

Oxcert protocol

Open protocol for certified non-fungible tokens

Version 1.0 (draft)

Authors: Kristijan Sedlak, Jure Zih

[Oxcert.org](https://oxcert.org)

Abstract

Oxcert is an open source permissionless protocol for non-fungible tokens on the blockchain. These tokens are stored in cryptographic wallets and are owned by users. In addition to common functions for transferring and managing standard non-fungible tokens, the Oxcert protocol provides another layer of conventions for creating certified non-fungible tokens for unique assets. These tokens are called Xcerts and are created through a custom minting process. Xcerts represent opinionated non-fungible tokens, which also hold an imprint of an asset. With Oxcert protocol, we can validate a proof of existence, authenticity, and ownership of these digital assets without third-party involvement.

Oxcert is a framework with a set of on-chain and off-chain rules for managing Xcerts and other standard non-fungible tokens. Our mission is to equip application developers with a secure blockchain agnostic platform, powerful tools, and community embraced conventions for managing non-fungible tokens. Oxcert is a pluggable settlement with an advanced integration layer for different dapps and relay applications. This enables developers to focus on the application layer and quickly build applications for issuing university certificates, KYC applications, applications for loyalty programs, warranties, badges, credits or even a decentralized non-fungible exchange.

Contents

1. Introduction	02
1.1. Overview	02
1.2. Fungibility	03
1.3. Decentralization	04
2. Specification	06
2.1. Xcert	07
2.1.1. Paradigm	07
2.1.2. Smart Contract	07
2.1.3. Asset Proof	08
2.1.4. On-chain Data	08
2.1.5. Off-chain Data	09
2.1.6. Minting	09
2.1.7. Decentralized Identifier (DID)	10
2.1.8. Burnable Xcert	11
2.1.9. Revokable Xcert	11
2.1.10. Pausable Xcert	11
2.2. Conventions	12
2.2.1. Paradigm	12
2.2.2. Asset Data	13
2.2.3. On-chain Data	14
2.2.4. Off-chain Data	14
2.2.5. Certification	15
2.2.6. Verification	16
3. Framework	18
3.1. Devkit (SDK)	18
3.2. Decentralized Exchange (DEX)	19
3.3. Decentralized Minter (DXM)	20
3.4. Continuous Integration	20
4. Protocol token (ZXC)	22
5. Oxcert Labs	24
5.1. ERC-721 Implementation	24

5.2. 0xcert Scanner	24
5.3. 0xcert Identity	25
5.4. 0xcert DEX	25
5.5. 0xcert DXM	25
6. References	26

1. Introduction

0xcert is an open-source permissionless protocol for non-fungible tokens on the blockchain. These tokens are stored in cryptographic wallets and are owned by users. In addition to various common functions for transferring and managing standard non-fungible tokens, the 0xcert protocol provides an additional layer of conventions for creating non-fungible tokens from unique assets. These tokens are called Xcerts and are created through a custom minting process.

Xcerts represent standard non-fungible tokens, which also hold an imprint of an asset. With 0xcert protocol, we can further validate proof of existence, authenticity, and ownership of these assets without third-party involvement.

The first implementation of the 0xcert protocol is focusing on the Ethereum blockchain. The 0xcert protocol is designed to be blockchain agnostic, and supports building on other blockchains as well.

1.1. Overview

The advent of blockchain has redefined technology and set the course for the future of everything. But despite being an amazing technology it is very complex in its nature. Writing and deploying smart contracts is difficult and can be a very perilous task. This fact prevents many people from adopting blockchain technology and building their decentralized applications on top of it.

Our mission is to equip application developers with a secure blockchain settlement, powerful tools and community embraced conventions for managing non-fungible tokens. 0xcert protocol extends the non-fungible paradigm with an opinionated certification and standardization layer for unique assets which is based on the 0xcert conventions. This allows for creating certified non-fungible tokens on the blockchain, which also carry an imprint of a unique real-world asset.

The protocol supports a wide range of use cases, where non-fungible assets and ownership play a role. Because the data are stored in decentralized blocks, the information can be fully trusted and verified by anyone and anywhere.

The Oxcert protocol is an open-source project so anyone can use the fully functional Oxcert protocol with no limitations. Developers have the ability to manually mint, burn, verify and transfer Xcerts. The protocol uses a publicly accessible network of digital wallets and smart contracts on the blockchain, making it extensible through third-party modules and a variety of dapps.

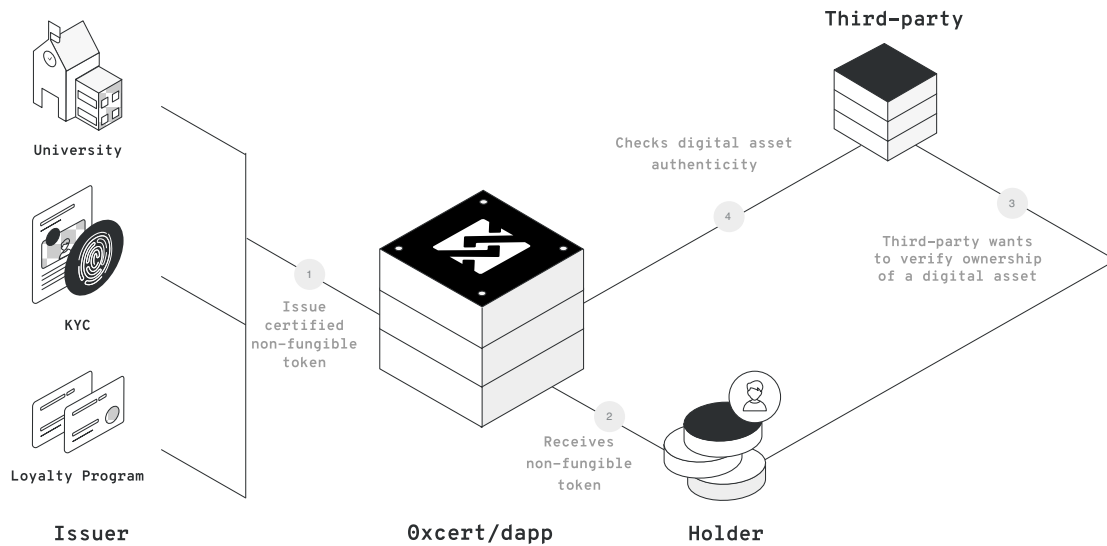


Figure 1: Oxcert protocol can act as an intermediary between parties.

Oxcert is an opinionated framework and supports numerous business models used by third-party dapps. These applications sit on top of the protocol and can use the protocol tokens as a fuel for their service.

The dapps form a network of public and private services for unique assets and offer higher-level features that simplify and automate the process of creating and managing non-fungible tokens, provide public and private listings, rewarding mechanisms, integration gateways and more.

1.2. Fungibility

The most common tokens of today’s crypto economy follow Ethereum’s ERC20 specification. These tokens are so called fungible tokens, because tokens of the same kind can be mutually interchangeable. If we make an analogy with fiat

currency, a dollar bill can be exchanged for any other dollar bill, which does not create any difference for the holder.

Recently, another kind of token called non-fungible tokens started getting attention in the crypto community. Though we knew non-fungible tokens before, it actually all started with Crypto Kitties - tradable collectibles - which set the foundation for the now accepted ERC-721 standard. Unlike ERC-20 identical tokens, non-fungible tokens are unique and carry some sort of data.

The 0xcert protocol goes even further and introduces an Xcert as a standardized and certified non-fungible token based on ERC-721 and 0xcert conventions that carries information about a particular unique asset. This mechanism is unique to the 0xcert protocol and is described in later sections.



**Fungible
tokens**



**Non-fungible
tokens**



Xcert

1.3. Decentralization

The protocol utilizes the blockchain, a distributed ledger technology that was first built to support the Bitcoin cryptocurrency. Blockchain can be best described as a distributed ledger that maintains a list of records called blocks. Each block has a timestamp and is built on top of an already existing block, preventing any data from being altered retroactively.

Blockchain offers a unique solution to the problem of secure online transactions. Due to its transparency and distribution of information to many decentralized blockchain nodes, it is nearly impossible to manipulate existing data records,

making it potentially suitable for recording events, records, identities, certificates, transactions and other documentation.

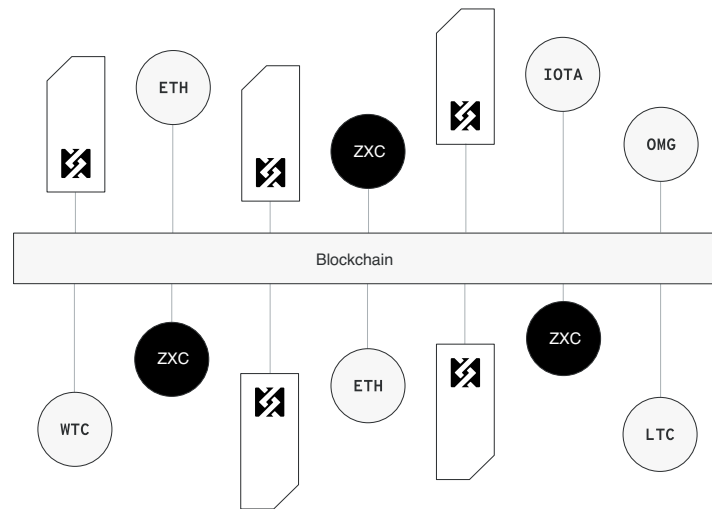


Figure 2: Oxcert protocol uses blockchain to enable decentralization.

By storing hashed data on the blockchain, individuals, companies, and institutions can keep a decentralized record of their asset proofs, while maintaining sensitive data completely private. At the same time, all certified records, their issuers, and owners can be easily authenticated and referenced.

2. Specification

0xcert provides a framework with a set of on-chain and off-chain rules for managing Xcerts and other non-fungible tokens. In addition, the 0xcert protocol is a pluggable settlement with an advanced integration layer for different dapps and relay applications.

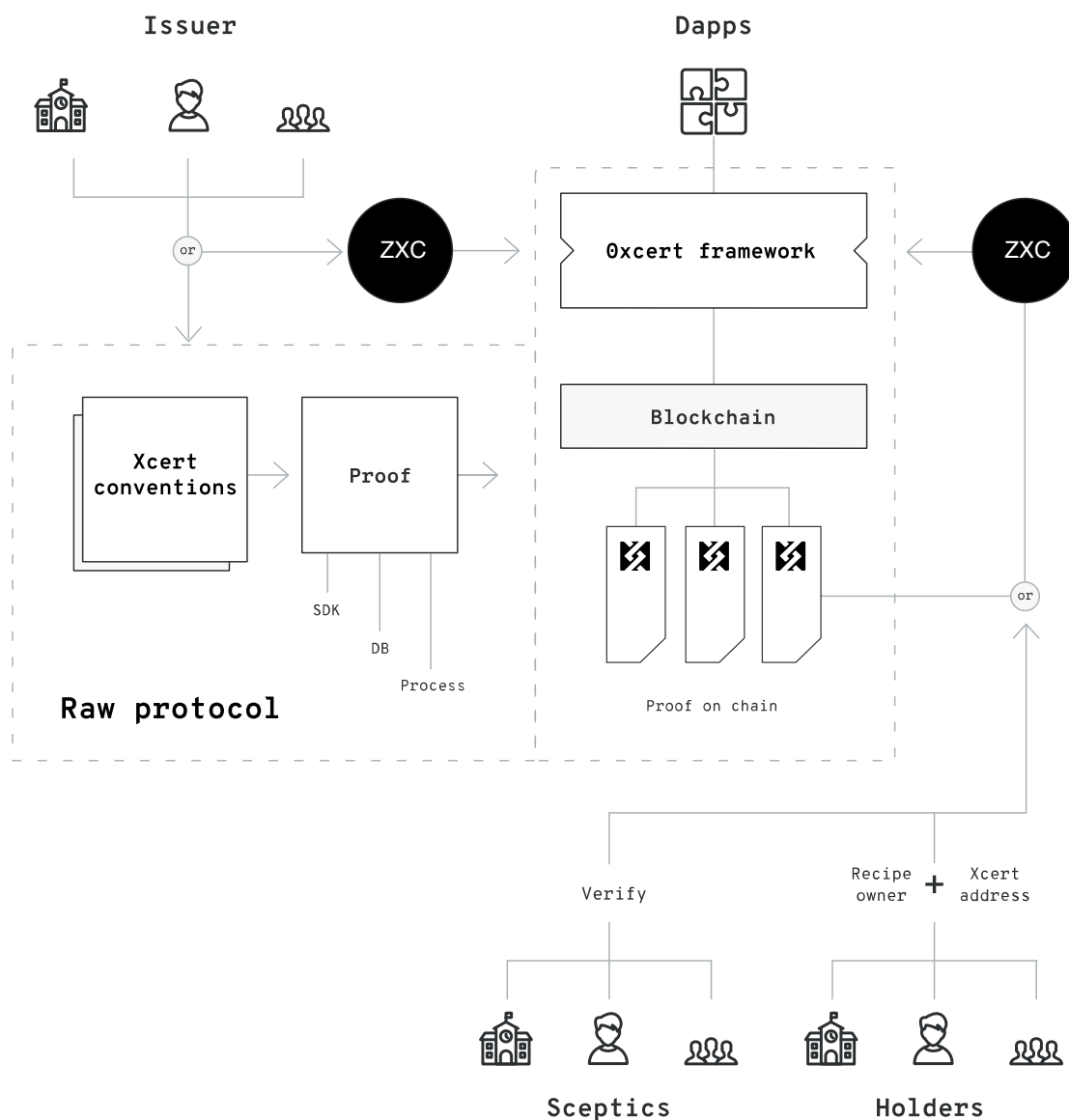


Figure 3: Users can interact with the protocol manually or through higher-level dapps.

2.1. Xcert

An Xcert represents a one-of-a-kind asset in form of a non-fungible token on the blockchain. It holds a proof of a real-world asset and has all the properties of a non-fungible token.

2.1.1. Paradigm

Digital assets on the blockchain as non-fungible tokens represent a new paradigm which enables application developers to build advanced and secure applications for managing real-world assets. Users hold asset ownership rights in their cryptographic wallets. They are able to exchange tokens between wallets and have control over the tokens they own.

The 0xcert protocol puts unique assets on the blockchain as non-fungible tokens. These tokens are called Xcerts and exist on the blockchain as an item of a specifically designed smart contract.

An Xcert is an item of a specifically designed smart contract which implements the non-fungible functionality. An Xcert is identified by an ID which is unique per Xcert smart contract and is always assigned to a cryptographic wallet. Besides the unique ID, a token can carry a proof of a digital asset, arbitrary on-chain data and a URI to additional off-chain data.

2.1.2. Smart Contract

An Xcert smart contract is an extended non-fungible token smart contract. It follows the Ethereum's ERC-721 specification which thus makes it compliant with the non-fungible token standard.

An Xcert smart contract holds assets of a particular 0xcert convention. This makes the contract opinionated and forces predictable data.

A smart contract should always expose information about the used convention and smart contract interfaces and other capabilities. Following the Ethereum's ERC-165 standard to implement this features is considered a good practice.

2.1.3. Asset Proof

A very important and a unique part of an Xcert is a cryptographic proof which is stored in the token itself.

An Xcert can thus carry an imprint of a unique real-world asset. The proof is the result of the 0xcert certification process which is described later in this document. It represents a cryptographic hash build from asset data and serves as a decentralized proof of an asset on the blockchain.

An Xcert does not include actual asset data, only the proof of it. This ensures data confidentiality because no information is disclosed to the general public and the actual content is always kept private to the involved parties only.

This concept makes the 0xcert protocol unique and extends the usability to a whole new level.

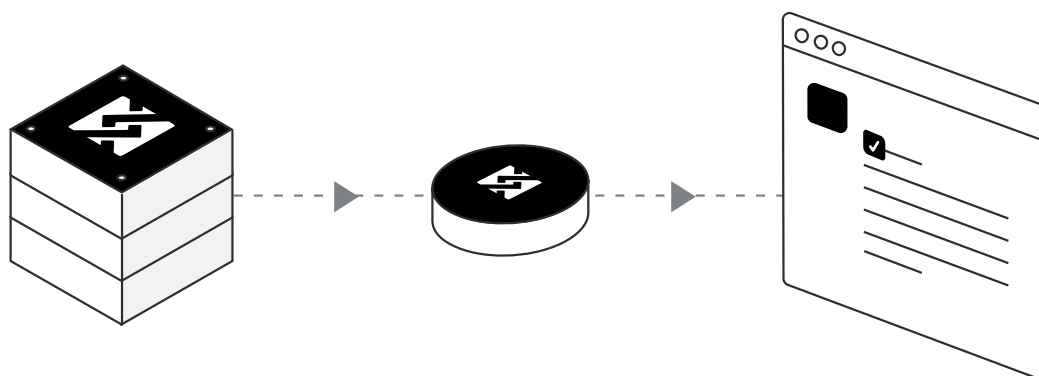


Figure 4: An Xcert is a non-fungible token that carries asset proof.

2.1.4. On-chain Data

We can attach additional public data to each Xcert. The parameters which are attached directly on the token itself usually participate in atomic swaps or other on-chain operations.

2.1.5. Off-chain Data

Storing data on the blockchain could be expensive. Sometimes we would want to provide also dynamic data about a particular Xcert. Managing data directly on the blockchain would not scale. By exposing additional information about a token as an off-chain data file solves many problems and makes the system flexible and scalable.

Each Xcert includes a URI to a publicly available metadata file. This data object is a specifically designed JSON object, which conforms to RFC-7159 and follows the mapping format defined by the JSON Schema specification.

The naming of JSON properties should follow the schema.org dictionary when possible. This is to enable an easy way to convert a data into a JSON-LD format. The convention also expects the JSON keys to be defined in alphabetical order.

A metadata file should be served through a secure HTTPS connection on the public web. The response returns data in "application/schema+json" content type. It also includes a Link header pointing to JSON Schema definition file of the received metadata object. The JSON Schema definition varies based on the token capabilities and the asset it represents.

Off-chain metadata JSON files are not mandatory but are highly recommended. We also recommend storing these files in the decentralized system instead of hosting them by a company itself.

2.1.6. Minting

The process of issuing new Xcerts is called "minting". This is enabled by the Xcert smart contract deployed on the blockchain.

The minting process creates a new unique Xcert for a particular asset and assigns it to a digital wallet. A new Xcert can be minted by the issuer, who owns the Xcert smart contract or by an entity authorized by the issuer.

Anyone can become an issuer by deploying a new Xcert smart contract to the blockchain. An issuer should represent a trusted authority that provides value for the interested public. The issuer uses Xcerts on the blockchain to provide proofs of ownership for its digitized assets.

The minting process starts with asset certification process which is covered later in this document. The result of the certification are asset data objects and a cryptographic proof of a digital asset. An issuer submits this content, together with additional protocol configuration and holder address to the blockchain which creates a new Xcert token and assigns the ownership to the provided holder. Optionally an issuer publishes the public metadata as well.

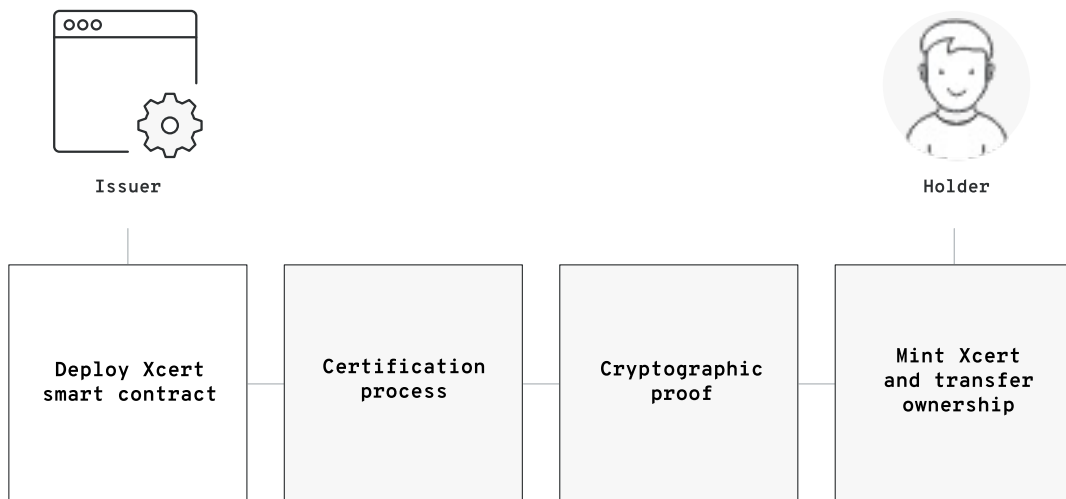


Figure 5: The minting process creates a new Xcert on the blockchain.

In terms of trust, the issuer is responsible to prove and promote their account authenticity information over arbitrary communication media when needed.

2.1.7. Decentralized Identifier (DID)

A decentralized identifier uniquely identifies an Xcert. A decentralized identifier or simply a DID is a string format which uniquely identifies an Xcert on the blockchain.

An Xcert identification consists of multiple pieces of information. The 0xcert protocol uses DIDs to uniquely describe an asset on the blockchain as a URI that can be resolved as a publicly available resource.

All DIDs are defined as "did:xcert:{URI}". The URI consists of multiple information joined with "/" following the sequence:

Index Include Description

- | | | |
|---|--------|--|
| 0 | Always | Blockchain identifier (e.g. "ethereum"). |
| 1 | Always | Xcert smart contract address. |
| 2 | Always | Xcert token ID. |

2.1.8. Burnable Tokens

Some digital assets can become invalid over time. By making Xcerts burnable, a user can clean up his/her wallet by permanently removing these tokens. An issuer can enable users to burn the Xcert tokens they own. When a user burns a token it permanently removes it from his/her wallet and thus from the Xcert smart contract.

2.1.9. Revokable Xcert

Sometimes an issuer requires more control over token management. By making Xcerts revocable the issuer can remove the token at any time. A user, in that case, has no control. This functionality is sometimes needed but it is not recommended. An issuer should always provide a good explanation for including this feature in the Xcert smart contract.

2.1.10. Pausable Xcert

Issuers can make Xcert smart contract pausable. This means that an issuer has the ability to pause and resume Xcert transfers. This feature is especially useful when migrating or upgrading issuer's local database.

2.2. Conventions

To simplify the process of describing assets as data objects and to enable interoperability between different applications Oxcert provides conventions for creating digital assets.

2.2.1. Paradigm

A digital asset is a data object which holds information about a real-world asset. Oxcert uses blockchain to store a cryptographic proof of a particular asset in form of a non-fungible token. The protocol provides conventions for defining these data objects and rules for converting them into Xcert tokens on the blockchain.

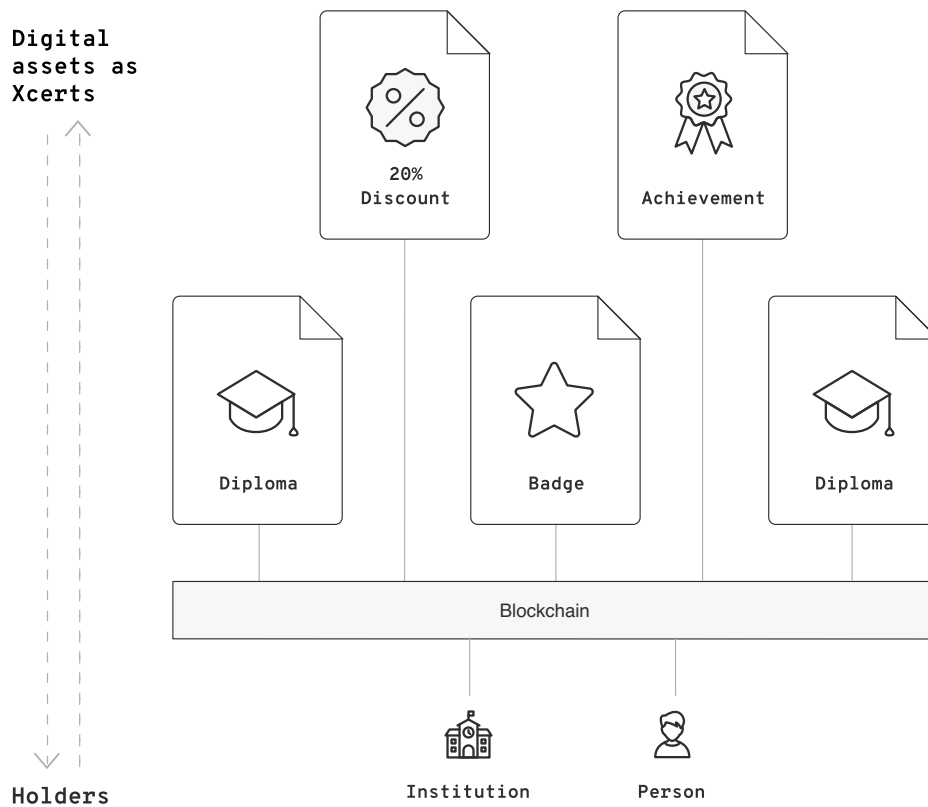


Figure 6: Asset data are defined by a convention.

A digital asset in the 0xcert protocol is defined and described in the form of specifically designed JSON objects, which conform to RFC-7159 and follow the mapping format defined by the JSON Schema specification.

Every digital asset in the 0xcert protocol has its own JSON Schema definition for describing the asset, on-chain properties, and off-chain metadata. The schemas represent a technical specification of a particular digital asset, which explains the JSON data object structure.

The naming of JSON properties follows the schema.org dictionary when possible. This enables an easy way to convert the data object into a JSON-LD format. The convention also expects the JSON keys to be defined in alphabetical order.

Schema documents are defined and approved by the interested community engaging the protocol. The community can propose updates and new conventions, which can then be included in the protocol, based on the majority consensus.

2.2.2. Asset Data

The main convention file is a JSON Schema which describes a data structure of a digital asset. These data are usually considered private and the content is known only to the issuer and token owner.

This data structure is used for creating a cryptographic proof for a digital asset which is carried by the Xcert token.

The 0xcert protocol can cover all sorts of digital assets. A simple imaginary schema, that describes a person, could look something like this:


```
{
  "$schema": "http://json-schema.org/draft-07/schema#",
  "description": "A person (alive or fictional).",
  "properties": {
    "name": {
      "description": "A full name of a Person.",
      "type": "string"
    }
  },
  "required": ["name"],
  "title": "Person",
  "type": "object"
}
```

Figure 7: Xcert schemas describe digital assets in a way that machines can understand.

2.2.3. On-chain Data

Some assets need additional parameters stored directly in the Xcert. This data is usually used by blockchain mechanics like atomic swaps where a transaction can be performed only under certain conditions.

2.2.4. Off-chain Data

Optionally an asset can also provide dynamic metadata on some public URI. These data provide additional information about an asset, should be publicly accessible to anyone and can change over time.

Every Xcert should have at least the basic metadata JSON Schema definition like this:

```

{
  "$schema": "http://json-schema.org/draft-07/schema#",
  "description": "An Xcert metadata object.",
  "properties": {
    "description": {
      "type": "string",
      "description": "A description of an asset.",
    },
    "image": {
      "format": "uri",
      "type": "string",
      "description": "An URI to the resource with mime
type image/*. Consider making any images at a width
between 320 and 1080 pixels and aspect ratio between
1.91:1 and 4:5 inclusive."
    },
    "name": {
      "description": "A unique name of an asset.",
      "type": "string",
    }
  },
  "title": "Xcert",
  "type": "object"
}

```

Figure 8: Metadata follow the JSON format of the ERC-721 standard.

2.2.5. Certification

An Xcert carries a proof of a unique asset data. It is a cryptographic hash which serves as a decentralized proof of a unique asset on the blockchain. The process of converting unique asset data into a cryptographic proof is called "certification". Tokens that hold these cryptographic proofs are thus called certified tokens.

The Xcert protocol provides a mechanism for converting the main data object into a cryptographic hash. The mechanism first flattens the JSON structure and sorts data parts by JSON keys. Values are then hashed into Merkle tree leaves

using the sha256 algorithm and finally calculated into Merkle tree root hash which represents the actual asset proof which we store in the Xcert.

The certification process starts by creating asset data objects. The main data object is then converted into a cryptographic proof. When the certification is completed, the issuer sends the main JSON data object over an arbitrary communication medium to the holder, so he will be able to provide the proof of ownership for the particular digital asset.

All parties involved in the certification process are expected to keep a copy of the JSON data object, in the same way as they keep a copy of their digital wallet credentials. They can store this information locally or can authorize third-party dapps to do that on their behalf.

2.2.6. Verification

A cryptographic proof is an imprint of an asset which at the same time ensures asset data confidentiality. This proof is used to verify the existence and authenticity of a digital asset.

The 0xcert protocol allows for trustless verification of any kind of digital asset existence and related ownership. Anyone is able to verify some information based on digital asset imprint - the cryptographic proof - stored inside Xcerts on the blockchain.

In order to obtain valid information about a particular digital asset, a holder must disclose asset information to a third-party. If the proof is created by using the 0xcert protocol's mechanism, then not all the data are required in the verification process and a third-party can selectively verify only some asset fields. For this to work, a holder must provide enough information for the third-party to be able to recalculate the proof. When the recalculated hash equals to the one stored in the Xcert the information can be treated as valid and the holder can be trusted. A holder must also provide the appropriate Xcert smart contract address on the blockchain, where the digital asset exists.

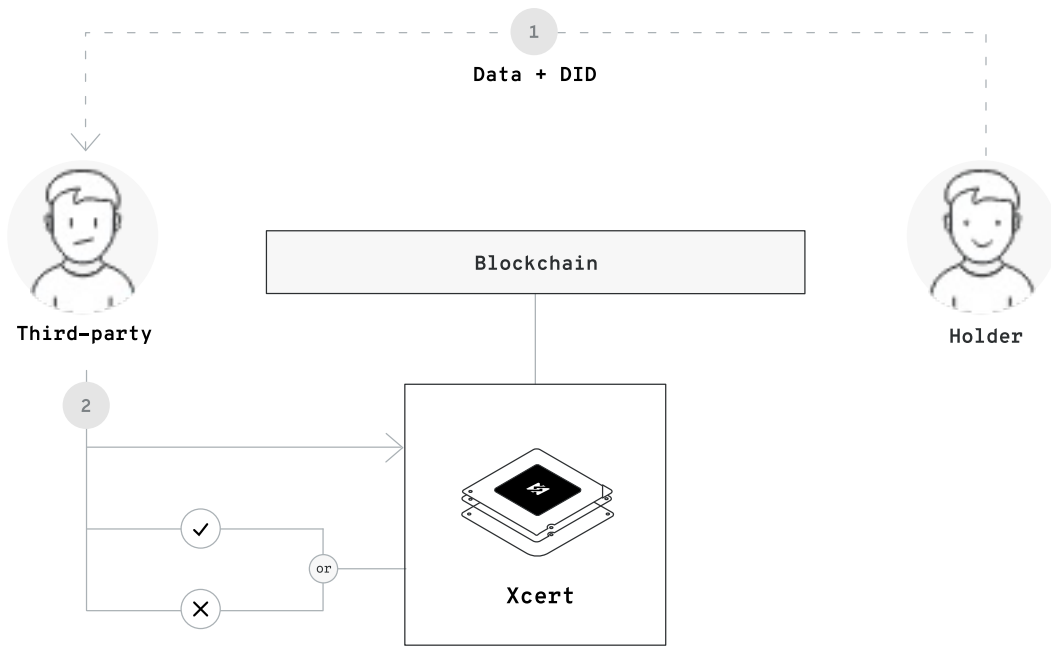


Figure 9: Xcerts carry a trustless proof of digital asset existence and ownership.

In terms of dapps, the verification process is usually automated. Some dapps might expect a holder to have the Xcert stored in his digital wallet. Holders are able to have all Xcerts stored in their digital wallets and share the proof of ownership with anyone at will. This enables a third-party to quickly and easily verify any provided information without unnecessary interaction.

3. Framework

The Oxcert framework consists of multiple parts which enable application developers to build secure decentralized applications with the support for custom business models. The Oxcert protocol is an opinionated all-in-one framework. It is blockchain agnostic, provides conventions, and includes powerful tools for building decentralized non-fungible applications.

In addition to the raw protocol logic, the Oxcert framework includes libraries and a set of smart contracts already installed on the blockchain. The Oxcert framework is a pluggable settlement with an advanced integration layer for different dapps and relay applications.

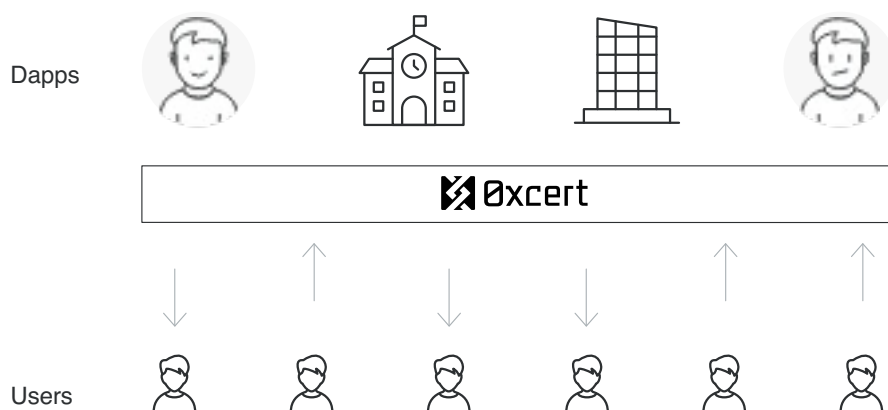


Figure 10: Dapps on top of the Oxcert protocol form a network of interoperable non-fungible services.

3.1. Devkit (SDK)

The framework tries to hide away the complex blockchain layer thus wraps the Oxcert protocol features into an easy to use SDK. This empowers developers with powerful decentralized tools that developers can use as a standard API library.

The 0xcert protocol can thus be easily integrated into existing systems. Applications don't have to struggle with the low-level blockchain complexity and can thus immediately start using a solid, secure and flexible non-fungible infrastructure that ensures interoperability between dapps by default.

3.2. Decentralized Exchange (DEX)

DEX is one of the key supporting components in the 0xcert framework. DEX represents a set of smart contracts installed on the blockchain which allow for a trustless exchange of multiple different types of fungible and non-fungible tokens as single atomic operations.

DEX consists of multiple contracts. To make it upgrade-able the smart contracts communicate through proxy smart contracts. This way we can upgrade the core DEX contracts while data stay untouched.

A proxy is best explained as a smart contract that allows or rejects access to some key functionality and is controlled by a multisig wallet or a DAO. This way proxies can be trusted since they only allow access to smart contracts that were approved through the DAO process.

The DEX process of exchanging tokens has several steps:

- Parties come to an off-chain agreement that party A will exchange fungible and non-fungible tokens with party B.
- Party A creates claims (blockchain signed messages) of the agreed data then sends these data together with claims to party B.
- Party A allows the proxies to transfer tokens on his/her behalf.
- Party B also allows the proxies to transfer tokens on his/her behalf.
- Party B submits the agreed data with claims to the swapper smart contract.
- The swapper performs an atomic operation which exchanges the tokens.

If any step of the process is not correct the swapper will not perform the operation. So if party B tries to change the data in a way that he/she would transfer less or different tokens the operation would fail because the claims would not match with the data party B provided.

3.3. Decentralized Minter (DXM)

DXM is another important component of the 0xcert framework. It allows for the trustless minting of Xcert tokens directly to recipients.

The DXM can mint and exchange Xcert tokens for other fungible and non-fungible tokens in a single atomic operation. It also enables an issuer to delegate the mint execution and payment of blockchain fees to the recipient.

DXM consists of multiple contracts. To make it upgradeable the smart contracts communicate through proxy smart contracts. This way we can upgrade the core DXM contracts while data stay untouched.

The minting of Xcert tokens using DXM is performed in multiple steps:

- Parties come to an off-chain agreement that the issuer will mint a specific Xcert for the recipient in exchange for some tokens.
- The issuer creates claims (blockchain signed messages) of the agreed data then sends these data together with claims to the participant.
- The issuer allows the proxies to mint the Xcert token on his/her behalf.
- The recipient allows the proxies to transfer tokens on his/her behalf.
- The recipient submits the agreed data with claims to the minter smart contract.
- The minter performs an atomic operation which creates a new Xcert token and transfers recipient tokens to the issuer.

If any step of the process is not correct the minter will not perform the operation. So if the recipient tries to change the data in a way that he/she would transfer fewer tokens the operation would fail because the issuer's blockchain signature would not match with the data the recipient provided. If the issuer or the recipient would not allow proxies to operate on their behalf the operation would also fail.

3.4. Continuous Integration

A smart contract cannot be changed after it is deployed to the blockchain. Changes can be applied only by deploying a new contract at a new address.

The protocol may include a decentralized governance (DAO) mechanism to allow the community to vote for improvements and possibly fork the protocol into multiple versions. The contracts may use protocol tokens to securely drive a decentralized continuous integration of updates with no disruption, while also protecting all the parties and stakeholders.

4. Protocol token (ZXC)

According to William Mougayar, author of "The business blockchain", a token is "a unit of value that an organization creates to self-govern its business model, and empower its users to interact with its products while facilitating the distribution and sharing of rewards and benefits to all of its stakeholders."

The ZXC tokens are the native utility tokens of the 0xcert protocol. These are fungible tokens and are compliant with Ethereum's ERC-20 standard.

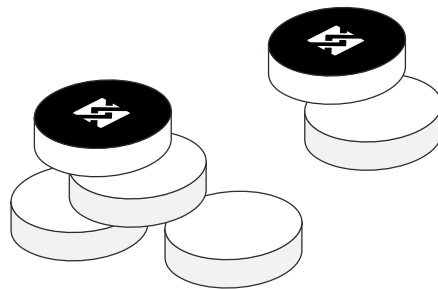


Figure 11: ZXC token is a native utility token of the 0xcert protocol.

The ZXC token is a protocol token and is introduced to align issuing parties with dapps and the community. With the infrastructure built around a system of smart contracts, its primary role is to provide the incentive mechanisms and to support the ecosystem with minimum possible fees. ZXC is the basic liquid asset for dapps that operate on the protocol. Similar to gas on the Ethereum blockchain the protocol token may play a role in all sorts of protocol activities.

Over time a decentralized governance may be introduced to further strengthen the 0xcert community. The protocol token may play a key role when creating a decentralized autonomous organization. The protocol token may not only be used as a rewarding mechanism but also as a distributed voting mechanism.

The 0xcert ecosystem may soon introduce issuer verification registry (IVR). It would be a form of a token curated registry proposed by Mike Goldin. The registry would list all issuers verified by the community. In the future, one of the fundamental problems in the blockchain space may become the authenticity of issuers. At the moment there is no strong incentive that would award fairness and honesty in the blockchain space. A self-sustaining verification registry which

would use staking and rewarding mechanisms based on the 0xcert protocol token seems like a good solution. Other solutions may be introduced in the future in order to protect our users and the 0xcert community reputation.

5. Oxcert Labs

The Oxcert team is determined to continuously bring value to the open-source community. Our mission is to empower developers with powerful tools and useful non-fungible applications.

We believe that we can only understand developers, the blockchain and decentralization if we actually use the protocol and build on top of it. We formed the Oxcert Labs as the Oxcert discovery group which will work on the latest innovations in the space of nonfungibility, decentralization and the blockchain.

In addition to the Oxcert protocol development, the purpose of the Oxcert team, as the core team behind the Oxcert protocol, is to provide a foundation for trustless, certified, non-fungible tokens on the blockchain and to manage and unify the community by connecting individuals and groups working in the area of non-fungibility and to provide resources and support for the related community driven incentives.

5.1. ERC-721 Implementation

We already successfully completed the complete implementation of the ERC-721 non-fungible token standard for the Ethereum blockchain.

The purpose of this implementation is to provide a good starting point for anyone who wants to use and develop non-fungible tokens on the Ethereum blockchain. Instead of re-implementing ERC-721, developers will use this code which has gone through multiple audits and we hope it will be extensively used by the community in the future.

5.2. Oxcert Scanner

The Oxcert team provides and manages an online Oxcert Scanner dapp. It enables a live view of the Oxcert network. This represents the central hub for non-fungible tokens on the blockchain.

5.3. 0xcert Identity

The 0xcert team will soon showcase identities as non-fungible tokens on the blockchain. This will be our first big use case which will show the community the enormous potential of this new technology.

5.4. 0xcert DEX

The 0xcert team is already working on a decentralized application on top of the 0xcert protocol for exchanging fungible and non-fungible tokens.

5.5. 0xcert DXM

The 0xcert team is already working on the first all-in-one decentralized application on top of the 0xcert protocol for minting Xcerts and other non-fungible tokens.

6. References

Non-fungible Token Standard

<https://github.com/ethereum/EIPs/blob/master/EIPS/eip-721.md>

Decentralized Identifiers (DIDs)

<https://w3c-ccg.github.io/did-spec/>

Cryptographic hash function

https://en.wikipedia.org/wiki/Cryptographic_hash_function

Cryptocurrency wallet

https://en.wikipedia.org/wiki/Cryptocurrency_wallet

Metadata

<https://en.wikipedia.org/wiki/Metadata>

GDPR

<https://www.eugdpr.org/>

JSON RFC-7159

<https://en.wikipedia.org/wiki/JSON>

Digital asset

https://en.wikipedia.org/wiki/Digital_asset

JSON Schema

<http://json-schema.org>

JSON-LD

<https://json-ld.org/>

HTTPS protocol

<https://en.wikipedia.org/wiki/HTTPS>

Link header

<https://www.w3.org/wiki/LinkHeader>

ERC-721 Standard

<https://github.com/ethereum/EIPs/blob/master/EIPS/eip-721.md>

ERC-721 Implementation

<https://github.com/0xcert/ethereum-erc721>

What is ERC-721

<http://erc721.org/>

Decentralized autonomous organization

[https://en.wikipedia.org/wiki/The_DAO_\(organization\)](https://en.wikipedia.org/wiki/The_DAO_(organization))

Token-Curated Registries 1.0

<https://medium.com/@ilovebagels/token-curated-registries-1-0-61a232f8dac7>