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ARTICLE 5

Digital Protocols as Accounting and Incentivization Mechanisms in Anti-Rival Systems:

Developing a Shareable Non-Fungible Token (sNFT)

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Acknowledgements:

This research received funding from the European Commission's EIC Pathfinder project ATARCA (Accounting Technologies for Anti-rival Coordination and Allocation), Grant No. 964678. We thank the consortium members for their support. We thank Timo Seppälä, Juri Mattila, Tomasz Mucha, and Kimmo Karhu for their helpful suggestions and efforts in compiling and editing the book.

Abstract

Decentralized ledger technologies (DLT), such as blockchains, have been primarily designed to facilitate the exchange of unique, scarce items. This paper presents an alternative decentralization protocol based on anti-rival goods, which gain value in repeated use and are not confined by scarcity. We explain the technical approach behind the concept, referred to as shareable non-fungible tokens (sNFTs), and illustrate our argumentation by presenting a pilot case on supporting the community of Streamr–an open-source, decentralized platform for sharing and streaming data. In addition to introducing this new token standard, we contribute to the discussion on the design of decentralized protocols and the growth of digital commons at large.

Keywords

Blockchain, Decentralized ledger technology, Anti-rival, Protocol, Digital commons

1 Introduction

Following the path laid out by Bitcoin, blockchains are commonly perceived as enablers of digital media of exchange in peer to peer (P2P) networks (Nakamoto, 2008). While decentralized ledger technologies (DLT) have been suggested to facilitate new types of economies (Gencer et al., 2018; Lovett & Thomas, 2021; Swan, 2015), the primary emphasis has been on establishing confidence among peers without a centralized authority through an immutable log of transactions (De Filippi et al., 2020). Accordingly, the attempts to develop the technology have followed along this path, e.g., by suggesting ways to utilize and enhance the smart contracts with different functionalities (Mattila et al., 2021; Rajala et al., 2018) or simply combining on-chain and off-chain transactions to reduce resource consumption in logging the exchanges (Hukkinen et al., 2019).[1]

However, surprisingly few proposals have challenged the inherent nature of economic exchange originating from the trade of physical resources. Digital technologies and infrastructures–including DLTs–are socio-technical systems (Nambisan et al., 2020) that reflect the whole society, its structures, and the economic rationale guiding their design (Mindel et al., 2018; Ostrom, 2005). Accordingly, the prevailing economic institutions, including ownership, money, and banking, have evolved to facilitate the structure of our global economy. Such models have been highly effective in describing markets for goods that are essentially scarce, often produced by tapping into a pool of exploitable, limited resources (like physical ones) (Ostrom, 1990). New, even radical, openings are needed that challenge our presumptions and the prevailing economic mechanisms in the design and development of economies based on purely digital goods.

This paper presents a promising approach to a DLT implementation that neither assumes nor requires artificial scarcity. Our insights are based on the work conducted in the ATARCA project, funded by the European Union's Horizon 2020 research and innovation program. The vision of the ATARCA is to *create new decentralized technology*, "anti-rival tokens," and scientifically founded *proposals for new policies* to enable efficient, decentralized, market-style *trading* and *ecosystems* for *anti-rival goods* to address these concerns.[2]

2 Background

A few key concepts are essential to the proposed vision. In particular, the discussions on anti-rivalry, efficiency, and economic systems and institutions provide the background for the vision. Overall, the vision challenges the orthodox economic assumptions and proposes new thinking to facilitate an anti-rival economy for digital goods.

2.1 Anti-rival goods and systems

For decades, economists and other scholars have differentiated between rival and nonrival goods. The basic principle is that rival goods lose value when consumed, whereas nonrival goods may be used repeatedly, without a loss of value (ATARCA, 2022). In Nobel laureate Elinor Ostrom's terms (2005), the value of rival goods will be subtracted upon use, meaning that their subtractability is positive. In contrast, several indications have been made that many digital or information goods have an "*anti*-rival" nature (Kubiszewski et al., 2010; Olleros, 2018). They differ from rival goods as anti-rival goods *gain* value when used, making their subtractability negative. Thus, the underlying economic principles for anti-rival goods are fundamentally different (ATARCA, 2022).

Contradicting the traditional economic thinking on rival resources, which lose value upon use, anti-rivalry focuses on the repeated and expansive use of resources (Weber, 2004). Following Weber (2004), we call these *anti-rival goods* and the incentive and accounting mechanisms that encourage value creation through anti-rival resource sharing *anti-rival systems*. As laid out in Table 1, anti-rival goods can be divided into "network goods," whose subtractability is negative, typically due to network effects, but that are excludable, and "symbiotic goods," whose subtractability is negative and that are non-excludable (Nikander et al., 2020). Notably, both subtractability and excludability are scales. Also, in many cases, the infrastructure on which the resources are handled affects the anti-rival properties of a good: e.g., if a sharing system has a significant transaction cost, a good loses its anti-rival characteristic (Olleros, 2018).

Of course, there are already several kinds of economic structures that are not based on exchangeability. For example, trust and interpersonal (and interorganizational) relationships can be used to organize anti-rival resources in small-scale communities (Barbrook, 1998; Ghosh, 1998). Large institutions can also set open-access

Table 1 The six types of rival, nonrival, and anti-rival goods

		Subtractability	
Excludability	**Rival**	**Nonrival**	**Anti-rival**
Excludable	Private goods (e.g. coffee)	Club/toll goods (e.g. museum visit)	Network goods (e.g. Fortnite)
Non-excludable	Common-pool goods (e.g. ocean fish)	Public goods (e.g. public beach)	Symbiotic goods (e.g. internet)

Source: Nikander et al. (2020).

policies for example in publicly funded research. Moreover, open-source software development has for decades been successful in facilitating anti-rivalry through collective efforts toward a shared goal (Weber, 2004).

However, the mentioned alternative systems have not been without limitations. The systems have either remained on a small-scale (based on interpersonal trust or an agreement of a limited set of actors), relied on institutional power (public funding or policies), or fitted for only some specific context (like open-source software). While there have been efforts in externalizing these structures for more large-scale and mainstream use, such efforts are predominantly prone to the so-called tragedy of commons (Hardin, 1982): failures of collective action happen when the participating entities use up a common resource for their individual gain, resulting in negative externalities and diminishing returns to everyone due to resource overconsumption (Greco & Floridi, 2004; Ostrom, 1990). Clearly, such alternative economic systems have not comprehensively resolved all of our economic systems' limitations.

2.2 Limitations of current economic systems

Our economic institutions, including ownership, money, and banking, have evolved to serve our global, *rival* economy well and the trade of most *nonrival* goods and services somewhat sufficiently. As more and more goods have transformed into digital format (Yoo et al., 2012), markets have failed and changed (Nikander et al., 2020; Nikander & Elo, 2019), and new legislation and new technology have been introduced.[3] However, neither of these have–so far–attempted to transform the underlying logics of value capture and value extraction (i.e., how the value is divided and distributed among the creator and user, respectively). As a result, these markets continue to fail; goods are distributed in an inefficient manner, and the systems might also contribute to increasing inequality.

Anti-rival goods do not fit traditional markets in which supply and demand depend on inherent scarcity. While it has been long argued that information resources need different strategies than other resources (Shapiro & Varian, 1998), efficient markets are still understood under the conditions of perfect competition; when supply and demand are at equilibrium at a market clearing price. However, for goods that have a very high first fixed cost of production, very low marginal cost, and low secondary fixed costs, existing market mechanisms work poorly (Mueller, 2008).

Consider a simple example of a digital resource: (a piece of) information. Thanks to its digital format (i.e., the bits representing the good), basically any holder of that resource can replicate it infinitely. With modern technology, the cost of producing additional copies of the obtained information or data is essentially zero (Weber, 2004; Yoo et al., 2012). This applies especially to anti-rival goods and is closely connected to the challenges of data markets (Koutroumpis et al., 2020; Nikander & Elo, 2019).

New approaches to anti-rivalry can address the problems of the two identified market equilibria associated with digital goods (Koutroumpis et al., 2020; Nikander et al., 2020): either *data is not produced at all,* or the *data is sold at its copying cost.* In terms of allocative efficiency, it has been commonly considered that consumer preferences are best met when consumers can access their desired digital goods at will, paying only the near-zero copying cost. Previous attempts in this field have often related to IPR (Intellectual Property Rights) laws to prevent unauthorized copying of digital goods (Landes & Posner, 1989); without proper structures, the initial production costs of digital goods cannot be covered, disincentivizing the creation of these goods. Hence, the prevalent mechanisms have relied on creating artificial scarcity, limiting the availability of the goods through legislation or technology, thereby leading 1) to, per se, lesser efficiency due to some parties not receiving a copy of the product and 2) to increased enforcement and technology cost. Past research has provided some conceptual models and anecdotal evidence on resolving such issues (Eloranta et al., 2019; Hakanen et al., 2022), while more work is needed (Nikander et al., 2020).

2.3 DLTs for anti-rival incentivization

DLTs and token systems enabled by DLTs provide fertile ground for experimenting and testing the concept of anti-rival tokens. Digital tools allow experimentation with concepts that may be hard to model, quantify, and measure in the analog world, such as anti-rivalry. As previously discussed, digital resources typically have a high marginal cost of production but a low cost of replicating, copying, or sharing. Thus, digital resources facilitate nonrival or even anti-rival characteristics if they are proliferated and shared openly, e.g., in free and open-source projects (FOSS) (Weber, 2004). However, this type of free and open sharing may not always fit the rivalrous market economy, and the anti-rival and nonrival resources are often converted to rival ones by introducing artificial scarcity (Hakanen et al., 2022), e.g., by adopting DRM (Digital Rights Management) technologies.

We contribute to the discussion of alternative economic institutions by presenting an approach based on anti-rival cryptographic tokens. These tokens exhibit anti-rival characteristics designed to capture (at least partially) the anti-rival value of the underlying system. These tokens can be "shared" in the same way anti-rival goods can be shared at minimal transaction cost. The tokens are used to represent quantified anti-rival value that can be accompanied by a qualitative description. In other words, they may function as a store of value or a unit of account that help us to understand *why* the users find those units valuable. The key difference to various other decentralization initiatives is that the tokens are designed to be shared instead of exchanged.

3 ATARCA project and the Streamr Community pilot

This paper is a conceptual article supported by illustrative evidence and results from the ATARCA project. Next, we shortly introduce one of the project pilot cases[4] and the technological approach behind the experiments.

The ATARCA project addresses the challenge of coordinating collective actions within a global digital economy. The focus is on creating cryptographically protected anti-rival tokens, testing their applicability to governing industrial data markets, and fostering cooperation in community-driven currencies. The project has defined three pilot use cases that explore novel incentive mechanisms to capture anti-rival value in different contexts. This paper will focus solely on the Streamr Community case while introducing the common technological approach behind all three pilots.[5] Streamr is a partner in the ATARCA consortium.

Streamr is an open-source platform that aims to create a global decentralized network for open but secure data transfer. The Streamr community members are connected by a shared social goal: the advancement and sustainability of the Streamr project. This goal requires not only technology development but also the *adoption* of it, i.e., use cases in different contexts that successfully adopt P2P technology developed within the Streamr project. Both code and non-code contributions from the community members are valuable for the project.

The Streamr community's underlying challenges relate to the limitations of information commons (de Rosnay & Stalder, 2020; Greco & Floridi, 2004). Open-source software projects or digital commons can also suffer from the "tragedy of commons" (Greco & Floridi, 2004; Hardin, 1982) – a scenario where the short-term benefits of individuals will decrease the value of the open-source community and eventually decay the whole system. In contrast to physical goods commons, information commons do not suffer from overconsumption; they instead become more sustainable through increased consumption due to network effects (Mindel et al., 2018). However, the tragedy of the information commons refers to the eventual collapse of the network when people only consume and no longer contribute to network maintenance (de Rosnay & Stalder, 2020; Greco & Floridi, 2004). These commonly noted challenges of collective action were addressed in the token and system design.

The leaders of the open-source software community (here, the Streamr team) have an interest in screening and protecting the community from low-quality proposals while fairly acknowledging the providers of high-quality efforts. However, the community leaders cannot truly know the future value of any specific contribution. Nor can the leaders know the true preferences of the community members; the screening process rather represents the vision of the leaders. In other words, there is a risk that the leaders are more likely to screen out and reject contributions that are not aligned with their personal views. Thus, open endorsements from community members can boost decentralization, increase transparency, improve coordination of effort, and enable more efficient allocation of resources within the community.

The main aim of the Streamr community pilot is to study and analyze a new incentivization model for reinforcing anti-rival feedback in the ecosystem that underlies the Streamr P2P platform. The specific interest is in incentivizing development contributions in both non-programming (participating in the discourse, sharing knowledge, etc.) and programming (writing and testing code). This experiment introduces a new type of a token that community members can receive and share with others who have also participated in the platform's development.

4 Technological approach: Token and system design

From the technological perspective, ATARCA is developing institutions and incentive systems that are based on cryptographic tokens. This paper presents a *new cryptographic token type*, titled *Shareable Non-Fungible Token* (*sNFT*),[6] which is a specific variant of the already well-known Non-Fungible Token (NFT). NFTs are cryptographical tokens that are unique (at minimum, the tokens have a unique serial number). The smart contract is defined so that each token is uniquely identifiable and separable from others, making the tokens non-fungible as a result. Also, a more specific variant, a *Shareable, Non-Transferable, Non-Fungible Token* (sntNFT), was developed in the project (ATARCA, 2022).

In the Streamr experiment, anti-rival tokens are bespoke cryptographical tokens defined by a smart contract. The identified tokenized incentives are intended to motivate and coordinate ecosystem stakeholders' activities toward the ecosystems' goals. In addition, the sNFT tokens are used to measure the community members' opinions about the desired path of technology development. The shareability of the tokens is an anti-rival feature that is a new protocol to be implemented for a DLT. These tokenized incentives are distinct to different scenarios.

The Streamr Community pilot features three token types build on top of the sNFT: *Contribution* token, *Like* token, and *Endorsement* token.[7] All of these have different mechanisms on how the token functions, incentives actions, and can be earned and utilized. Tokens developed in the Streamr pilot case have gone through a process of ecosystem design that was facilitated through a series of online workshops using collaborative tools (e.g., Miro boards).[8]

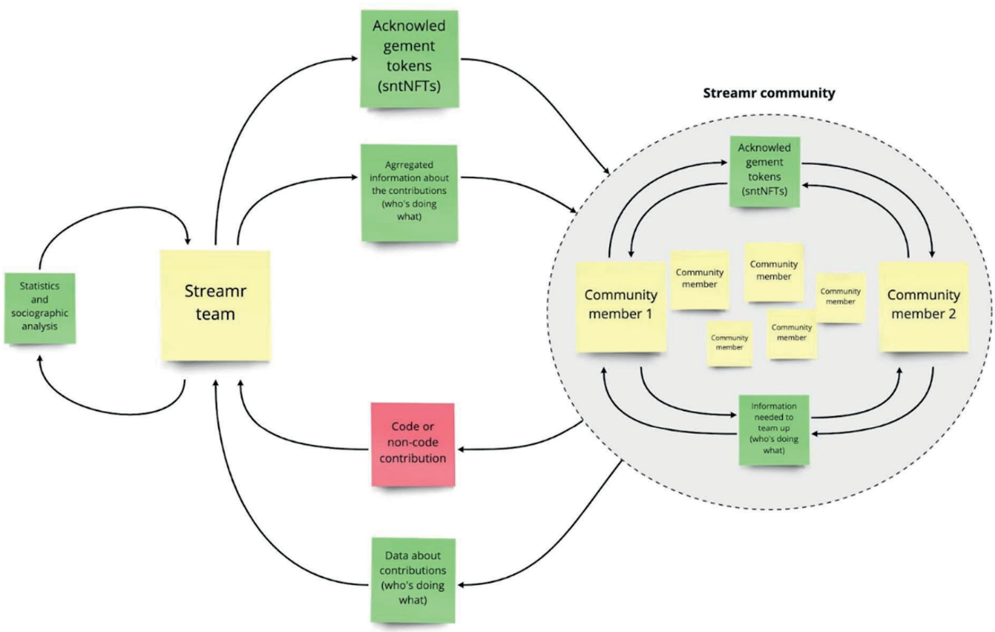
4.1 Mechanism design

Several constraints apply to the Streamr community case mechanism design. Mechanism design has been approached from both the macro and micro levels. On the macro level, we have mapped and reflected macro-level features in relation to sustainability drivers and factors of information commons (Mindel et al., 2018). On the micro level, we have approached the mechanism design and incentive compatibility with the game theoretical approach of a 2x2 game.

The mechanism design aims to actionalize the goals, rules, and incentives of the whole community. In this case, the ecosystem social goal refers to producing valid code- and non-code contributions. What constitutes a valid contribution is specific to the context of the Streamr community pilot experiment use cases. However, all of them should be thought of as an impactful contribution towards the social goal. To improve the sustainability of the digital commons (Mindel et al., 2018), the mechanism design system sought to define a reinforcing loop: the more members the community has, the better the quality of the contributions, the more valuable the community becomes, and the more members will be attracted.

Figure 1 maps and categorizes the value flows between the Streamr team (left-hand side) and Streamr community (right-hand side). Red notes represent flows of

Figure 1 Summary of value flows between the Streamr team and Streamr Community in the Streamr Community pilot. Green items indicate nonrival or anti-rival sharing; red item indicates rival exchange.



rival goods, and green notes flows of non/anti-rival goods. As demonstrated in the figure, self-reinforcing loops emerge between the Streamr team and the Streamr community and inside the Streamr community itself.

The mechanism design seeks to capture these value flows and their positive externalities to maximize the value of the community. The tokens should reflect the identified value flows and actionalize these as tokenized incentives. In the context of anti-rival tokens, incentives are non-monetary, merit-like, and, by definition, 'eternally owned' by their receivers. The shareability function of the sNFT means that Streamr community members who receive a Contribution token are able to share the credit and acknowledge their collaborators essentially by minting a copy of their Contribution token with reference to the original token and appended metadata of the co-contribution, denoting that their contribution has been influenced, affected or contributed to by someone else's contribution. Lastly, a community member can voice their opinion about what contributions they see as valuable by issuing a Like token, or an Endorsement token, given that they already have earned Contribution tokens. These mechanisms help to highlight the merits of a specific contribution (or a Contribution token).

In addition, a linkage between off-chain and on-chain information is utilized to enrich the data stored in the tokens and the DLT. Awarded on-chain tokens are connected to the off-chain metadata to provide further qualitative details of a specific contribution. Metadata is designed to contain information about the type of contribution, e.g., code/non-code, other categorization, receiver (nickname) of the token, a brief natural language description of the contribution itself, and a link to the contribution when possible. When combined with informed consent to release and access metadata, such an approach enables compliance with the general data protection regulation (GDPR), such as the participants' right to be forgotten.

4.2 Token design

DLTs and programmable smart contracts enable us to experiment with new types of digital tokens. Our choice of a DLT platform for the token development has been motivated by its extendability, maturity, and availability of development resources. In the pilot experiment, we have chosen to use NFTs. This choice came from the need to be able to differentiate the tokens from each other and from the need to associate metadata to them when applicable.

The Streamr pilot has different types of NFT tokens in play with different requirements. These tokens have a unique requirement–shareability–which has a different meaning and different implementation depending if the token allows permissioned or open sharing. Shareability is a generic term that can take various forms. For example, one can "share" a digital resource by making a copy of it and by giving it away (share a file), or by agreeing to take turns using one (share a Netflix account with a friend), or one could share a physical resource by giving away a fraction of a whole (share a birthday cake). Thus, the meaning and nature of the sharing depend on its context.

We chose to design and develop tokens on Ethereum Virtual Machine (EVM) compatible smart contracts implemented with Solidity language. EVM is a quasi-turing complete state machine, limited only by the finite number of computational steps available during code execution measured in gas (Antonopoulos & Wood, 2018). Despite the computational limitations, this gives us ample room to explore new types of token implementations.

Current NFT standards do not define nor implement shareability and, hence, have neglected a rational functionality and requirement for any system. The starting point for our technical design and implementation work has been utilizing existing EVM-compatible token standards defining rival tokens, such as ERC-721 NFT "standard implementation" by OpenZeppelin.[9] We focused on removing or adapting elements that impose scarcity and prevent sharing.

We have approached shareability by defining a new Ethereum Improvement Proposal (EIP), EIP-5023.[10] It introduces a new interface that facilitates the creation of shareable NFTs by extending existing NFT contracts with the EIP-5023 sNFT interface (i.e., IERC-5023, Interface of Ethereum Request for Comments). It defines the basic building blocks for sharing – a function method of Share and an event Share. As the meaning of sharing varies between contexts, we believe that the sNFT interface is a valid representation and improvement to current token standards. It leaves the exact implementation of sharing to be handled by its users. At the same time, it enables interoperability between smart contracts as developers can trust that token contracts that use the given interface will behave as defined.

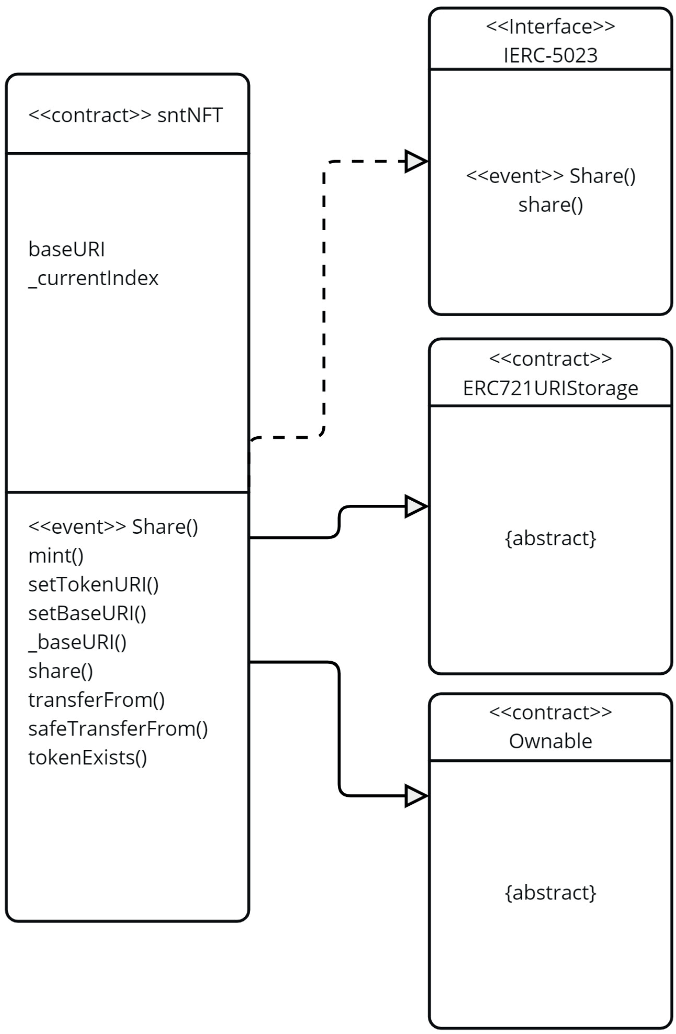
Figure 2 sNFT interface definition

```
/// Note: the ERC-165 identifier for this interface is 0xded6338b

interface IERC5023 is IERC165 {

  /// @dev This emits when a token is shared, reminted and given to another wallet that isn't function caller

  event Share(address indexed from, address indexed to, uint256 indexed tokenId, uint256
derivedFromtokenId);

  /// @dev Shares, remints an existing token, gives a newly minted token a fresh token id, keeps original
token at function callers possession and transfers newly minted token to receiver which should be another
address than function caller.

  function share(address to, uint256 tokenIdToBeShared) external returns(uint256 newTokenId);

}
```

IERC-5023 share methods expect the function caller to pass two parameters, a wallet or contract address to whom she shares and a token ID to be shared. The function returns a new token ID for the new token minted from the given token and sent to the desired address. A shared event is expected to be emitted during the execution of the share method stating who has shared which token to whom and what is the token ID of the new shared token. Figure 2 summarizes the sNFT interface definition.

In the Streamr Community pilot, the sNFTs have been made *non-transferable* (sntNFT) by overriding transfer-related functions in the contract code. Transfer

Figure 3 The reference implementation of sntNFT



functions are internally usable in the contracts to facilitate token sharing and minting, but they do not allow transferring tokens away from contract users. The sntNFT contract implements the IERC-5023 interface by defining the share "event" and "function" methods. In the reference implementation and in Streamr pilot experiments' contracts, shareability means creating a copy of an existing NFT and giving that copy away at the contract level. This process of copying files the share event of IERC-5023 and a transaction event of IERC-721 contracts conveying that a share has happened and that a shared token has been transferred to a recipient. The events and their associated details are stored in the blockchain's transaction history as log records that can be queried at any time.

Figure 3 presents a UML (Unified Modeling Language) model of the reference implementation of sntNFT, a shareable, non-transferable NFT.[11] The reference implementation builds on top of OpenZeppelin's ERC721URIStorage and Ownable contracts that define NFTs that can have metadata and that contracts can have an owner.[12] The contracts that ERC721URIStorage inherits have been left out of the figure for readability.

4.3 Implementation and governance

The Streamr Community pilot implements and governs three adaptations of the presented token design. Endorsement, Like, and Contribution token contracts implement the IERC-5023 interface and define the sharing functionality in their own contracts. These contracts follow mainly the logic of reference implementation of sntNFTs portrayed in Figure 3. Contribution token contracts access control is set so that only selected members of the Streamr team can mint and transfer Contribution tokens to community members who have successfully contributed to the Streamr community (permissioned sharing). Metadata related to contributions and shared contributions is kept up to date off-chain in a centralized database during the pilot period. Only members who have received contribution tokens can share and re-share their tokens with other community members with the share functionality. Only members who have received Contribution tokens can use Endorsement tokens to support any existing Contribution tokens. However, Like tokens, which reference implementation resembles Endorsement tokens, allow any community member to use Like tokens to support any existing Contribution token (open sharing).

Sharing an Endorsement or a Like token indicates that a person has voiced or shared their opinion with the community by minting "a copy" of a Contribution token to themselves. The Contribution tokens are differentiated between 'original' (minted by the Streamr team) or 'shared' (minted by community members). The contracts for Endorsement and Like tokens query the status of Contribution tokens directly from the Contribution token contract. An Endorsement token has a copy of the Contribution token's metadata appended with a short message from the endorser. Like token does not contain metadata but refers to the Contribution token's metadata when queried. The contract tracks the Likes and Endorsements, and only one Like and Endorsement per wallet address is allowed per each Contribution. Token contracts are built on OpenZeppelin's ERC721Upgradeable token standard. Upgradeability allows the contract owner to change the contract behavior when required. For example, users are able to remove their Likes and Endorsements by burning the tokens they own.

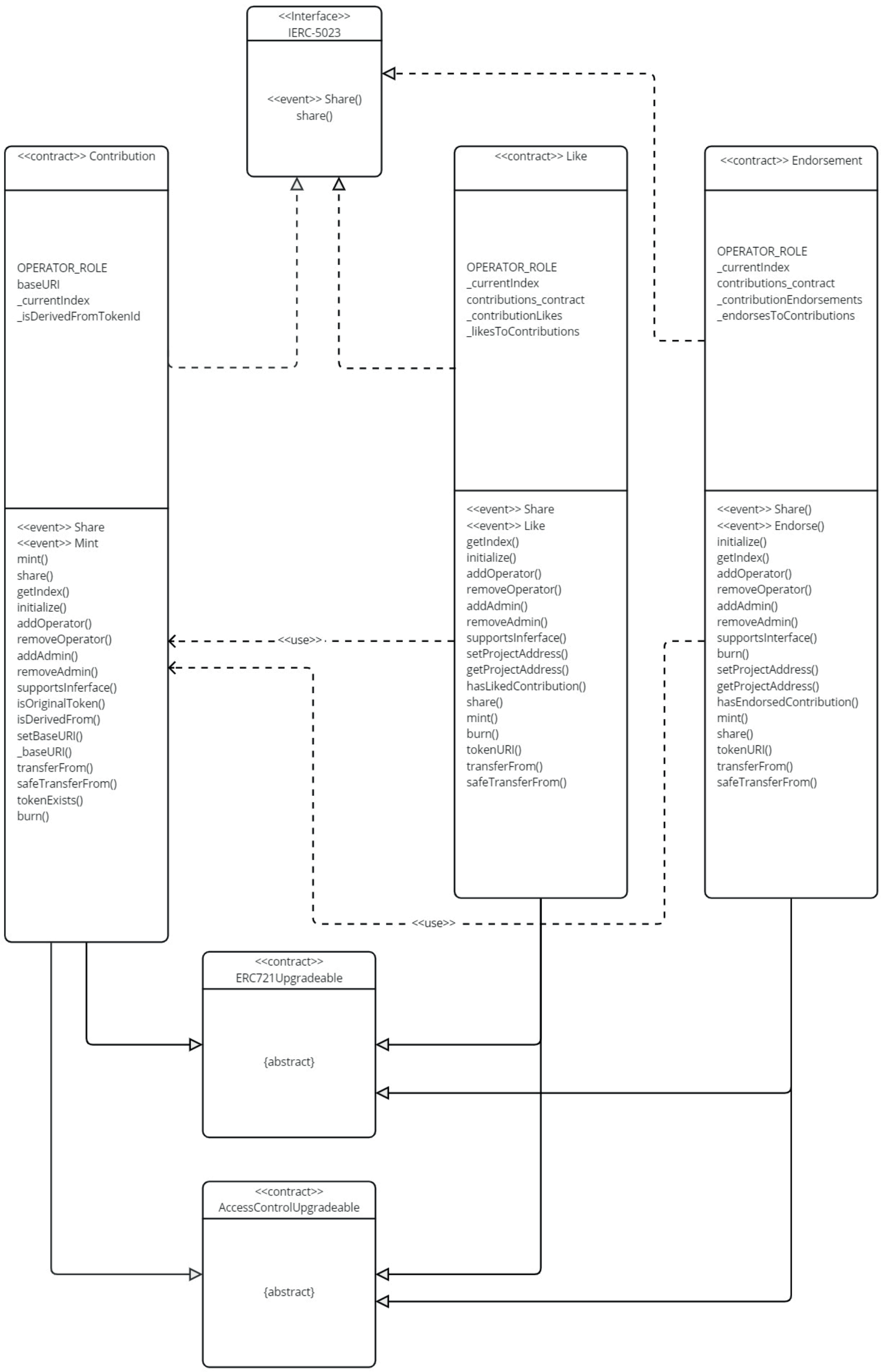
In the Streamr community case, the governance mechanisms are mostly centralized due to the nature of the pilot experiment. The consensus protocol, or the criteria for rewarding the primary Contribution token, is centralized to the Streamr team members responsible of the pilot experiment. The Streamr team establishes the criteria for rewarding a token, and each contribution is evaluated against the criteria. Any conflicts arising in the token system are resolved centrally.

There are different management and governance mechanisms underlying the sNFT tokens. In general, only the owners of the relevant token contracts–selected members of the Streamr team and the research personnel–are allowed to mint and transfer tokens to appraise member contributions. Once Contribution tokens are minted and transferred to their recipients, they cannot be exchanged or transferred away. However, the receiver of a Contribution token can share and transfer it to new owners. Anyone can mint a Like token to themselves as long as the corresponding contribution token continues to exist. Endorsement tokens can only be minted if the minter has an existing Contribution token on her wallet. Like and Endorsement tokens are always linked to a contribution token, thereby maintaining the connection to the original contribution and keeping a record of a growing network of community preferences. Figure 4 shows a UML representation of Contribution, Like, and Endorsement token contracts.

5 Implications

The aim of this paper is to showcase the potential of designing anti-rival systems. The ATARCA project has addressed the issues of open market valuation and the structural disparities in the digital goods and data markets. We believe that such work is needed, as it addresses the root causes related to the market failures of data economy (Nikander & Elo, 2019), poorly working or nonexistent markets for industrial data (Koutroumpis et al., 2020), and many existing data markets reducing to effectively near-zero price (Nikander et al., 2020). In this paper, we focused on how can the crypto-economic mechanisms be used to incentivize the production of anti-rival goods. We have illustrated this work through the process of appraising code and non-code contributions in the Streamr community.

Figure 4 UML model of Contribution tokens, Like tokens and Endorsement tokens contracts



5.1 Token valuation

None of the tokens in the Streamr Community pilot hold any direct monetary value. The main purpose of the tokens is to document the activities and inputs performed by the community members. Hence, they visualize the process leading to an outcome, while enabling a coherent history of previous and linked contributions toward a certain target. Moreover, they provide insights on the views, hopes, and preferences of the community members.

The described system utilizes different instances of the sNFT protocol (Contribution, Like, and Endorsement token) to appraise the work and activities conducted within the system. The transferability of these tokens has been disabled by choice in the design of the incentive mechanism (hence the notion of non-transferability, or sntNFT). This prevents a monetary exchange of these tokens and speculation towards a financial reward, which is found to be a common issue in cryptocurrencies (de Rosnay & Stalder, 2020; Kher et al., 2021). Hence, the approach differs from the predominant view on the design of decentralized protocols that has focused on the tokenization of value in an effort to produce scarce accounting units to be exchanged (Hakanen et al., 2022).

Nevertheless, contribution and endorsement tokens are expected to hold indirect value and capture at least some of the positive externalities arising in the community. Tokens are expected to derive value from the functionality of the Streamr project and from the interaction and information sharing within the community. Further indirect value can be achieved if these kinds of tokens are later used in other domains outside the Streamr ecosystem. Possible use cases include the acknowledgment of open-source community contributions or the creation of meritocratic governance mechanisms in other decentralized open-source projects.

5.2 Research implications

In this paper, we reflected on the current and evolving understanding of the potential of using crypto-economic mechanisms for incentivizing the production of non-/anti-rival goods, especially in ways that omit the need for artificial scarcity. Moreover, we illustrated how digital tools and infrastructures align the creation and sharing of value with anti-rival and nonrival goods. We modeled their impact on alternative incentive mechanisms while creating new types of crypto-economic tokens to capture (some of) the value of network externalities in digital communities (cf. Karhu et al., 2021).

The consortium has sought to reconsider the foundational structures and institutions of our economic systems, many of which are based on concepts that predate the modern era–such as accounting, ownership, private property, money, and banking.

These concepts still shape the contemporary approaches to our economic models, with the implication that the notions of ownership and exchange are often considered an inseparable components in all economic systems, including cryptocurrencies. However, such tendencies have implicated that new approaches were required to facilitate a global economy for digital goods.

Digital information goods deviate from prevalent economic models because they are inherently nonrival (maintaining their value when copied) (Mueller, 2008; Olleros, 2018; Shapiro & Varian, 1998). They are goods with a very high fixed cost of production for the first unit but a very low marginal cost and low secondary fixed costs for the secondary (replicated) units. Moreover, many digital goods and infrastructures have anti-rival characteristics (increasing their value with shared use) (Olleros, 2018; Weber, 2004). For example, the value of an item, such as a piece of software, often increases as more people use the software (Weber, 2004). Thus, the existing market mechanisms work poorly in describing the transaction of digital information goods. New mechanisms are needed to create proper incentive structures to cover the initial production costs of digital goods for more sustainable and efficient digital economies.

In addition, this work highlights a novel avenue for advancing work on collective action and decentralized communities. The technological protocols presented here provide concrete mechanisms to document the work, for instance, in networks or ecosystems without formal hierarchical structures (Autio et al., 2018; Eloranta et al., 2019). More broadly, our work provides an interesting tangent to exploring independent and autonomous agents motivated by a system-level goal, also known as "meta-organizations" (Gawer, 2014; Gulati et al., 2012).

5.3 Managerial implications

We see that the sNFT token and its practical use cases have the potential to be analogous to the manner in which Bitcoin implementation (Nakamoto, 2008) allowed a broad instantiation of blockchains and cryptocurrencies (Swan, 2015). A notable difference is that, while the value of Bitcoin is based on and confined to an artificial scarcity, the value of the sNFTs will be based on visualizing the underlying human relations, efforts, and the value of different interactions. The value of sNFT tokens reflects how relationships and contributions are developed over time through repeated interactions, benefiting all members and various aspects of the community (Barbrook, 1998; de Rosnay & Stalder, 2020; Hakanen et al., 2022; Weber, 2004). Thus, sNFTs can serve as a metric of value, a medium of sharing, and even a store of credit.

We believe that the crypto-economic mechanisms illustrated with the Streamr Community pilot use case are applicable and generalizable to other Web3 communities. We expect that the technology can facilitate an industry-wide contribution of acknowledging positive contributions beyond the scope of this pilot while addressing (some) of the issues in digital commons (Greco & Floridi, 2004) across the FOSS industry (Weber, 2004).

From a managerial perspective, the monetization of digital goods commonly relies on controlling access rights. In many cases, such policies diminish the benefits and value potential of virtually zero copying costs associated with digital resources (Olleros, 2018; Weber, 2004). Yet, if the data access were completely free, creators of these information resources would have limited incentives to invest in creating and providing the good in the first place (Mueller, 2008; Nikander & Elo, 2019; Shapiro & Varian, 1998). Shareable or anti-rival goods and network externalities likely remain outside the traditional market transactions due to limitations in accounting or rewarding for the generation of anti-rival values. The development of anti-rival tokens and a new distributed ledger accounting system enables one to measure, record, and appreciate the anti-rival value and positive externalities.

6 Limitations and further research

This paper is an early attempt to contribute to the design and modeling of digital protocols supporting anti-rivalry, with potentially important implications for the literature on economic institutions. However, more work is needed to provide a deeper understanding of the economics of digital goods (Autio et al., 2018; de Rosnay & Stalder, 2020), especially at the infrastructural level (Mindel et al., 2018; Olleros, 2018). Herein, we agree with the calls for research on allocative inefficiencies, new types of quantified value, and new institutionalisable means of shared and collaborative governance (Koutroumpis et al., 2020; Lovett & Thomas, 2021; Nambisan et al., 2020; Nikander et al., 2020). We also call for further research on increasing and capturing of positive externalities enabled by the circulation of anti-rivalrous community currencies.

Endnotes

1 Several initiatives have been proposed, see, for instance, "Monoplasma: A simple way to broadcast money to millions of people: https://medium.com/streamrblog/monoplasma-revenue-share-dapps-off-chain-6cb7ee8b42fa" or "Bitcoin Smart Contract 2.0: Trustless contracting by combining on-chain and off-chain transactions:" https://xiaohuiliu.medium.com/bitcoin-smart-contract-2-0-d1e044abed5a

2 ATARCA stands for Accounting Technologies for Anti-Rival Coordination and Allocation (EU H2020 Grant No. 964678), see https://atarca.eu for more details.

3 For instance, consider US Digital Millennium Copyright Act: https://en.wikipedia.org/wiki/Digital_Millennium_Copyright_Act or Digital Rights Management (DRM): https://en.wikipedia.org/wiki/Digital_rights_management

4 ATARCA pilots are referred to as: Barcelona Green Shops; Streamr Community Case; and Food Futures. See "Use Cases" at https://atarca.eu/ for more details.

5 For detailed descriptions and rationale behind the ATARCA pilot use cases, please refer to public project deliverables D1.1 and D2.1 at: https://atarca.eu/

6 ATARCA consortium's "sNFT" Ethereum Improvement Proposal was made public on Apr 15, 2022, and accepted on Jan 3, 2023, immortalizing it as part of the Ethereum project. The full description can be found at https://eips.ethereum.org/EIPS/eip-5023.

7 For a more thorough description, please visit: https://blog.streamr.network/streamr-awards-are-here-contribute-and-earn-unique-snfts/.

8 We utilized the anti-rival business design toolkit in this work. See: https://github.com/ATARCA/Anti-Rival-Business-Design-Toolkit/.

9 OpenZeppelin: The standard for secure blockchain applications, see: https://github.com/OpenZeppelin/openzeppelin-contracts

10 Reference implementation available on Github at: https://github.com/ethereum/EIPs/blob/master/EIPS/eip-5023.md

11 Reference implementation available on Github at: https://github.com/ethereum/EIPs/blob/master/EIPS/eip-5023.md

12 Details for ERC721URIStorage: https://github.com/OpenZeppelin/openzeppelin-contracts/blob/master/contracts/token/ERC721/extensions/ERC721URIStorage.sol and Ownable: https://github.com/OpenZeppelin/openzeppelin-contracts/blob/master/contracts/access/Ownable.sol

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