Participation by Design: Designing Incentives for Collaborative Economies in Local Communities

Irene Domenicale[1,2,*], Flavia Fredda[1,2,*], Emanuele Spadaro[2] and Claudio Schifanella[2]

[1]University of Camerino, International School of Advanced Studies, Piazza Cavour 19F, 62032 Camerino (Italy)
[2]University of Turin, Corso Svizzera 185, 10149 Torino (Italy)
[2]University of Turin, Corso Svizzera 185, 10149 Torino (Italy)

Abstract

The integration of blockchain technology into collaborative economies presents a transformative opportunity to empower local communities—conceived as systems built around shared goals and collective processes. This research explores how tokenomics can support civic engagement and community participation by introducing blockchain-based tokens as tools to manage access to resources and recognize individual contributions, with a focus on non-monetary incentive. Adopting an interdisciplinary approach, the proposal bridges socio-economic theory and blockchain system design. It identifies the specific needs of local communities and introduces a curated set of token-based artifacts and smart contract templates aimed at supporting the development and long-term sustainability of tokenized collaborative economies.

Keywords

Token Economy, Incentives, Toolkit, Collaborative Economies, Blockchain for Local Communities

1. Introduction

The integration of blockchain technology to enhance collaborative economies represents a transformative approach to empower local communities, intended as a closed system characterized by shared goals and collective processes. Collaborative economies, characterized by the sharing of resources and services, align well with blockchain's capabilities to foster transparency, trust, and decentralized governance [1]. The relevance of blockchain in the context of non-monetary exchanges is particularly highlighted by its tokenomics aspect, which addresses the system of value exchanges allowing for the creation and management of tokens that represent various forms of non-monetary value. The synergy between blockchain and collaborative economies is especially significant for small local communities [2], where traditional economic systems often fail to address the unique challenges and opportunities inherent in collaborative environments and where transparent systems for non-monetary value exchanges can enhance social cohesion and economic stability. Indeed, while blockchain has been extensively studied in the context of financial transactions and large-scale enterprise applications, its potential to revolutionize non-monetary value exchanges in small, collaborative economies remains largely untapped. Existing literature on this topic is sparse [3], highlighting a significant gap in understanding how tokenomics can enhance the efficiency, transparency, and sustainability of local sharing systems. Addressing this research gap will provide valuable insights and practical frameworks for leveraging blockchain technology to support and strengthen the economic and social fabric of local communities.

This proposal aims to address the following research questions:

- RQ1 What non-functional requirements are essential for designing a tokenized collaborative economy?
- RQ2 What types of incentives can effectively support the sustainability and engagement of such systems?

DLT2025: 7th Distributed Ledger Technology Workshop, June, 12-14 2025 - Pizzo, Italy
*Corresponding author.
irene.domenicale@unicam.it (I. Domenicale); flavia.fredda@unicam.it (F. Fredda); emanuele.spadaro@unito.it (E. Spadaro); claudio.schifanella@unito.it (C. Schifanella)
0009-0008-1955-8123 (I. Domenicale); 0009-0001-2528-3372 (F. Fredda); 0000-0001-7449-6529 (C. Schifanella)

- RQ3 What types of token-based artifacts are best suited for representing and implementing the incentive model?

This research provides several key contributions. Methodologically, it proposes an interdisciplinary framework that integrates socio-economic theories with the technical design of blockchain-based systems. In particular, it highlights the role of motivation theory and non-financial economic models as design principles for incentive mechanisms and token engineering within tokenized collaborative economies. A second contribution is the identification of context-specific requirements for local communities, intended to guide the design of tokenized systems and inform the development of non-monetary incentive structures that promote user participation. Finally, it develops and presents a curated set of tokens readily usable by local communities seeking to implement a tokenized system for a collaborative economy.

This paper is structured as follows: Sections 2 and 3 introduce the theoretical background and related literature. Section 4 builds on this by identifying system requirements and mapping key actors and needs. Section 5 explores suitable incentive structures, with a focus on non-monetary incentives. Section 6 presents a set of tokens that reflect these requirements and incentives, illustrating their application through concrete case studies. Finally, Section 8 offers concluding reflections and outlines potential next steps for future research and implementation.

2. Background

2.1. Blockchain for Local Communities

In recent years, there has been a growing proliferation of blockchain-based applications and experimental initiatives aimed at fostering social impact, promoting social good, and supporting sustainable development, particularly through the co-production of public services within the social domain [4]. Within this emerging landscape, our research investigates the potential of blockchain technology to support local communities by enabling systems that foster civic participation and facilitate alternative forms of value circulation within local economies. In contrast to traditional market-driven models, these applications prioritize non-monetary exchanges, mutual support, and community-driven approaches to resource sharing and cooperation [2, 5]. A distinctive feature of blockchain-based systems for local communities lies in their emphasis on participatory design processes and local accessibility, combined with their capacity to promote civic engagement. [6]. Concrete examples of these dynamics within local community contexts include decentralized systems for resource sharing (such as Libraries of Things), where everyday objects are lent and exchanged, fostering sustainable consumption and strengthening social ties. Additionally, blockchain systems can support mechanisms for recognizing and rewarding citizen participation, for instance through local tokens that can be exchanged for discounts, cultural event access, or shared space usage, thereby reinforcing engagement in local socio-economic life. Further applications include the transparent management of community-owned spaces and the development of incentive structures to promote sustainable tourism practices, where tour operators can encourage environmentally responsible behavior among visitors through token-based rewards.

2.2. Collaborative Economies

The field of collaborative economies encompasses a wide variety of different economic models and sectors, for this reason it is difficult to give an univocal definition [7]. It is necessary here to briefly address the different types of collaborative economies in order to clarify which applications will be considered for the present research. A general framework can be given by stating that collaborative economy platforms aim to match people who want to share assets and services [7]. The term collaborative economies is often associated with terms such as sharing economy, gig economy, platform economy, to name a few [8]. Part of this phenomenon has resulted in the commodification of social relations and the proliferation of extractivist digital platforms [9]; it is from this type of outcome that we intend to distance ourselves. Instead, we intend to consider for this research those models of collaborative economies oriented toward nonprofit and peer-to-peer transactions. These cases can be

defined as new socioeconomic models [10] and allow the redistribution of resources according to a logic of mutualization, which refers to the possibility of access to resources without implying the transfer of ownership [11**?**].

2.3. Motivation Theory

Another crucial aspect to consider in participatory contexts is the motivation of participants. To address this, we draw upon motivation theory to better understand what drives users engagement. Research in psychology has extensively examined human motivation, which encompasses the reasons behind our actions, desires, and needs, while traditional economic models often prioritize extrinsic motivations, particularly financial incentives. For this reason a more comprehensive understanding necessitates considering intrinsic and varied forms of motivation, as highlighted by Self-Determination Theory (SDT, [12]). SDT emphasizes the distinction between the amount of motivation and its orientation, recognizing that the underlying reasons for action are crucial, especially when examining behaviors like volunteering in non-profit organizations [13]. SDT differentiates between intrinsic motivation, driven by inherent interest, and extrinsic motivation, pursued for external rewards. Furthermore, SDT claims that social and environmental factors significantly influence intrinsic motivation, which is seen as an inherent human tendency that flourishes under supportive conditions. Cognitive Evaluation Theory (CET) [14], a sub-theory of SDT, specifies that social contexts fostering feelings of competence are key to enhancing intrinsic motivation through elements like optimal challenges and positive feedback. While classical perspectives contrasted extrinsic motivation unfavorably with intrinsic drive, SDT offers a more nuanced view, acknowledging that some forms of extrinsic motivation can be internalized and pursued with a sense of volition. In essence, understanding both intrinsic motivation, which involves engaging in activities for inherent enjoyment and fuels development, and extrinsic motivation, which is directed towards separable outcomes and is often influenced by social connections and the need for belonging (relatedness), is crucial for a more complete picture of human economic behavior [15].

3. Related Work

3.1. Incentive Mechanisms for Blockchain-based Systems

The work of Kim et al. [16], broadly categorizes the study of token economies into the economist's perspective and token engineering. The economist's perspective, exemplified by works like Catalini and Gans [17] and studies on mining incentives [18, 19], speculative investment [20], and platform usage [21], predominantly employs closed-form economic models. These models, while providing analytical rigor, often simplify the complex interactions between multiple stakeholders within tokenized ecosystems, even in studies incorporating dynamic elements [22]. In contrast, the token engineering field, as highlighted by Pazaitis et al. [23] and Dhaliwal et al. [24], emphasizes a systematic approach to designing token economies, prioritizing simulation-based modeling to capture the nuanced behaviors and interactions of diverse participants. Beyond these broad categories, research grounded in motivation theories offers valuable insights into the drivers of participation in tokenized systems. Restuccia et al.'s work on participatory sensing [25], while focusing on a specific application domain, provides a useful taxonomy of incentive mechanisms, distinguishing between application-specific and general-purpose approaches, and further categorizing the latter into game-theoretical and non-game-theoretical methods. Notably, their analysis points to the limitations of assuming perfect user rationality in game-theoretical models and suggests the potential of behavioral game theory (BGT) to better understand user behavior. Similarly, Hülsemann and Tumasjan's investigation [26] into prediction markets, utilizing agent-based modeling and drawing from the Token Classification Framework (TCF) and user motivation theory, empirically demonstrates the varying effectiveness of different token designs (cryptocurrencies, network tokens, investment tokens) in attracting and retaining users, highlighting the importance of non-monetary rewards for long-term engagement. Furthermore, the challenge of managing common resources within tokenized systems has been addressed by works like Kraner et al.'s [27], which applies tokenization to the "tragedy of the commons". This research argues that traditional monetary systems

are inadequate for addressing issues with complex, non-monetary dimensions like environmental impact, and proposes multi-dimensional tokens to incentivize self-regulation by aligning individual actions with the collective good. Their mathematical framework explores how this approach can deviate from traditional, potentially unsustainable, economic optima.

While the cited literature provides a strong foundation in understanding token economics, incentive design, and the role of user motivations, a noticeable gap exists. The majority of contributions tend to focus on either abstract economic models or specific application domains. There is a relative scarcity of research that specifically models and designs token-based incentive mechanisms tailored to the unique characteristics and goals of social collaborative economies within localized community settings.

3.2. Classification of tokens

Prior research on token economies has largely focused on the economic incentives and classifications of tokens, laying the groundwork for understanding their financial functions in blockchain systems. [28] provides an early framework categorizing tokens into asset, payment, and utility classes, whereas [29] offers a detailed taxonomy by proposing eight primary token archetypes and refining these through multiple dimensions such as purpose, technical layer, and aspects of trading and ownership. Similarly, [30] introduces both structural and behavioral classifications, highlighting token characteristics like fungibility and divisibility, and examining incentive mechanisms related to governance and financial inclusion. While these works note potential applications in areas such as healthcare, identity management and decentralized energy systems, they fail on explicitly addressing collaborative mechanisms.

In contrast to these works emerging studies are beginning to explore tokens in settings that emphasize collective and social benefits. For example, [31] reinterprets tokens as experimental units in a public goods game, where they serve as tools to study cooperation and community governance, while [32] investigates tokenization in cultural services with a focus on democratization of access, transparency, and community engagement. [33] further extends the discussion by applying a multi-dimensional token model to address the tragedy of the commons, suggesting that token-based mechanisms can contribute to sustainable, self-regulated outcomes. Additionally, [34] examines the impact of token incentives on information-sharing behavior, revealing complex interactions between intrinsic motivation and financial rewards.

Despite these contributions, several literature gaps remain. There is no structured comparison of token designs that promote cooperation, inclusivity, and participation in collaborative economies. Existing work focuses on financial mechanisms and ownership, neglecting non-financial incentives crucial for community resilience and public-goods funding. These gaps highlight the need for further exploration into token designs that support the collaborative and participatory governance mechanisms vital for local community development.

4. Local Community Requirements

4.1. Collaborative Economy Requirements

Table 1 presents a structured overview of the *Design* feature as a fundamental element in collaborative economy systems of local communities, organized into two primary design dimensions: *core objectives* and *operational attributes*. Under *core objectives*, three distinct value orientations are defined. The first, *social value*, underscores the function of the system as more than just a technical infrastructure. It functions as a social instrument that fosters trust and recognizes individual contributions within the community, highlighting how economic transactions are embedded in broader social relationships. In doing so, it challenges the notion of money as a neutral and isolated medium of exchange, instead framing value circulation as deeply intertwined with social dynamics and communal meaning. The second value orientation, *Collective Decision-Making*, involves participatory governance frameworks, allowing token holders or verified community members to vote on critical decisions such as feature development, allocation of shared digital or physical resources (e.g., community spaces, digital infrastructure) or updates to local usage policies. The third value orientation, *shared benefits*, refers to mechanisms that

Feature	Dimensions	Types
Design	Core Objectives	social value
		collective decision-making
		shared benefits
	Operational attributes	Continuity
		Interoperability

Table 1
Overview of the required design features in collaborative economy systems

redistribute the value generated by the platform back to its contributors. These benefits may take the form of periodic token-based dividends, access to exclusive services or tools, or increased governance weight, thus encouraging long-term participation and reinforcing a sense of shared ownership and collective gain.

The second dimension, *Operational attributes*, captures cross-cutting attributes essential for sustainable operation. *Continuity* highlights the importance of ongoing system evolution driven by user input, such as built-in feedback loops, community-led testing initiatives, or issue-reporting dashboards, which allow the platform to iteratively improve over time. *Interoperability* refers to the system's capacity to seamlessly integrate with external platforms and local infrastructures. This could include linking with municipal digital identity systems, embedding cultural event calendars from local institutions, or enabling authentication through existing civic apps. Together, these design components ensure that the collaborative economy platform remains context-aware, community-driven, and capable of adapting to the complex and evolving needs of local ecosystems.

Feature	Dimensions	Types
Participation	Incentives	Diversified
		Secure
		Rewarding
		Adaptable
		Calibrated
	Governance structure	Engaging
		Managerial
		Social

Table 2
Overview of the required participation features in collaborative economy systems

Table 2 outlines the *Participation* feature as a central pillar of local community collaborative economy systems, structured into two key sub-features: *Incentives* and *Governance Structure*. The *Incentives* dimension encompasses a variety of mechanisms designed to attract, recognize, and retain meaningful community engagement. A *Diversified* incentive system is necessary to account for the heterogeneous nature of contributions, ranging from knowledge sharing and peer assistance to resource provision and maintenance, by translating these actions into recognition forms such as badges, participation tokens, or access privileges. To preserve integrity and trust, these mechanisms must also be *Secure*,

relying on decentralized verification methods (e.g., cryptographic proofs, zero-knowledge attestations, or blockchain-based audits) that eliminate dependence on centralized gatekeepers. A *Rewarding* system further enhances participation by ensuring that all forms of engagement yield tangible benefits. To maintain long-term relevance, incentive mechanisms should be *Adaptable* flexibly in response to shifts in community priorities or needs, such as prioritizing collaborative design contributions during development phases or support services during rollout periods. Finally, incentives should be *Calibrated* to the singular citizen to emphasize sustained involvement over time, for example, through mechanisms that provide compounding rewards for ongoing participation.

The second sub-feature, *Governance Structure*, defines the participatory architecture through which collective decision-making and resource management are enacted. An *Engaging* governance structure enables shared ownership and accountability, potentially realized through decentralized autonomous organization (DAO) models or token-based voting systems. A *Managerial* component is equally vital, addressing the stewardship of shared community resources, digital or physical, by empowering members to curate, maintain, and evolve the communal offerings. This could involve roles such as resource coordinators, peer moderators, or maintenance task forces. Lastly, the *Social* aspect of governance involves creating communicative spaces, either through embedded community forums, chat integrations, or links with existing social platforms, where members can exchange feedback, deliberate on system proposals, and foster mutual learning.

Feature	Functional Categories	Types
Authentication	Privacy	Identity
		Data
	Attributes	Adaptability
		Scalability

Table 3
Overview of the required authentication features in collaborative economy systems

Table 3 presents the *Authentication* feature as a critical element in the design of local community collaborative economy systems, focusing on enabling secure, trustworthy access while preserving individual privacy and aligning with community-specific contexts. This feature is structured around two sub-categories: *Privacy* and *Attributes*.

Within the *Privacy* category, two core types are identified. The first, *Identity*, emphasizes the need for robust yet socially sensitive identity verification mechanisms. These may include the use of verifiable digital credentials, such as decentralized identifiers (DIDs) or digital wallets linked to national electronic identities (eIDs), as well as community-based verification models, in which existing trusted members vouch for new participants. This hybrid approach ensures both accountability and inclusivity. The second type, *Data*, addresses the ethical management of personal information. It requires strict privacy-preserving protocols to protect user data, ensuring that sensitive attributes, such as address, participation history, or token holdings, are not exposed, sold, or repurposed without explicit consent. Technologies such as end-to-end encryption, differential privacy, and zero-knowledge proofs may be employed to achieve these goals, reinforcing user trust and compliance with data protection regulations.

The second category, *Attributes*, pertains to the structural qualities of the authentication process itself. The first attribute, *Adaptability*, reflects the need for authentication methods to align with the cultural and operational norms of the specific community. For instance, in low-tech or tightly-knit local groups, in-person or offline verification (e.g., local assemblies, trusted peer introductions, or physical token issuance) may be more appropriate and acceptable than purely digital solutions. The second attribute, *Scalability*, acknowledges that the system does not require large-scale user onboarding typical of global platforms. Altogether, the *Authentication* feature balances technological rigor with human-centered

design, ensuring that access control supports both system integrity and community values.

4.2. Actors

Local communities are characterized by unique features that are not present in other web3 configurations. For instance, even though these systems are blockchain-based and digitally conceived, there is still a need for human roles. Defining distinct actors within a community is essential for designing effective tokens that achieve their intended purpose.

Actors are autonomous entities, such as users or software programs, that interact by sending and receiving messages. Within this specific context, these actors are designed and implemented to embody corresponding roles within the local community system:

- **Human Actor**
  - Token Issuer: a local community association responsible for designing, issuing, and managing the tokens. Humans here set policies and adjust parameters as needed to reflect community values and objectives.
  - Individual user: the community member who participates in local events, initiatives, or volunteer opportunities and ultimately earns tokens as recognition for their contributions.
  - Validator: trusted community members who verify that a token transfer or reward is justified (e.g., confirming a volunteer's contribution). Their endorsement adds a layer of trust and accountability.
  - Auditor: a human oversight team that reviews flagged transactions, handles disputes, and ensures that the system's operations align with community guidelines. They step in when automated systems detect irregularities or when nuanced judgment is required.
  - Smart Contract Administrator (Human Oversight): while the contract itself automates most operations, a human administrator is needed to manage updates, resolve issues, and adjust the system rules in response to evolving community needs.
- **Automated Actor**
  - Transfer Facilitator: a smart contract or mobile app module that verifies transaction conditions (e.g., event attendance via QR codes) and executes token transfers without manual intervention.
  - Benefit Distributor: an automated platform or interface that allows community members to redeem tokens for non-monetary benefits (like discounts at local businesses or event access). It validates token balances, applies redemption rules, and updates user statuses seamlessly.
  - Automated Audit Systems: software tools that continuously monitor and record transactions, flag anomalies, and generate reports.

4.3. Core Needs for Blockchain-Based Collaborative Economies in Local Communities

Based on the identified requirements, it is possible to delineate a set of core needs for local communities seeking to implement token-based systems in support of collaborative economies.

Role Differentiation: A foundational need lies in the ability to define and manage differentiated roles within the community. These roles shape the interactions and relationships that the token system is designed to facilitate. Accordingly, tokens may serve a range of functions—from enabling value exchange and granting access to services, to conferring governance rights. Crucially, the functionality of the token is contingent upon the broader economic logic adopted by the community. In the context of collaborative economies, this logic transcends market-driven principles to incorporate forms of reciprocity, redistribution, and non-market exchange [35], which are essential for fostering social cohesion and collective agency.

The present proposal identifies four essential roles commonly found within a local community context. These roles form a dynamic framework that each community can specify and adapt to reflect their particular needs, structures, and objectives.

- *Initiator*: Typically the community manager, this role is responsible for launching the tokenized collaborative economy and has the authority to assign roles to participants.
- *Association*: Community-based, non-profit organizations that offer services and organize initiatives to support the local social fabric.
- *Local Retailer*: Small businesses and commercial entities operating within the community.
- *Community Member*: Citizens who actively participate in the socio-economic life of the community.

Token Typologies Aligned with Community Values: Local communities require tokens that reflect a variety of use cases and value systems, including:

- Asset Representation: Tokens that represent tangible or intangible assets, designed to meet the circulation needs defined by values of the community and the collaborative economy purpose see 2.1 and 2.2
- Non-Monetary Incentives: Tokens functioning as drivers of participation, aimed at recognizing and motivating civic engagement through mechanisms that go beyond financial remuneration. See 2.3

Section 6 presents token types that can represent use cases aligned with the needs of a local community.

Tools for Initiate a Collaborative Economy: Given the technical complexity inherent in blockchain-based infrastructures, there is a pressing need for tools that facilitate both the initiation and long-term management of community systems. These tools must mediate between technical design and community engagement, supporting the early stages of organizational setup while also enabling processes of co-design, capacity building, and the progressive decentralization of governance.

For this reason, Section 6 presents a toolkit containing a repository of smart contracts designed to reflect the requirements for designing and implementing a collaborative economy in a local community. These smart contracts implement role-based logic and provide communities with a ready-to-use set of tokens to support the launch of their collaborative systems.

5. Incentives

Motivations can be classified into two main types, as mentioned in 2.3

- Extrinsic Motives: These arise from external rewards, such as financial compensation or material benefits. In this case, the primary driver is not the action itself but the anticipated outcome or utility. While extrinsic incentives are common and often necessary, they should not be the sole motivator.
- Intrinsic Motives: These stem from internal satisfaction and personal engagement with the work. Individuals driven by intrinsic motivation find meaning, enjoyment, or intellectual stimulation in their tasks, leading to personal growth and skill development.

Effective incentive design requires a diversified approach that addresses these different types of motivations. In motivation theory, an incentive is defined as anything that prompts an individual to act. The study of incentive structures is central to understanding economic activities, both at the level of individual decision-making and in the context of cooperation and competition within institutions [36]. Incentives can be broadly classified as positive (offering rewards) or negative (threatening punishment),

and they can motivate agents in various ways. Our aim here is to broaden the understanding of incentives beyond the specific application of cryptoeconomics, which focuses on designing incentives to encourage honest behavior within competitive environments, particularly in blockchain-based ecosystems. Tokens serve as one example of such economic incentives within blockchains [37]. As native units of value, they primarily incentivize the use and operation of the blockchain [38]. Building upon these foundations, this proposal focuses on positive incentives and distinguishes between monetary and non-monetary forms. Our goal is to identify the most effective ways to design incentives that resonate with these diverse types of motivations.

Monetary incentives involve compensating participants with a specific amount of tokens, which, in the given context, take the form of community currency. These incentives function as rewards and can be categorized based on their timing: input-based compensation, which is provided prior to task completion, and output-based compensation, which is granted upon fulfillment of a task. While such incentives predictably augment extrinsic motivation, their impact on intrinsic motivation is often detrimental. This phenomenon can be attributed to the crowding-out effect [39], wherein the introduction of tangible rewards shifts the motivation from inherent enjoyment or personal gratification to the external incentive, thereby undermining intrinsic interest in the activity itself.

Non-monetary Incentives This section proposes a classification of incentives, tailored for a local community context, that fall outside the monetary domain. Recognizing the inherent interconnectedness of intrinsic and extrinsic motivation, a clear dichotomy between non-monetary incentives and intrinsic motivation is not always discernible. Rather, certain incentives exhibit a stronger affinity with intrinsic drivers, while others appeal to both intrinsic and extrinsic factors. The latter category includes, for instance, access to resources or services offering tangible benefits, and gamification strategies that integrate the inherent enjoyment of an activity with external objectives such as the acquisition of collectibles or other forms of reward.

Another example of a non-monetary incentive strongly linked to intrinsic motivation is ”Contribution,” which can manifest as access to a voting system or membership privileges. This form of incentive directly addresses the fundamental psychological needs of autonomy, competence, and relatedness, as posited by self-determination theory. [12] We conceptualize ”Contribution” as a mechanism for recognition that serves as an alternative to traditional reputation systems, deliberately avoiding rating systems and instead focusing on the acknowledgment and valorization of the effective contributions made by individual participants.

Incentive	*Form*	*Example*
Monetary	Input-based Compensation	Airdrop, “Welcome reward”
Monetary	Output-based Compensation	Reward for a task
Non-monetary	Access	Resources, Services
Non-monetary	Gamification	Collectible
Non-monetary	Contribution	Membership, Voting

Table 4
Incentive Forms for Collaborative Economies in Local Community Context

6. Tokenization for Local Communities

In this section, we propose in details the incentive tokens engineered to foster engagement and value exchange within local communities, following the results found in Sections 4 and 5. We begin by delineating each token construct according to four dimensions: their functional category that delineates

the primary purpose of the tokens, on-chain characteristics that focus on the role-based conditions that shape token's design -such as minting, burning and transferability, incentive forms (based on Section 5 and [30]), and illustrative real-world usage scenarios. Thereafter, we present our open-source toolkit on GitHub, which implements these constructs, enabling researchers and practitioners to instantiate and evaluate token-driven ecosystems with minimal setup.

In the following use cases, we define a structured role-based framework for managing token functions within the community ecosystem. Each role is assigned to a particular component, defining clear responsibilities and privileges. With this organized approach, actions related to token management are performed only by designated participants who possess the appropriate authority.

6.1. Community Value Token

***Category*:** This token can be considered a form of community currency, designed to support collective goals within local social and economic contexts. Its primary purpose is to facilitate the exchange of services and resources that promote community well-being, mutual support, individual empowerment, and stronger local connections. A designated issuer creates and distributes these tokens (community coins), which can be exchanged among community members for goods, services, or shared resources. Issuers retain the ability to mint additional coins when necessary, in response to community needs or to provide specific incentives. In this way, community token function both as a medium for exchanging social value and as a monetary reward mechanism that encourages active participation and contribution within the local ecosystem.

***Characteristics*:**

- Base token standard: ERC20
- Open Transferability: this token can be transferred without restriction.
- Designed Tokenomics: The behavior of the token and its underlying economic model are critical design elements that should be collectively determined by the community.

***Incentive Form*:** Fungible token designed for use within a specific community, acting as both a medium of exchange. It can be considered a monetary incentive and incentive enabler: medium of exchange and unit of account.

6.2. Purpose Driven Token

***Category*:** This token is designed to support clearly defined social, civic, or environmental objective within a given ecosystem. Unlike general-purpose or purely speculative tokens, purpose-driven tokens are engineered to support mission-aligned behaviors, incentivize targeted actions, or facilitate access to resources that advance the goals of a community or initiative. This token serves as a means to recognize and reward community members for their engagement in collective actions. Its value proposition lies in transforming civic engagement from an often unrewarded effort into one that is acknowledged, incentivized, and empowering for participants. In this context, a specific association can issue a token tailored to reward a defined civic activity or to support targeted community initiatives. Through the definition of a Purpose Driven Token, it will be possible to define sub-communities (of citizens or associations or stores) identified by new roles, and it will be possible to establish within a smart contract the paths that the tokens can take, so that specific community initiatives can be implemented.

***Characteristics*:**

- Base token standard: ERC20
- Role-based Minting: The ability to mint tokens is assigned to specific roles—such as *Association* —who act as authorized issuers within the system.
- Role-based Transferability: this token can be transferred with some limitation based on the purpose of the case. It can be transferred from *minter* to *token holder*, but not between *token holders*.

***Incentive Form*:** Monetary incentive, output-based compensation. Fungible token designed for use within a specific community, serving as a mechanism to recognize participation in community activities. It functions as a an incentive driver by allowing participants to get rewards.

***Example scenario*:** A possible scenario involves the recognition of youth volunteering through token-based incentives. Young volunteers participate in civic activities organized by local associations and, in return, receive reward tokens in their digital wallets. These tokens are issued by a social cooperative responsible for educational initiatives on behalf of the municipality. Volunteers can then use a dedicated exchange mechanism to convert their tokens into digital coupons, which are redeemable at participating local businesses and cultural venues. This system not only acknowledges civic engagement but also strengthens the connection between youth, community services, and the local economy [2]. In this example scenario, the purpose driven token allows:

- to identify a specific group of citizens (the youth volunteers)
- to make only certain types of token transfer possible (from the association promoting the initiative to youth and from youth to shops)

Defining these sub-communities of users and transfer constraints within a smart contract allows for the implementation of specific spending circuits

6.3. Coupon

***Category*:** These tokens are issued in order to represent specific benefits as: discount vouchers for local goods and services; free access passes to cultural or community events; time-limited rights to use shared spaces (e.g., music rehearsal rooms, coworking areas). Once issued, the coupons can be distributed to users, who may then redeem them. Upon redemption—especially if the tokens are returned to the original issuer—they are considered "consumed" and cannot be reissued or recirculated.

***Characteristics*:**

- Base token standard: ERC20
- Role-based Minting: The ability to mint tokens is assigned to specific roles—such as *Association* or *Local Retailer*—who act as authorized issuers within the system.
- Open Transferability: this token can be transferred without restriction.
- Burnable Upon Use: Once a coupon is used to access the intended service or resource, it is burned, when it is transferred from a *Community Member* to the *Association* or *Local Retailer*

***Incentive Form*:** Non-monetary incentives, Access. Fungible tokens used to grant access to services or resources within a community. They function as incentive enablers, as they confer the right to utilize specific services or material resources.

***Example scenario*:** Community tokens (e.g., ERC-20), earned through civic participation or contributions to the community, can be exchanged for digital coupons. This mechanism incentivizes active engagement in the local socio-economic ecosystem, promoting both community participation and local economic circulation. For example, volunteers may use their tokens to obtain coupons issued by local commercial or cultural service providers. These coupons, which represent specific benefits or discounts, are redeemed in person by transferring them to the retailer's wallet [2].

6.4. Badge

***Category*:** It is an artifact—a unique, non-fungible token (NFT) recorded on the blockchain—used to certify the completion of a task. In a community context, this NFT serves to represent achievement and merit. Badges are verifiable proof of participation,confirming that an individual has carried out a specific activity, attended an event, or been present at a designated location.

***Characteristics*:**

- Base token standard: ERC721
- Role-based Minting: The ability to mint tokens is assigned to specific roles—such as *Association* or *Local Retailers*—who act as authorized issuers within the system.
- Role-based Transferability: this token can be transferred with some limitation based on the purpose of the case. It can be transferred from *Association* to *Community Member*, but once received, it becomes non-transferable.
- Unique Acquisition: A *Community Member* can only earn a specific badge once from the *Association.*
- Task-Based Acquisition: Badges are awarded upon the completion of specific tasks or task sequences, or as proof of presence at designated events or locations.
- Additionally, the badge can be designed with two possible functionalities:
  - Burnable for Additional Rewards: Users may choose to burn multiple collected badges in exchange for further rewards or benefits.
  - Collectible as Proof of Presence or Achievement: Alternatively, badges may serve as immutable proof of participation, presence, or task accomplishment, contributing to a user's reputation or history within the system.

***Incentive Form*:** Non-monetary incentive, Gamification. It can be considered as an incentive drivers by allowing participants to get rewards.

***Example scenario*:** A possible application of this token could be in the tourism sector, aimed at incentivizing visits to lesser-known locations and promoting sustainable tourist practices. In this scenario, local businesses and associations could collaborate to create a networked circuit, where each participating activity or site is part of a shared system. Tourists who visit one or more of these locations would receive a badge as proof of participation. Upon completing the entire circuit, tourists could gain access to additional offers, rewards, or experiences within the local area, thereby fostering both sustainable behaviors and local economic engagement.

6.5. Membership - Soul Bound Token

***Category*:** These tokens verify eligibility to participate in governance processes, access community services, and benefit from collective resources. Because SBTs are secure and immutable, they provide a reliable method for verifying identity and membership status, helping to ensure that only eligible participants engage in restricted community functions. Their non-transferable nature reinforces the authenticity of each member's contributions, creating a permanent and tamper-proof record of involvement. This can promote long-term engagement, as members know their contributions are formally recognized. In this model, receiving an SBT after participating in community activities effectively grants individuals full membership status, including voting rights and access to community services—thus encouraging sustained civic participation and collective responsibility.

***Characteristics*:**

- Base token standard: ERC721
- Role-based Minting: The ability to mint tokens is assigned to specific roles, such as an *Initiator*
- Role-based Transferability: The token can be transferred only from the *Initiator* to the *Community Member*, and its transferability is strictly tied to community membership: it is non-transferable and permanently linked to their account
- Multiple Acquisition Method
  - Contribution-Based: Members collect ERC20 reward tokens by completing tasks and then exchange these reward tokens for a SBT membership token representing their contribution.

- Attendance-Based: Members collect ERC721 Proof of Presence tokens by participating in community events and then exchange these for a SBT membership token representing their attendance.

***Incentive Form*:** Non-monetary incentive, Contribution. It is used to recognize community members' contributions, acting as an incentive driver by granting access to roles and benefits within the community.

***Example scenario*:** In a local neighborhood, a community association holds regular meetings to discuss and manage various activities, such as neighborhood clean-ups, local events, or neighborhood improvement projects. These meetings are crucial for governance and decision-making within the community. At each meeting, attendees receive a Proof of Attendance token (or attendance record), which can be tracked digitally. The system is designed so that after a member has attended a specified number of meetings or completed certain community engagement tasks, they earn eligibility to receive an SBT, which grants them full membership status within the community.

6.6. Representation of Physical Objects

***Category*:** This artifact, implemented as a non-fungible token (NFT), serves as the digital representation of a physical object within the tokenized system. It facilitates borrowing dynamics among participants by offering a verifiable and transferable record of ownership and possession.

***Characteristics*:**

- Base token standard: ERC721
- Role-based Transferability: this token can be transferred with some limitation based on the purpose of the case. It can be transferred to *Community Member* to *Community Member*.
- Temporary Transfer: The transfer of the token is specifically linked to the act of borrowing an item. When an item is borrowed, the corresponding non fungible token is transferred to the borrower's account for the duration of the borrowing period.

***Incentive Form*:** Non-monetary, Access. A non-fungible token (NFT) used to represent physical objects within a tokenized system, granting access to the community lending system. For this reason it is an incentive driver that enables the access to a resource.

***Example scenario*:** Consider a decentralized "Library of Things" where physical objects are represented by unique ERC721 non-fungible tokens. A blockchain-based application facilitates the reservation and regulation of object exchanges. The exchange of the physical object occurs directly between two participants, eliminating the need for intermediaries as found in traditional libraries. In this model, the ERC721 token functions as the digital representation of the shared resource, with properties ensuring its uniqueness, clear ownership and transferability limited to the duration of a borrow [40].

6.7. Event Ticketing

***Category*:** This token is designed to enable local associations, grassroots initiatives, or informal groups of citizens to autonomously create, distribute, and manage digital tickets for community-based events such as cultural performances, concerts, exhibitions, and educational workshops.

***Characteristics*:**

- Base token standard: ERC721
- Role-based Minting: The ability to mint tokens is assigned to specific roles—such as *Associations* or *Local Retailers* —who act as authorized issuers within the system.

- Role-based Transferability: this token can be transferred with some limitation based on the purpose of the case. It can be transferred from *Association* to *Community Member* and from *Community Member* to *Association*, but not between *Community Members*.
- Lifecycle Options:
  - Burnable: Tickets are burned either after they are used for the event entrance or once the event has expired.
  - Collectible NFT: Tickets are not burnt, serving as collector's items or memorabilia.

***Incentive Form*:** Non-monetary incentive, Access and Gamification. It acts as incentive enabler giving the right to participate to events or use community shared spaces

***Example scenario*:** Tickets can be used to manage events such as concerts, exhibitions, and festivals within local communities. These events play a vital role in strengthening local identity, fostering social cohesion, and activating public spaces. This can be especially valuable for smaller community-led associations, which often lack access to affordable and adaptable ticketing infrastructure that aligns with their values of inclusivity, transparency, and decentralization.

Toolkit We have released an open-source software toolkit on GitHub [1] that provides a reference implementation of the token constructs delineated in our proposed use-cases. This toolkit encompasses the full lifecycle of each token variant offering practitioners a robust foundation for the deployment of token-based local communities. Central to the architecture is a modular registry component, which maintains a comprehensive record of all defined community roles and systematically associates each community member's address with its role that defines its permitted token operations. By cloning the repository and specifying the requisite role definitions within the registry, researchers and developers can instantiate a token-governed ecosystem for experimental evaluation or production use.

7. Blocchi Project Use Case

A concrete use case for the implementation of tokenized collaborative economies is Blocchi project[2], currently developed through the integration of CommonsHood [41, 42], a blockchain-based wallet platform, and FirstLife [43], a geo-referenced civic social network. This use case targets the challenge of increasing tourist flows to lesser-known mountainous regions by enabling the creation of tokenized systems designed directly by stakeholders.

CommonsHood enables non-technical users—including citizens, institutions, and merchants—to issue and manage cryptographic tokens via customizable templates using a no-code interface. In this project the platform is integrated with FirstLife's interactive mapping and geolocation capabilities, in order to support the promotion of local tourism ecosystems by allowing visitors to discover, interact with, and benefit from geographically located services and opportunities.

Merchants can independently create discount tokens and offer promotions and also collaborate to design tourism circuits, creating interoperable, token-driven experiences that encourage mobility and cross-promotion among local actors. This fosters a bottom-up economic network grounded in mutual benefit and shared governance principles. The system architecture enables the issuance of multiple token types functioning as non-monetary incentives.

- **Coupons** represent a non-monetary incentive that grant access to specific services or discounts.

[1] https://github.com/EmanueleSpadaro/tokenized-communities

[2] BLOCCHI: tokenization tools for supporting tourism in rural and mountain areas. part of the NODES project, funded by MUR – Mission 4, Component 2, Investment 1.5 – Creation and Strengthening of "Innovation Ecosystems", building "Territorial RD Leaders" – of the PNRR, funded by the European Union – NextGenerationEU grant agreement no. ECS00000036. 2023 - 2025

- **Badges**, issued as non-transferable NFTs, serve a dual function: they act as proof-of-presence tokens within tourism circuits and activate gamification mechanisms that stimulate intrinsic motivation through collection and achievement-based engagement. Completion of a full circuit unlocks additional utility (e.g., reward coupons), reinforcing continued participation.

This layered token model enhances the attractiveness and dynamism of the tourist offering while creating network effects among local businesses. Preliminary co-design sessions with local stakeholders validated both the interaction model and the underlying infrastructure, confirming strong interest in token-based tools that serve both commercial and civic purposes. Findings also emphasized the need for localized onboarding strategies, including simplification of crypto terminology and a user-friendly wallet interface. This use case demonstrates a practical implementation of a multi-token system supporting diverse motivational drivers through non-monetary incentives. While currently limited in scope, the architecture is extensible: future iterations will integrate governance modules (e.g., DAOs) to allow local stakeholders to make collective decisions regarding token issuance and resource allocation. Moreover, interoperability frameworks will be developed to allow token recognition across multiple communities, enabling scalable, decentralized networks of collaboration anchored in local value creation.

8. Conclusion

The integration of blockchain technology into collaborative economies presents a promising pathway for empowering local communities through decentralized, transparent, and participatory systems. By conceptualizing local communities as closed systems with shared goals and processes, this study has examined how blockchain—particularly through tokenomics—can facilitate non-monetary value exchange and support collective action. Through an interdisciplinary approach, we have identified the non-functional requirements and socio-economic needs critical for establishing a tokenized collaborative economy. Drawing on motivation theory, we argue that non-monetary incentives are essential to ensure long-term sustainability, user engagement, and alignment with the intrinsic and transcendent motivations of community members.

Furthermore, we have mapped the core roles that typically emerge within such ecosystems and explored which types of tokens are most appropriate to represent the diverse use cases and value exchanges within these contexts. As a practical contribution, this research proposes a toolkit comprising a repository of smart contracts specifically designed to translate the identified requirements into operational components for implementing tokenized systems tailored to the needs of local communities. These contracts serve as modular building blocks for configuring non-monetary incentive mechanisms, managing value flows, and supporting community participation. As a future line of research, we plan to expand the toolkit by integrating additional token types, incorporating decentralized voting mechanisms, and developing simulation tools to model and optimize the dynamics of token economies, with the goal of ensuring long-term sustainability and governance adaptability.

Ultimately, enabling local communities to autonomously manage their economic infrastructure through blockchain technologies requires both theoretical investigation and practical tools. Addressing this gap contributes to a more robust understanding of how digital infrastructures can be leveraged to reinforce social cohesion and economic resilience at the local level. To improve the evaluation of design principles and non-functional requirements, we propose using the OKR (Objectives and Key Results) methodology. This provides clear, outcome-focused benchmarks that streamline early research and are easy for communities to adopt. While a standard OKR framework will be included in the design toolkit, communities can customize it to reflect their local needs and values. Future developments will explore the integration of Decentralized Autonomous Organizations (DAOs) as governance actors within these systems. Embedding modular governance mechanisms will enable stakeholders to collectively manage decision-making processes, including funding allocations and token issuance policies. Additionally, the framework will be extended to support interoperability, allowing tokens to be recognized and exchanged across different community networks—thus enabling cross-community collaboration and resource sharing while preserving local autonomy.

Declaration on Generative AI

The authors did not use Generative AI tools during the writing of this paper.

References

[1] O. Kolade, D. Adepoju, A. Adegbile, Blockchains and the disruption of the sharing economy value chains, Strategic Change 31 (2022) 137–145. doi:https://doi.org/10.1002/jsc.2483.

[2] C. Viano, Context-based civic blockchain: Localising blockchain for local civic participation., Digital Geography and Society (2024) 100090.

[3] B. Tomlinson, J. Boberg, J. Cranefield, D. Johnstone, M. Luczak-Roesch, D. J. Patterson, S. Kapoor, Analyzing the sustainability of 28 'blockchain for good'projects via affordances and constraints, Information Technology for Development 27 (2021) 439–469.

[4] D. Cagigas, J. Clifton, D. Diaz-Fuentes, M. Fernández-Gutiérrez, Blockchain for public services: A systematic literature review, IEEE Access 9 (2021) 13904–13921.

[5] A. Klimczuk, V. Česnuityte, G. Avram, The Collaborative Economy in Action: European Perspectives, University of Limerick, 2021.

[6] C. Viano, S. Avanzo, G. Boella, C. Schifanella, V. Giorgino, Civic blockchain: Making blockchains accessible for social collaborative economies, Journal of Responsible Technology 15 (2023) 100066.

[7] G. Petropoulos, An economic review of the collaborative economy, Technical Report, 2017.

[8] R. Botsman, Defining the sharing economy: what is collaborative consumption–and what isn't, Fast Company 27 (2015) 2015. URL: https://doi.org/10.2139/ssrn.2783662.

[9] F. Celata, F. Stabrowski, Crowds, communities,(post) capitalism and the sharing economy, 2022.

[10] I. P. Tussyadiah, J. Pesonen, Drivers and barriers of peer-to-peer accommodation stay–an exploratory study with american and finnish travellers, Current Issues in Tourism 21 (2018) 703–720.

[11] A. Acquier, T. Daudigeos, J. Pinkse, Promises and paradoxes of the sharing economy: An organizing framework, Technological Forecasting and Social Change 125 (2017) 1–10.

[12] R. M. Ryan, E. L. Deci, Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions, Contemporary educational psychology 61 (2020) 101860.

[13] R. J. Vallerand, Deci and ryan's self-determination theory: A view from the hierarchical model of intrinsic and extrinsic motivation, Psychological inquiry 11 (2000) 312–318.

[14] R. M. Ryan, E. L. Deci, Intrinsic and extrinsic motivations: Classic definitions and new directions, Contemporary educational psychology 25 (2000) 54–67.

[15] R. Bénabou, J. Tirole, Intrinsic and extrinsic motivation, The review of economic studies 70 (2003) 489–520.

[16] H. M. Kim, M. Laskowski, M. Zargham, H. Turesson, M. Barlin, D. Kabanov, Token economics in real life: Cryptocurrency and incentives design for insolar's blockchain network, Computer 54 (2021) 70–80.

[17] C. Catalini, J. S. Gans, Some simple economics of the blockchain, Communications of the ACM 63 (2020) 80–90.

[18] D. Easley, M. O'Hara, S. Basu, From mining to markets: The evolution of bitcoin transaction fees, Journal of Financial Economics 134 (2019) 91–109.

[19] L. W. Cong, Z. He, Blockchain disruption and smart contracts, The Review of Financial Studies 32 (2019) 1754–1797.

[20] S. Krückeberg, P. Scholz, Cryptocurrencies as an asset class, in: Cryptofinance and mechanisms of exchange: The making of virtual currency, Springer, 2020, pp. 1–28.

[21] E. Pagnotta, A. Buraschi, An equilibrium valuation of bitcoin and decentralized network assets, Available at SSRN 3142022 (2018).

[22] B. Biais, C. Bisiere, M. Bouvard, C. Casamatta, The blockchain folk theorem, The Review of Financial Studies 32 (2019) 1662–1715.

[23] A. Pazaitis, P. De Filippi, V. Kostakis, Blockchain and value systems in the sharing economy: The illustrative case of backfeed, Technological Forecasting and Social Change 125 (2017) 105–115.
[24] E. Dhaliwal, Z. Gurguc, A. Machoko, G. Le Fevre, J. Burke, Token ecosystem creation, Outlier Ventures (2018).
[25] F. Restuccia, S. K. Das, J. Payton, Incentive mechanisms for participatory sensing: Survey and research challenges, ACM Transactions on Sensor Networks (TOSN) 12 (2016) 1–40.
[26] P. Hülsemann, A. Tumasjan, Walk this way! incentive structures of different token designs for blockchain-based applications (2019).
[27] B. Kraner, N. Vallarano, C. J. Tessone, Tokenization of the common: An economic model of multidimensional incentives, in: Proceedings of the 4th International Workshop on Distributed Infrastructure for the Common Good, 2023, pp. 37–42.
[28] J. Schwiderowski, A. Pedersen, R. Beck, Crypto tokens and token systems, Information Systems Frontiers (2023). doi:10.1007/s10796-023-10382-w.
[29] L. Oliveira, L. Zavolokina, I. Bauer, G. Schwabe, To token or not to token: Tools for understanding blockchain tokens, in: Proceedings of the 39th International Conference on Information Systems, 2018.
[30] R. M. Pierluigi Freni, Enrico Ferro, Tokenomics and blockchain tokens: A design-oriented morphological framework, Blockchain: Research and Applications 3 (2022) 100069–. doi:https://doi.org/10.1016/j.bcra.2022.100069.
[31] J.-K. Choi, T. K. Ahn, Strategic reward and altruistic punishment support cooperation in a public goods game experiment, Journal of Economic Psychology 35 (2013) 17–30. URL: https://api.semanticscholar.org/CorpusID:144331622.
[32] F. Rubino, D. Agostino, D. Spallazzo, Strategizing blockchain adoption in public cultural services: a comprehensive scoping review, International Journal of Public Sector Management 38 (2024). doi:10.1108/IJPSM-12-2023-0383.
[33] B. Kraner, N. Vallarano, C. Tessone, Tokenization of the common: An economic model of multidimensional incentives, in: Proceedings of the 24th International Middleware Conference, 2024, pp. 37–42. doi:10.1145/3631310.3633486.
[34] M. C. Ballandies, To incentivize or not: impact of blockchain-based cryptoeconomic tokens on human information sharing behavior, IEEE Access 10 (2022) 74111–74130.
[35] K. Polanyi, The great transformation: The political and economic origins of our time, Beacon press, 2001.
[36] M. Armstrong, T. Stephens, A handbook of employee reward management and practice, Kogan Page Publishers, 2005.
[37] N. Lipusch, D. Dellermann, P. Ebel, Managing initial coin offerings: Towards a taxonomy of ico processes (2019).
[38] S. I. Shin, J. B. Kim, D. Hall, T. Lang, What information propagates among the public when an initial coin offering (ico) is initiated? a theory-driven approach (2019).
[39] M. Osterloh, B. S. Frey, Motivation, knowledge transfer, and organizational forms, Organization science 11 (2000) 538–550.
[40] N. Vanzo, E. Spadaro, C. Viano, C. Schifanella, A blockchain-based object sharing system for local communities, in: Proceedings of the 2024 International Conference on Information Technology for Social Good, GoodIT '24, Association for Computing Machinery, New York, NY, USA, 2024, p. 324–332. URL: https://doi.org/10.1145/3677525.3678678. doi:10.1145/3677525.3678678.
[41] S. Avanzo, G. Boella, C. Schifanella, Viano, Commonshood: Participatory design of token economies in local communities, in: Titolo volume non avvalorato, CINI-Consorzio interuniversitario nazionale per l'informatica, 2023.
[42] S. Balbo, G. Boella, P. Busacchi, A. Cordero, L. De Carne, D. Di Caro, A. Guffanti, M. Mioli, A. Sanino, C. Schifanella, Commonshood: A blockchain-based wallet app for local communities, in: 2020 IEEE International Conference on Decentralized Applications and Infrastructures (DAPPS), IEEE, 2020, pp. 139–144. URL: https://doi.org/10.1109/DAPPS49028.2020.00018.
[43] G. Boella, A. Calafiore, E. Grassi, A. Rapp, L. Sanasi, C. Schifanella, Firstlife: Combining social

networking and vgi to create an urban coordination and collaboration platform, IEEE Access 7 (2019) 63230–63246.