Non-fungible Mutable Token: Enabling and Protecting Mutability in NFTs

An NTF extension to provide regulated mutability to NFTs

PhD of National Interest in Blockchain and Distributed Ledger Technology, Cycle 38 – 2022/2023 – Social System and Smart Societies Curriculum

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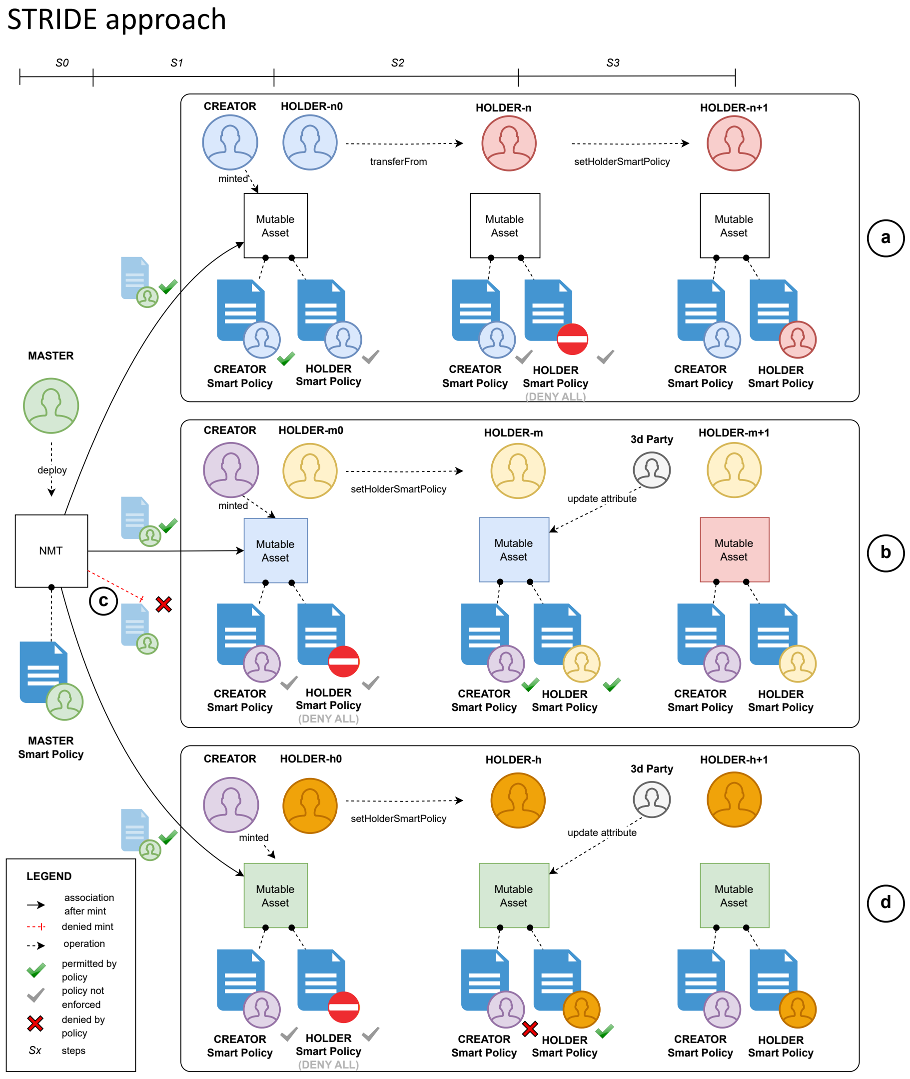
1 INTRODUCTION

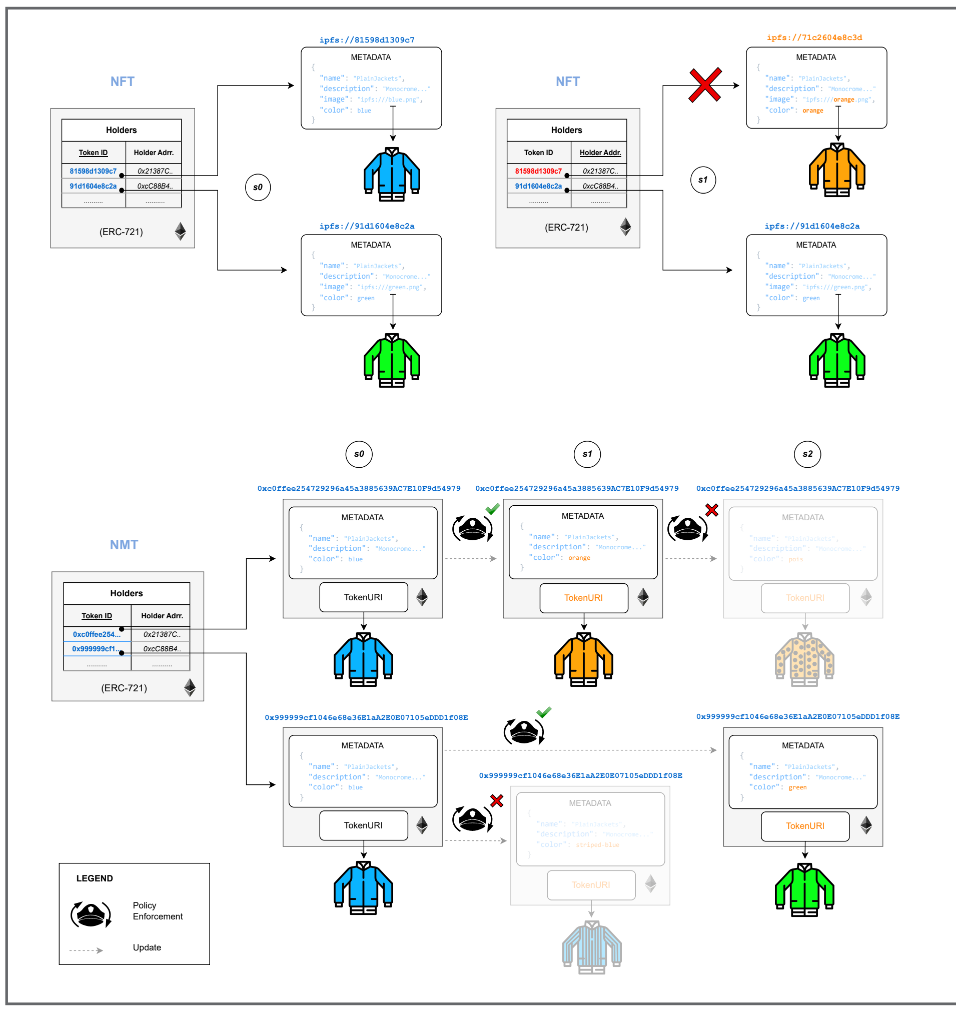
Traditional Non-Fungible Tokens (NFTs) are valuable for securely managing digital assets, uniquely identifying them, and enabling ownership transfer. However, NFTs cannot represent **mutable assets -** those whose characteristics evolve over time - without compromising uniqueness. This research introduces **Non-Fungible Mutable Tokens (NMTs)**, which address this limitation by **enabling asset attribute updates -** NMTs support lifecycle changes to asset attributes while maintaining uniqueness and security, **implementing access control** - using an XACML base Attribute-Based Access Control (ABAC) model. NMTs regulate operations such as minting, ownership transfer, and updates.

2 METHODS

- **NMT formalisation**: definition of a general architecture implementing the NMT approach, consisting of a set of base smart contracts.
- **NMT protection**: definition of a full protection mechanism to control changes on mutable assets, where all the operations that can be executed on mutable assets during their life cycle, including minting, ownership, transfers, and attribute updates, can be regulated through proper access control policies.
- **NMT validation**: discussion of two use cases focused on the Metaverse, Wearables and Digital Event Ticket; definition of complex policies for regulating the updates that can be executed on those mutable assets; cost evaluation for deploying all the smart contracts and executing the main operations from the general architecture and exploiting of the complex policies defined.
- **NMT Security analysis**: presentation of a detailed security analysis following the STRIDE approach



NMT actors, operations, and Smart Policies illustrated in four use cases: a) minting, transfer, and Holder Smart Policy setting of a mutable asset; b) minting, Holder Smart Policy setting, and attribute update of a mutable asset; c) denied minting: d) minting, Holder Smart Policy setting, and denied attribute update of a mutable asset.



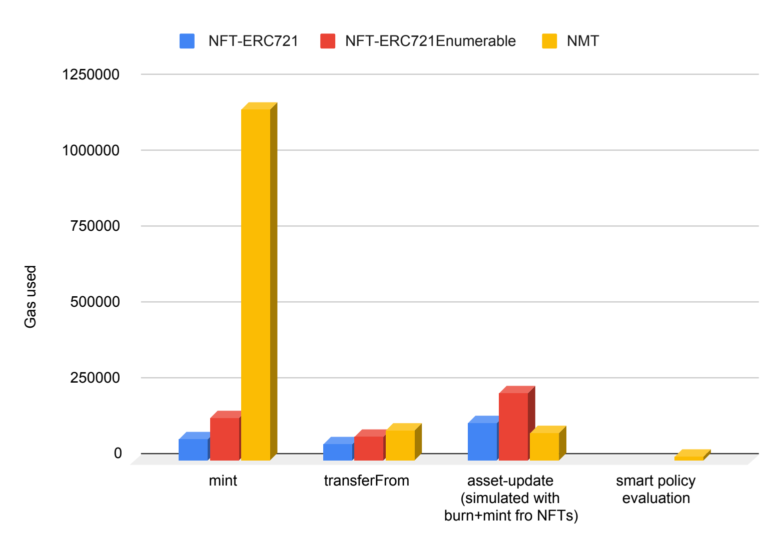
***a)** Representation of a wearable asset with NFTs. Case (s1) shows how standard NFTs are constrained by using the hash of the asset content as link to the asset itself, as any change to the asset content invalidates the hash linked in the NFT.*

***b)** Representation of a wearable asset with NMTs. Cases (s1) and (s2) illustrate how NMTs overcome the NFT limitation by using as token ID a smart contract address and by controlling changes through policies.*

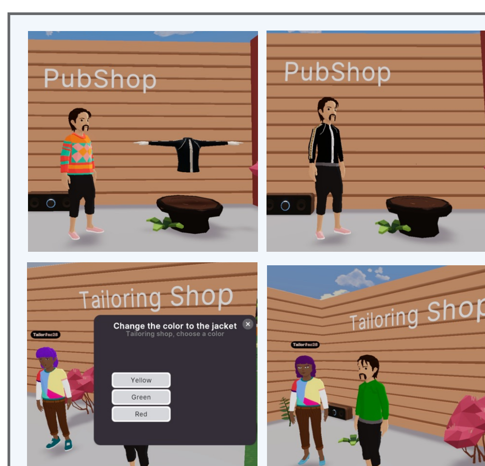
Comparison of standard NFTs and NMTs when updating attributes of a wearable asset.

3 RESULTS

The results of the set of experiments conducted on the two use cases showed that the cost of creating and managing mutable assets with the NMT approach heavily depends on the underlying blockchain. For instance, on Polygon all the operations on the two use cases cost less than one USD cent. Instead, on Ethereum, deploying our approach for managing the Wearable Mutable Asset costs around 66 USD, which is affordable since this operation is executed only once, independently on the number of jackets that are created. Creating a new Wearable Mutable Asset costs around 27 USD, which can be considered affordable or not depending on the cost of the asset. If we suppose that our approach is meaningful to be adopted in case of high-fashion garment (which cost several hundreds of USDs), the creation cost can be considered affordable. The operation to change the colour of the Wearable Mutable Asset costs around 2.5 USD, which is an affordable cost as well. A similar discussion holds for the Event Ticket Mutable Asset. Comparing the costs of executing the main operations of a mutable asset in the NMT approach with the cost of performing/emulating similar operations on a standard NFT, it can be noted that, minting a new NFT is significantly less expensive (one order of magnitude) compared to minting a new mutable asset in the NMT approach. This difference arises because, in the NMT approach, a new smart contract is deployed for representing the new mutable asset, and this substantially increases the overall cost. The cost of transferring an asset from one Holder to another is quite similar for the the NFT and the NMT approaches. Instead, if an attribute of a standard NFT needs to be updated, the typical approach would be to simulate this by destroying (i.e., burning) the original NFT (i.e., transferring it to the Burn Address) and minting a new NFT with the new attribute value.



Comparison of gas consumption and costs for NFT and NMT transactions.



Decentraland scenes: an Avatar purchasing, wearing and changing the colour of his new jacket

4 CONCLUSION

This research provided an in depth description of the NMT approach, which is an innovative solution meant to overcome the limitations of the current NFT standard by allowing to represent mutable assets, i.e., digital assets which change over time. The NMT approach is innovative also because it is focused on mutable asset protection, by integrating a fine grained and blockchain based access control system allowing to protect mutable assets from undesired or malicious modifications, which could hinder or devalue the assets themselves. To this aim, the NMT approach leverages three access control policies which regulate the right to execute all the operations defined to update the digital assets. The NMT approach could be extended in several ways. An interesting research direction concerns the portability of NMTs across distinct blockchains and distinct metaverse protocols. In this way, for instance, a given wearable could be transferred from Decentraland to The Sandbox, preserving all its attributes. A further enhancement could involve mutable assets that exist on several metaverses at the same time, where the updates that are made on one metaverse must be synchronised with the others. Finally, a further future work could involve the integration of Self Sovereign Identity and Zero Knowledge techniques in the NMT approach for supporting user privacy.