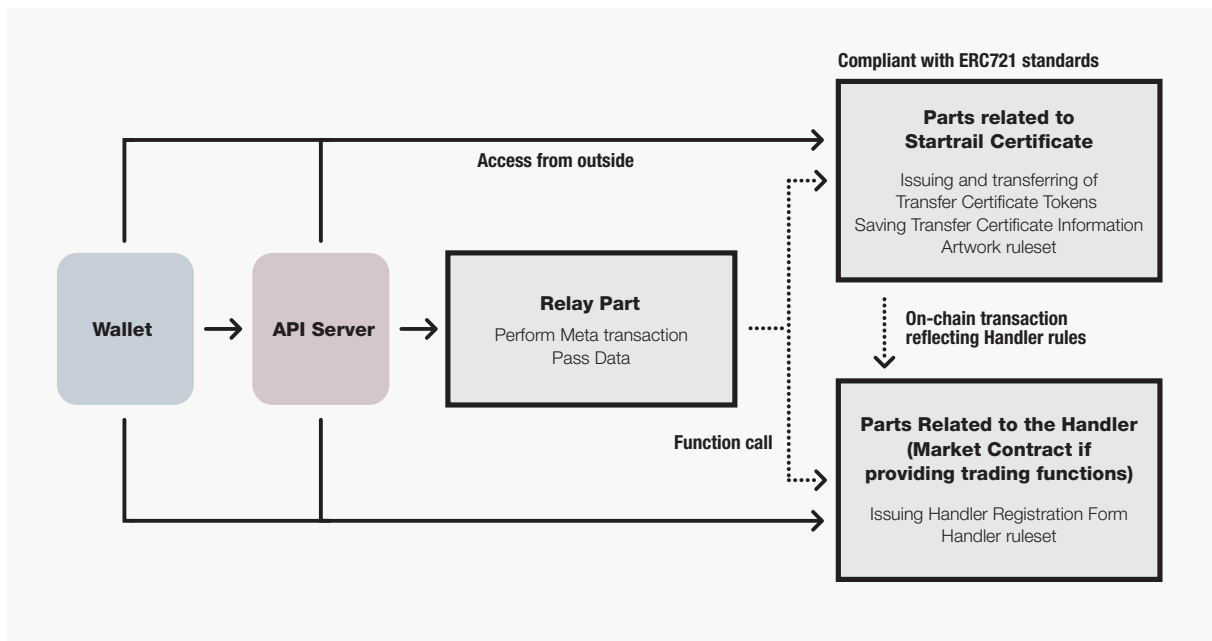


Figure 12: Startrail Smart Contract Overview

5.2.1. Using ERC721 standard

Each Startrail Certificate will be issued on the Startrail as NFT^{*24}, using one of Ethereum's leading token standards called ERC721^{*25}. In a more detailed code level, it inherits the ERC721 library of OpenZeppelin, which is industry standard in the Ethereum community. Our Startrail development team comply with all the ERC721 standard and add more functions, allowing Startrail to record more data of an artwork. This allows a form of token management that represents the

interests of multiple stakeholders and roles.

In the past, traditional web applications required dedicated applications and interfaces for one to access their information. ERC721 standards allows individuals to use any generic wallet that supports ERC721 to transfer Startrail Certificates and check the items they possess.

5.2.2. Designing Flexibly for Artwork Transactions

Startrail contract architecture is flexible to support upgradability. A Proxy contract^{*26} is a permanent endpoint and art related data stored to a fixed address with unstructured storage pattern provided by OZ-SDK (OpenZeppelin SDK) toolkit. This proxy endpoint forwards all calls with `delegate_call` to external contract to execute functions. The set of contracts accessed from the Proxy contract has not only state information such as ownership, but also logic information related to Handler operation and ruleset. With this data storage and logic separated structure,

the contract of the logic portion can be redeployed on Ethereum while retaining characteristics of a tamper-resistant blockchain. These actions can only be performed via a Governance Contract under the agreement of all participants. Since the storage of Proxy contracts can be accessed permanently and continuously, system malfunctions are easy to respond to when adding functions to the system as access can be maintained to existing data.

5.2.3. Using Flexible Data

Public blockchain comes with many restrictions on saving data into Ethereum. There is a limit to the amount of stack and memory available within a single transaction, and the GAS fee increases with the amount of data included in the input. To solve this, metadata that is not required for program

functionality is stored off-chain outside the Ethereum network, and only the URIs or hash values linked to them will be stored on-chain. As hash values are generated based on information from the original data, it plays the role of verifying tampering after writing to Ethereum.

5.2.4. Addressing GAS

Meta Transactions

A GAS fee (Ethereum usage fee) is required to register and update information on the Ethereum blockchain. This fee is paid by the address that signed the transaction when registering or updating the information. This farel can easily become a significant barrier when using the Ethereum blockchain.

Startrail has developed a technology called a meta transaction, which allows the platform to pay the GAS fee instead of the user, while allowing the delegation of smart contract execution to an account that has an ether address.

Reducing GAS Fees

Like the users, GAS fees are a concern for the platform as well. Startrail has devised a solution that minimizes the costs of GAS fees by separating the storage location of the data used on the network. The data that is mandatory to run Smart Contracts calculations would be considered “necessary” and would be kept on-chain in storage. Other data that is not required for program functionality would be categorized as “unnecessary” (for e.g., recorded static information that would not be used by programs), and be kept off-chain or as an event log, as to avoid paying the GAS fee on them.

5.3 | Privacy Measures

Although the art industry needs to ensure the transparency of the provenance of artworks, not every detail should necessarily be shared publicly. The degree and parameters of preferable privacy are also artwork and owner dependent and is situationally different. As described in Section 4, many owners would prefer to keep certain transactional details (such as what artworks they currently possess and how much they paid for them) to themselves and unavailable on the public chain.

Blockchain was designed to distribute and manage data in a transparent way, and so for this reason, all nodes are designed to save and view the same data, resulting in anybody being able to see the data on the blockchain network. However, many new blockchain network protocols that strongly emphasize data privacy are emerging (such as the Enigma protocol), and Startrail is considering using such protocols in the future.

When using the current Ethereum protocol, the details within the provenance information are split into public and private. The public portion can be seen by anybody through the event log Ethereum generates, and such data is available to the public indefinitely.

On the other hand, there are three typical methods used to keep information private.

The first method is to encrypt the data off-chain and then record it on the blockchain, making it possible to read proven private information without the key used for encryption. The other two methods fuse the records off-chain. The first off-chain method is to store only the link to the data on-chain and store the actual information in space provided by an external storage service. The access rights to the stored data would be set by the user through the storage service, allowing owners to change and modify the access rights to their stored information themselves. The second off-chain method would be to record only the IDs of records on-chain that no user but the owner would be able to verify. For example, when a payment is made using a payment platform provided by a third party, the generated payment ID would be recorded on the blockchain. With only that piece of information on-chain, those without the other information required to make the IDs relevant would not be able to access or see the record, making this method another option to keep data private from third parties while retaining a record that a transaction exists.

5.4 | Security

5.4.1. Managing Access

The storage and event logs on a contract are public and can be viewed by anybody, yet the creation, deletion, and editing of data would require exclusive access to view. Startrail automatically changes these access rights when Certificates are turned over to a new party during the transfer ownership process.

Additionally, if an agent other than the original owner of the

artwork were to manage and handle these transactions, a multi-sig function would be implemented, where the actual process of granting access to additional users would not run unless approved by both the content creator and current owner. Startrail is planning on introducing more security and authority management features in the future as well.

5.4.2. Meta transactions Vulnerabilities and Countermeasures

Meta transactions (covered in 5.4.2) allow the platform to cover the GAS fee on the user's behalf; however, certain security risks may be present when implementing such a feature. Security risks and vulnerabilities when using Smart Contracts can be found listed on SWC (Smart Contract Weakness Classification and Test Cases)*²⁷. Startrail has pulled security risks relevant to Meta transactions from this list and will describe these potential issues and identify the solution Startrail has constructed for each example.

An example of a risky scenario would be if a malicious user

generated a valid unused signature by partially modifying a signature to be used as an argument. Startrail's solution is to utilize a design where a digital signature would not be included in the argument of the hash function when generating the signature (SWC117). In addition to this, data mapping is performed on-chain and is designed to prevent any signature being reused (SWC121). Lastly, when receiving an electronic signature from an off-chain location, a method that reliably restores the signer's address (using a restoration method that conforms to elliptic curve cryptography) has been adopted (SWC122).

5.4.3. Private Key Management

In order to access Startrail, a user needs a private key linked to its EOA address, and managing this key is extremely important. There are several options available regarding this scenario. Users could manage their own keys, Startrail could manage the keys for the users, or a third party key management company (custody company) could be contracted. Managing keys through a key management company would be the safest option for storing keys, but this option would also detract from the user

experience provided by the platform, as this integration depends on the technical progress and service updates performed by the custody company. To prevent this risk, for the time being, Startrail has decided to develop its current system under the assumption that Startrail will manage keys that do not have Ether at that moment, and have the users manage their own keys, and the platform would eventually select a dependable management company.

5.5 Support

Access to contracts on Ethereum is possible using the contract's ABI^{*28} and address. As the convenience of the

initial implementation may not be seamless, Startrail provides a complimentary RESTful API^{*29} for the users.

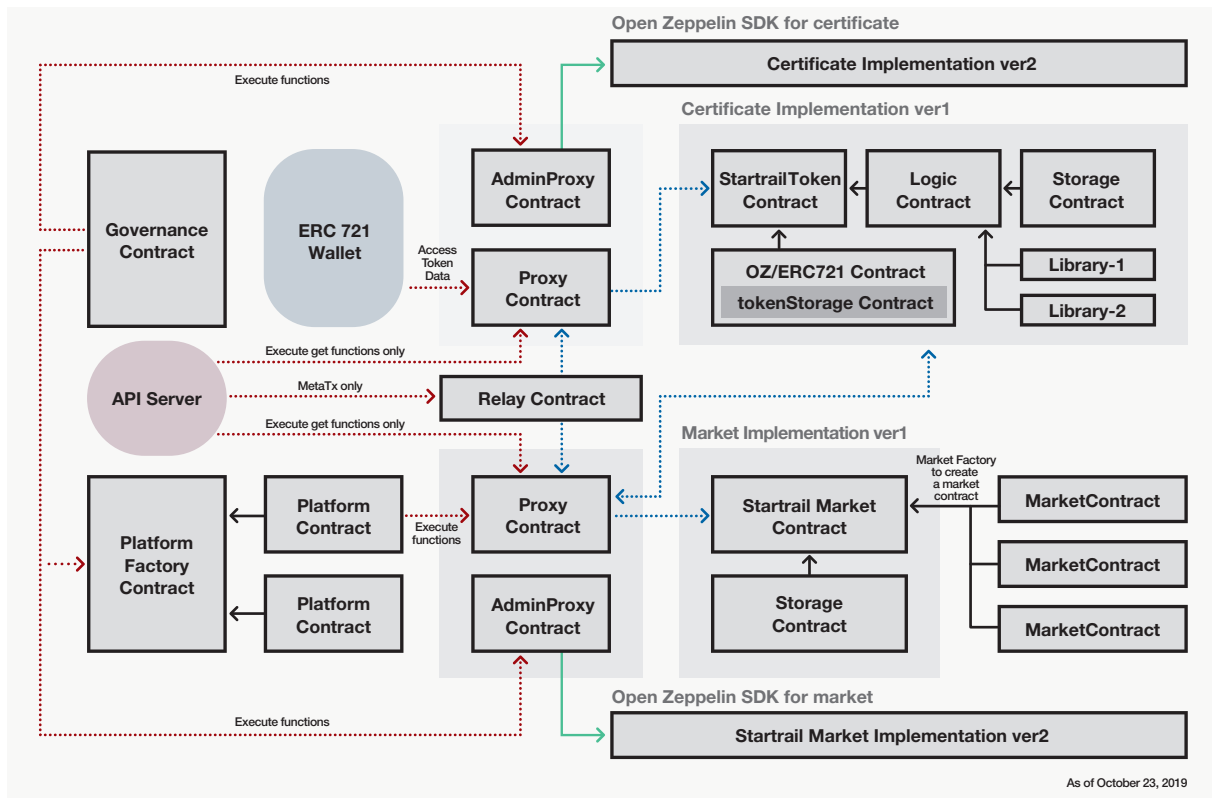


Figure 13: Startrail Smart Contract Architecture

Explaining Contracts

Relay

Relay is an endpoint where a meta transaction is executed. From when it is assigned as an argument and hash data, a signer's EOA address will be reproduced and passed as an argument to invoke_call method toward Proxy Contract which allows creating art certificates and market contracts. After the validation that msg.sender is equal to Relay contract address inside calling contract, the EOA passed as an argument is validated with the corresponding EOA set for each function.

Proxy

The proxy is an endpoint that enables access from relay contracts after meta transactions are executed, from a wallet that is accessible to a private key and from read-only access. Executing the delegate_call function enables it to execute functions in an external contract with reference to the internal storage of the proxy contract. This contract is not upgradable, which allows other contracts to be upgraded by providing its fixed contract address and permanent storage.

StartrailToken

The Startrail token implements ERC721 contracts provided by OpenZeppelin, which allows users to invoke some ERC721 based functions such as minting tokens and transferring the token's ownership. By overriding each function, Startrail's own restrictions and functions are added. Additional Startrail Certificate data can be stored into the Startrail token contract managed by a key-value storage contract. By saving this data into the proxy's unstructured storage pattern provided by OpenZeppelin SDK, it supports the upgradability of the Startrail token contract.

Logic

Logic contract provides utility functions that can store metadata of artworks or record provenance data, which is not related to ERC721 token information. Logic contract can directly access data as it implements the storage at the logic contract. The logic contract can be upgradable as a new function can be added due to functional requirement changes.

Storage

Storage where the multidimensional key-value data format is defined as upfront, which allows the use of the same data format from multiple contracts.

Library

Library provides the code that executes storing/retrieving data and calculations, and does most calculations based on the data provided into it. Separate deployment from the logic contract makes upgradeability more effective by reducing GAS.

AdminProxy

AdminProxy manages contract addresses that have authentication to upload/change a group of contracts that are packaged as Startrail Implementation with OpenZeppelin SDK. The governance contract addresses will be registered in this contract in the future.

StartrailMarket

StartrailMarket plays the role of not only deploying a market contract which represents a one to one relationship with a single market but also mapping a deployed contract address with market-related attributes such as EOA of a market owner or the name of a market. This mapping with contract address makes it possible to utilize the market's ruleset when using transfer_from function in ERC721 provided by OpenZeppelin because only the address format can be an argument. Additionally, the usage of OpenZeppelin-SDK

guarantees upgradeability with the maintenance of storage data as it is shown in the StartrailToken contract.

MarketContract

A market contract is the contract deployed from the StartrailMarket contract. As described above, since the objective is to map the contract address with some market information, it only provides minimum functions.

PlatformFactory

By obtaining the certification through governance, it is possible to deploy the platform contract corresponding to the platform on a one-to-one basis. The generated contract address and the platform owner's EOA are mapped as certified and can be saved and viewed. Doing this prevents malicious users on the platform by regulating market contract creation rights to only verified platforms, or verifying whether the market contract has been authorized.

PlatformContract

A contract generated using PlatformFactory used to identify the platform and its owner.

GovernanceContract

A governance contract is a contract that issues tokens. Token holders will be given voting rights for actions like renewing Startrail contracts and veto rights for malicious transactions according to the Startrail Consortium protocols.

Notes

- * 23 This article does not classify the specific differences between consortium and private blockchains
- * 24 NFT is an acronym for Non-fungible token, a type of cryptographic token using the ERC721 standard that is unique and non-interchangeable in nature. On the contrary, interchangeable tokens would be classified as fungible tokens.
- * 25 erc721.org/
- * 26 Refer to smart contract architectural diagram at the end of section
- * 27 <https://smartcontractsecurity.github.io/SWC-registry/>
- * 28 ABI(Application Binary Interface) is a general term that has a different meaning when used in context of Ethereum, and is defined to provide compatibility with the binary code of Smart Contracts executed on EVMs (Ethereum Virtual Machines).
- * 29 Reference and documentation is available through the official Startrail website. To better the user experience using this API, GET requests can be directly sent to the Contracts to make the data extraction easier.

06

Interoperability with Other Blockchain Projects

6.1 The Necessity of Interoperability

As mentioned in Section 3, many art-related projects use blockchains, but the standards among such infrastructures are not fully standardized. Like Startrail, some platforms provide history management services and applications related to trading using provenance information recorded in such projects. The current lack of collaboration between projects is problematic,

as not only will the user experience be degraded, but potential synergies and optimizations in the art ecosystem will be unmet.

Startrail aims to create an ecosystem that allows each art blockchain project to collaborate by letting users connect to other projects.

6.2 Realization of Interoperability with Other History Management Networks

6.2.1. Realization of Interoperability with History Management Projects using Blockchains other than Ethereum

"Two-way Peg": A Mechanism for Realizing Interoperability

To realize interoperability with other art blockchain projects, Startrail is using models that provide a way for value to enter and exit the network (such as a gateway in XRP Ledger) as a reference for its design.

In this method, when the token (in this case, an Startrail Certificate) crosses between blockchains, the certificate is fixed (locked) in the project before transferring. When this happens, a new certificate is issued within the destination project. For instance, when transferring a certificate from

Startrail to a project created on another blockchain, the Startrail Certificate is locked on Startrail, and a new certificate (non-Startrail) is issued on the destination network. When returning the non-Startrail certificate to Startrail, the lock is released and distributed again. This method is called a Two-way peg.

This method is made possible by gateway companies that manage the movement of tokens between two blockchains. Startrail and other blockchain projects can connect via gateway company locking and unlocking tokens.

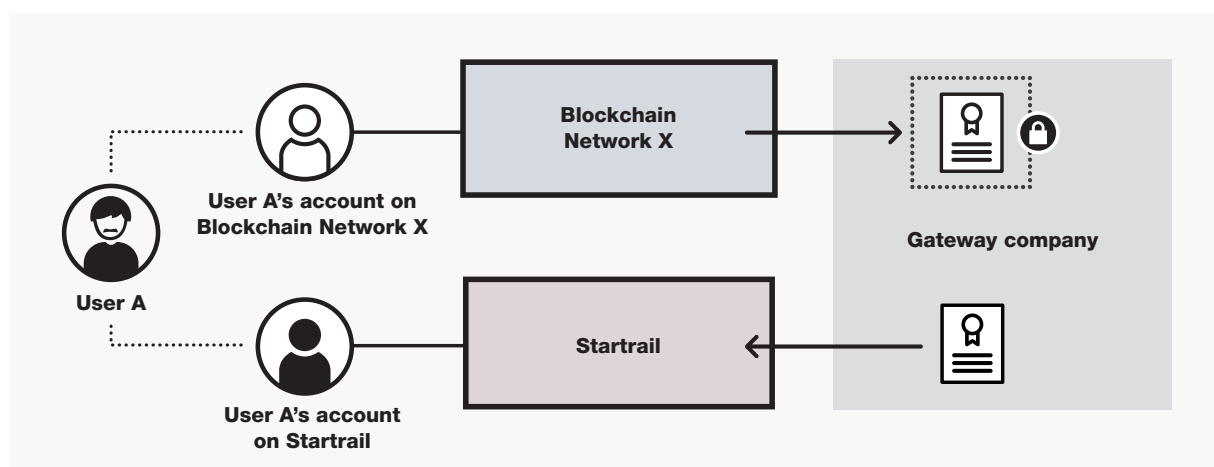


Figure 14: The Mechanism for Realizing Interoperability using the Two-way peg method

Addressing the Token Circulation Problem

Connecting to other networks via gateway companies around Startrail enables seamless certificate movement across different blockchains. On the other hand, the movement of tokens without going through Startrail could potentially cause tokens to circulate in multiple networks.

In order to prevent multiple networks carrying the same token, each token has information attached identifying the platform it originated from. When a token moves to another network via Startrail, a request is made to the issuing network to delete the token.

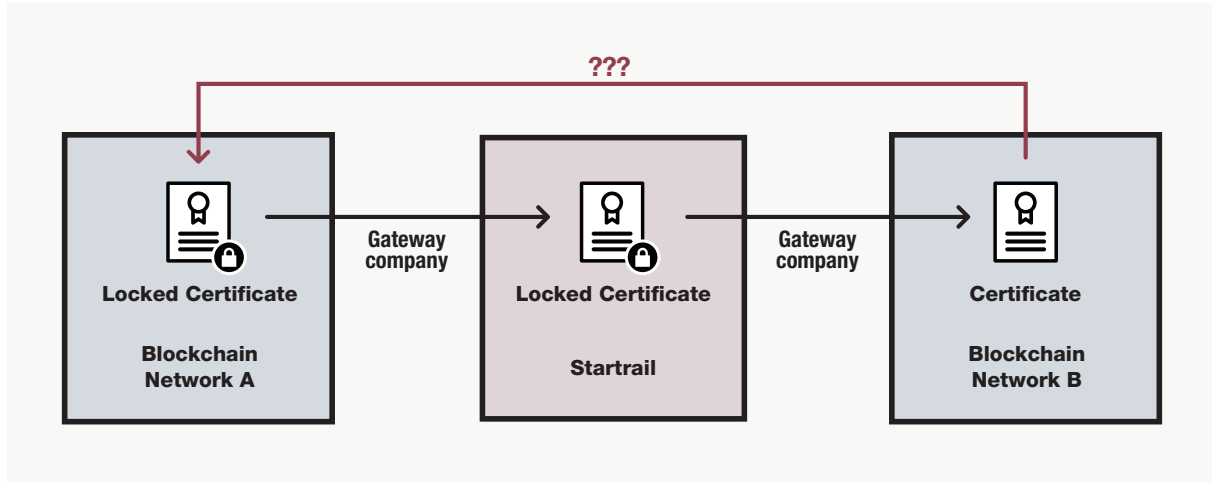


Figure 15: Token Circulation Problem

6.2.2. Interoperability between Projects using Ethereum

If the non-Startrail project is an Ethereum-based project like Startrail, interoperability is easier. When contract specifications are close to Startrail, interoperability is possible by calling the contract address of the other party directly from the contract

of Startrail. Furthermore, if it is developed using the ERC721 standard (like Startrail), the token can be managed with a wallet that supports the same standard.

6.3 Realization of Interoperability between Projects using Startrail Provenance Record

Split Ownership of a Project using Blockchain

As a sample of interoperability with a non-Startrail project using Startrail Provenance Records, the below describes

Startrail's interoperability with a project that splits ownership of an artwork.

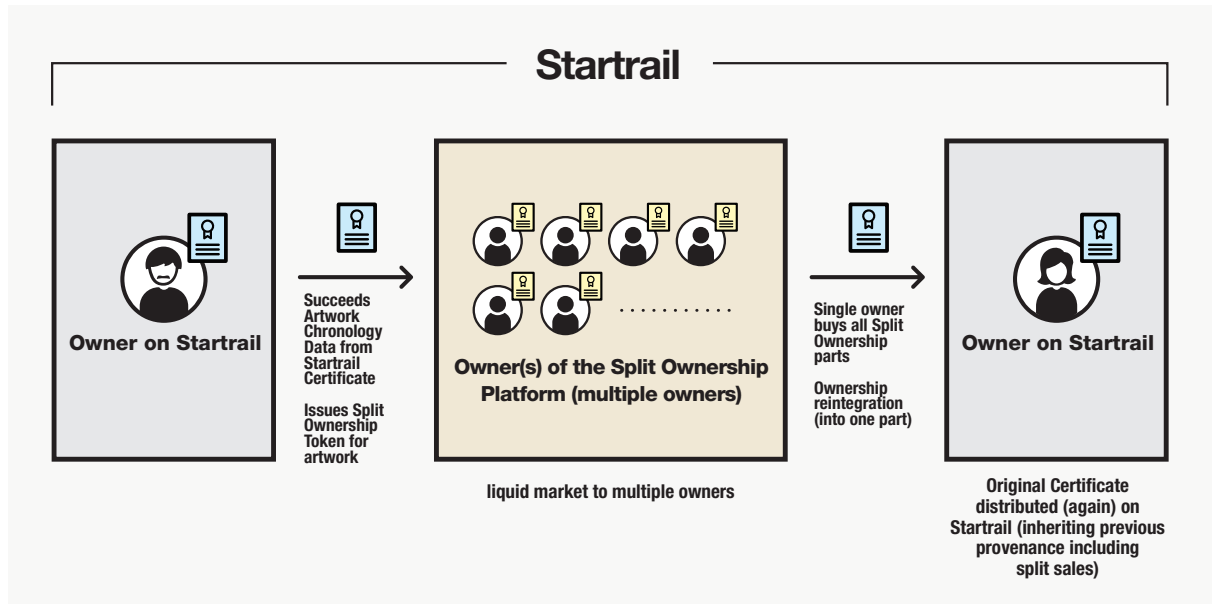


Figure 16: An Example of Interoperability for a project that splits ownership of an artwork

Suppose there is a platform available that enables users to sell and trade ownership of artwork. Startrail issues a split ownership token by using the provenance information for each artwork provided via the relevant Startrail Certificate, so users

can purchase split ownership tokens with confidence, providing Startrail users a market with a wide range of choices and more rapid liquidity.

07

Governance

7.1 | The Network Startrail Aims to Be

Startrail aims to retain the brand value and credibility nurtured over time by significant players in the art world, such as career artists and long-established businesses. The network that we strive for is an open platform that also provides opportunities for young artists and new companies to participate. Startrail aims to be a network open to all.

To realize this, Startrail aims to create a network that broadly reflects the intentions of all participants by eliminating

centralized management by specific parties.

However, open decentralized systems are not only at risk of malicious users coming to disrupt it, but may also be slow to react when such things happen, based on its inability to make a swift decision as a collective. Startrail aims to reduce such risks by adopting the following governance system set by the Startrail Consortium.

7.2 | The Startrail Consortium

To realize the network Startrail strives to be, members who sympathize with the Startrail mission and vision will be recruited to form the Startrail Consortium. By becoming a council organized by reliable professionals, companies, and organizations, Startrail aims to (1) operate with independence and fairness and (2) expand awareness both inside and outside the art world.

The Startrail Consortium will be an independent membership-based organization. As it expands, it will be associated with an incorporated association with its headquarters based in Japan. In line with the expansion of Startrail, Startrail aspires to remain respectful and follow local rules and guidelines to incrementally spread the decentralized management Startrail upholds.

Startrail has two primary purposes: maintaining operation of

Startrail, and updating and modifying its system. As Startrail is open and inclusive, there will be a certain amount of risk that it attracts malicious actors, requiring features that protect the platform from such risk. Connection platform authentication, artist address identity verification, and the correction of incorrect information all fall under such preventative measures. In addition to this, updating the system in response to future market changes and technological development, as well as responding to fatal system failures are essential functions to maintain the system.

In order to make this possible, each member of the Startrail Consortium will be issued a Governance Token, enabling them to vote on the blockchain, as well as perform regulating tasks on it as well.

7.3 | The Role of the Governance token

The Governance token has the following roles:

① Controlling Connections to Startrail

By holding a Governance Token on the address, operators using Startrail can deploy their own Handler Registration Forms and issue official Startrail certificates.

Setting these restrictions prevents users from being harmed by businesses whose identity cannot be confirmed or has

a history of fraud.

The Startrail Consortium will make decisions democratically regarding the granting and stripping of Governance Tokens to and from businesses.

② Voting Rights

The Startrail Consortium votes on the blockchain, making decisions as a group without a single party managing the

voting process. To vote, a Governance Token is required. The network is considering adopting a subtractive voting process(i.e., a veto-based voting system), that only counts ballots “against” a decision in order to expedite the decision making process in the initial stages.

In the primary stages of Startrail being released, the veto-based voting system would be efficient. Further, this voting method cuts down costs and lets the organization maintain a decentralized voting system.

For the smooth start-up and updating of the network, the initial operation of the Startrail Consortium will be led by startbahn, Inc. To reflect the opinions of more Startrail Consortium members regarding discussions on settings and Startrail specifications, Startrail plans to move to decentralized governance in the future. Those who wish to participate in the community for the future development of Startrail should contact the Startrail Consortium^{*30}. We look forward to hearing from you.

| Notes | * 30 Please contact us from the URL below if you are interested in joining the Startrail Consortium (URL: <https://startrail.io>).

08

Organizing Legal Relationships

8.1

Participating Companies and Other Artists in Relation to the Startrail Consortium

General terms of service will look like the following:

In addition to the general terms and conditions set by each platform market, general users of Startrail will agree to Startrail's general terms and conditions set by the Startrail Consortium, presented to each user through each individual platform or Handler on the network.

For example:

- Users may not provide false information;
- Owners are to transfer or receive the Startrail Certificate along with the transfer or receipt of an artwork;
- The terms of use of an individual artwork carry over with its transfer;
- All parties understand that the terms and conditions of use

of each artwork can be amended if both the artist and current owner of the artwork agree upon such changes;

- All parties involved in any transaction of an artwork on the Startrail network agrees to voluntarily provide information if an investigation occurs in the future; and
- If cases of falsifying information or breach of contract are discovered, the Startrail Consortium may refuse the participation of any individual or Handler to participate in the network.

As Startrail is both a framework and infrastructure that supports the art world by being a market, specific measures regarding compliance with international law and regulations will be implemented in Startrail's rules and regulations via each platform and Handler.

8.2

Relations Between Artists and Owners and Owners and Owners

The Startrail Certificate transfers a set of terms between the artist and owner to the next owner upon transfer. When the transfer occurs when a new party purchases the artwork, the transfer assumes the ruleset by the artist in advance and assumes that

they will be transferred, unless there was a consensual change before the transfer. Upon transfer, the contract between the former owner and the artist ends, and a new contract between the new owner and the artist is created and becomes active.

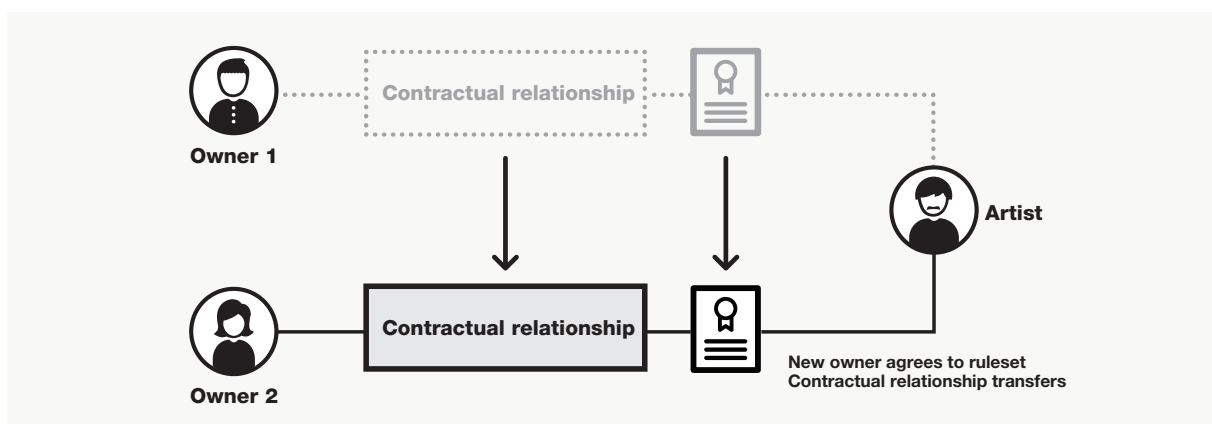


Figure 17: Transfer of Contract Relationships when Transferring Startrail Certificate

In a transfer, there are cases where the copyright and ownership / usage rights transfer with the piece or remains

with the original artist.

8.3 | Relations Between Artists and Handlers

As mentioned in Section 4, the ruleset for each artwork on the network as well as the Handler's rulesets are to be set per occurrence accordingly, to allow for each Artist and Handler to have maximum amounts of flexibility.

Startrail also adopts a policy where the creator of an artwork can receive a portion of future sales where a work is sold on the secondary market. This is completely optional and is noted in the Startrail Certificate which all parties can see before any purchase or exchange happens.

Each Handler will be expected to comply with corresponding laws and set the contents of their rulesets (such as the percentage the copyright holder receives when work is resold) accordingly.

The Startrail Consortium is not responsible for determining such rates or collecting any kind of revenues. The council will cooperate in the communication between the artists and the Handlers, but is no way obligated to collect or redistribute funds regarding such fees.

With features such as these, Startrail will continue to collaborate with other projects to create synergies and provide greater convenience to our users.

If you are interested in connecting to Startrail or are involved in projects that could be interested in joining the Startrail Consortium, please contact us here:

<https://startrail.io>

Lastly, if there are changes and updates based on feedback from users and other projects,
or any changes in how Startrail is designed,
a revised version of the white paper will be released accordingly.

09

Roadmap

2016	Q1	Begin studying the use of blockchain
	Q3	Create a mockup of the project that eventually becomes Startrail
2017	Q1	Begin planning Startrail project design
	Q2	Begin research and development of Startrail prototype 1.0
2018	Q3	Begin interviews and Startrail stakeholder recruitment
	Q4	Begin research and development of Startrail prototype 2.0
		Release Startrail testnet
		Begin Startrail-related operations on startbahn.org
2019		Announce Startrail collaboration Proof of Concept with 5 companies (Tanseisha, BTCompany, Tagboat, Amatorium, Busunit)
	Q1	Begin research and development of Startrail prototype 3.0
		Announce Startrail collaboration Proof of Concept with AG Holdings
		Begin designing Startrail operational governance
	Q2	Begin research and development of Startrail prototype 4.0
		Announce Startrail collaboration with SBI Art Auction
		Startrail Certificates issued to interested parties for artworks worth approximately 450 million yen auctioned at SBI Art Auction in April
		Begin Startrail collaborative operations with B-OWND
	Q3	Startrail Certificates issued to interested parties for artworks auction at the SBI Art Auction in July
		Begin research and development of Startrail prototype 5.0
		Announce partnership with Maecenas (art fractional ownership platform)
		Hold Startrail Consortium pre-meetups (25 companies participated in July, August and September)
	Q4	Release Startrail White Paper
		Startbahn release of Startrail compatible API (Testing with partner companies)
2020		Begin recruiting Startrail Gateway companies
		Begin recruiting Startrail Consortium members
	March	Begin Startbahn Cert. operations by Startbahn (Oracle issue solution by matching the artwork with an IC tag, https://cert.startbahn.io)
		Torus (https://tor.us/) release of White label (login solution) for Startrail
		Release Startrail mainnet
		Release copyright management feature
		Begin Startrail Consortium operations
		Begin governance token operations
		Begin recruiting Startrail compliant API distributors
		Develop and release additional features

After taking into account feedback on the content published in this white paper, Startrail is planning its release on the mainnet in 2020.

After the mainnet release, further releases are in the works. Governance operations using Governance Tokens are scheduled to start in the first half of 2020.

10

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About Startbahn, Inc.

Startbahn is a company that aims to realize a more vibrant society by providing the technology required by artists and those involved in the art world globally.

We have designed and constructed the Startrail, an infrastructure to distribute artwork and record transactions regarding such artwork.

Startbahn was found in 2014 by artist Taihei SHII.

The company has raised a total of 470 million yen to date with investments from UTEC, Dentsu, SBI Investment, SX Capital, and other organizations.

Currently, it has an office on the University of Tokyo campus and has a 30-member team.

Company website

<https://startbahn.jp/>

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