Crypto Tokens and Token Systems

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Abstract

Cryptographic tokens are one of the cornerstones of the new blockchain world but the knowledge about these digital objects is still limited. In this research, we argue that *crypto tokens*, cryptographically secured digital tokens connected to DLT systems, form socio-technical systems through their reciprocal relationship with their foundational DLT systems. We also argue that today's crypto token systems evolved out of earlier physical and digital token systems, a socio-technical transition facilitated by changes in the wider socio-cultural, economic, and technical environment. Based on an extensive structured literature review as well as the application of text analytics methods to more than 506 blockchain whitepapers, we develop two results: a crypto token classification built around three crypto token archetypes, and a crypto token system taxonomy. Our findings are relevant for both blockchain researchers and practitioners alike by enhancing our understanding of complex blockchain systems.

Keywords

tokens, token system, blockchain, taxonomy, classification, topic modelling

1 Introduction

Tokens of different types have been around for millennia, shaping and being shaped by cultural and cognitive aspects of societies (Crisà et al., 2019a). Tokens presumably emerged with the cultivation of cereals between 9,000 and 3,500 BCE where they represented farm products (Schmandt-Besserat, 2019). Examples of physical tokens include armor tokens in ancient Greece (Schäfer, 2019), royal tokens (Valin, 2019), vouchers (Valkama & Bailey, 2001), casino chips (Oliveira et al., 2018), and, obviously, money (Maurer, 2017). Over time, physical tokens were complemented by digital ones, and finally crypto tokens emerged, allowing the digital representation of real-world objects on distributed ledger technologies (DLT) such as blockchain (Heines et al., 2021).

Crypto tokens based on blockchain have a significant effect on both the economy and society at large, and may potentially become as important as the Internet itself (Beck, 2018). They are considered foundational to the proposed blockchain economy (Beck et al., 2018), and they have the potential to disrupt and even revolutionize the economy as we know it (Tapscott & Tapscott, 2016). A major concept associated with blockchain and enabling this disruption are *cryptographic* (or *crypto*) *tokens*. These tokens have a variety of purposes in DLT systems, but they are often used as internal units of account for keeping track of services like block-writing and validation (Conley, 2017). They can either be native to a blockchain (as in the case of cryptocurrencies) or built on top of it, governed by smart contracts, decentralized applications (dApps) and decentralized autonomous organizations (DAOs). Crypto tokens, and especially Bitcoin and Ether tokens, have drawn the attention of investors due to huge price and volume fluctuations that offer the opportunity for arbitrage (Gandal et al., 2021). Tokens have been the drivers behind the initial coin offerings (ICOs) hype (Adhami et al., 2018), as well as cryptographic art in the form of non-fungible tokens (NFTs) (Franceschet et al., 2019). As more physical and digital objects are tokenized —that is, represented in the form of different types of crypto tokens (Babich & Hilary, 2019)— it becomes increasingly important to differentiate and identify token archetypes and the governance systems they inhabit.

Tokens come in many different types, but they all share common characteristics: They can be owned and indicate certain rights and values. They can represent things as abstract as memories, beliefs, or emotions (Crisà et al., 2019a). They are transferable, which means that their ownership can be altered, and they can be exchanged in return for something else. Lastly, tokens create and exist in a system based on trust, mutual agreement, and consensus (Crisà et al., 2019a). In this sense, tokens can be considered as *humanely designed* objects with a specific architecture; they shape and are shaped by the systems in which they exist. Hence, there is a reciprocal relationship between tokens and their foundational systems that defines their governance relation. In summary, *a token* is a physical or digital object that can be owned and transferred, that represents something else, and that exists within a system. The reciprocal interaction between a token and its surrounding systems creates a *socio-technical system* that we call a *token system*. Both tokens and token systems can be described in terms of their *architectural* structures (that is, their technical and material parameters) as well as their *governance* structures (that is, the control and operational processes of interactions). We define a *cryptographic* or *crypto token* as a digital token that is cryptographically secured and exists in a DLT system.

The rise of blockchain has increased the interest in token-related topics, specifically research in token taxonomies, but there is still a dearth of research on crypto tokens and corresponding token systems from a more holistic, socio-technical view (Kranz et al., 2019). In this research, we develop a classification system for crypto token types and based upon, a comprehensive taxonomy of crypto token systems. In our research, we combine results from a structured literature review with empirical insights from a topic modeling approach where we analyzed more than 500 whitepapers dealing with blockchain. This mixed method approach allows us to augment our literature-based classification of token characteristics with empirical insights from current crypto token applications. Using these insights, we will explore *how crypto token systems lay the foundation for the emerging blockchain economy?*

The remainder of this paper is organized as follows. In part 2, we will provide an overview of the methodology used to conduct this study. Parts 3 and 4 present the outcomes of our extensive literature review and our topic modelling approach. In part 5, we describe our derived crypto token classification and system taxonomy, and part 6 discusses the results of our study. Finally, in part 7, we summarize our main findings.

2 Methodology

In this research, we apply a mixed-method approach consisting of three research steps. First, we conduct structured literature reviews (SLR) on tokens and token systems to understand how they developed and how tokens transitioned from the physical to the digital and ultimately to the crypto format. Next, we identify crypto tokens in 506 whitepapers from blockchain start-ups and projects and use a topic modelling approach to analyze how crypto tokens are used and defined in these environments. This two-part approach allows us to identify general token characteristics while also alerting us to new token and token system characteristics associated with crypto tokens. We use these insights to build a crypto token classification and a crypto token systems taxonomy.

2.1 Structured Literature Review

Tokens and token systems have been used in very different forms since their first instantiations sometime between 9,000 and 3,500 BCE (Schmandt-Besserat, 2019). The idea of considering historical aspects of phenomena in conducting research on contemporary phenomena is not new (Mason et al., 1997a, 1997b) and enables us to gain insights into general characteristics of tokens and token systems. To find relevant historic discussions of tokens, we carry out a broad literature search for the term "token" in works written before the blockchain era, as well as on the terms "ancient token" and "historic token" without restrictions. After screening the abstracts of identified papers and the introductions of books to detect those most relevant for our research, we read the materials in detail.

To gain a specific overview of which types of crypto tokens exist and how they are regarded in the Information Systems (IS) community, we conduct a SLR inspired by the works of Okoli (2015), vom Brocke et al. (2015), and Webster and Watson (2002). As data source we use Web of Science and the conference proceedings of ICIS, ECIS, and HICSS. Given our focus on crypto tokens, we limit our search to the years 2008 and later as well as peer-reviewed articles, using the search string:

("distributed ledger technology" OR "blockchain") AND ("token" OR "digital asset" OR "digital wallet" OR "tokenomics" OR "cryptonomics" OR "identity and credential" OR "initial coin offering" OR "security token offering" OR "initial exchange offering").

We read and evaluate the abstracts of the found papers to identify the most relevant ones for our classification and taxonomy. Subsequently, we conduct a forward and backward search on the remaining articles. By reading and evaluating the abstracts of these papers, we identify the final sample of articles and reports which we use for finding crypto token types and characteristics.

2.2 Topic Modelling

Text analytics and especially topic modelling has previously been used in blockchain research. The technique of latent Dirichlet allocation (LDA) has been applied to build a tool for the automated categorization of ICOs (Chuanjie et al., 2019) and a learning-based cryptocurrency rating system (Bian et al., 2018). It was also used on 200 blockchain whitepapers finding that cryptocurrency prices are in part determined by the currency's underlying technology (Liu et al., 2020).

Given a growing number of blockchain initiatives using tokens in some way, whitepapers are an adequate supplementary source for collecting information on crypto tokens, especially from a practical perspective. We are able to crawl whitepapers covering a wide range of industries and maturity levels from a total of 506 blockchain projects listed in the databases All Crypto Whitepapers (2021) and whitepaper.io (2021). Using the statistical programming language R (R Core Team, 2021b), we analyze these whitepapers employing different word frequency count procedures and versions of LDA topic modelling. This allows us to gain highly topical practical insights into the global blockchain space and to enrich and substantiate the crypto token findings from the SLR.

2.3 Classification and Taxonomy Development

The different crypto token types and characteristics revealed by our analysis serve as basis for the development of a crypto token classification and a tree-based taxonomy of crypto token systems. The taxonomy is based upon an empirical-to-conceptual approach where we chose a phonetic approach as we are not interested in the evolutionary trajectory of the characteristics in the taxonomy (Nickerson et al., 2013). However, our evolutionary token SLR was highly valuable in identifying general token characteristics (such as ownership, transferability, representation, surrounding system) and for guiding our general research.

3 Literature Background

3.1 Physical and Digital Tokens

The first tokens emerged between 9,000 and 3,500 BCE as a means of representing farm products; thus the appearance of tokens is connected to the emergence of sedentary agriculture (Schmandt-Besserat, 2019). These first tokens were simple geometric objects that over time developed into more complex forms (Schmandt-Besserat, 1986). Scholars argue that clay tokens found in old Mesopotamia dating back more than 3,000 years may be the origin of writing (Schmandt-Besserat, 1996). Moreover, tokens are seen as the beginning of counting and hence of accounting and data processing (Schmandt-Besserat, 1983). Tokens also played a crucial role in the democratization of the constitution in Old Athens in the fifth century BC, where they were used in the lottery that distributed public offices and enabled citizens to run the city's businesses (Crisà et al., 2019a).

Over time, more types of tokens came into existence. One type mainly represents rights to receive or obligations to pay for something. Besides the clay tokens mentioned above (Schmandt-Besserat, 2019), other examples include bamboo tallies, pub tokens, coat check tokens, casino chips, stock certificates, promissory notes, and vouchers (such as those used for schooling (Epple et al., 2017), food (Hidrobo et al., 2014), or housing (Miles et al., 2017)).

A second type of token allows access to or membership in something. Examples include tickets, which permit the holder to participate in certain events; railway tokens, which allow trains to enter certain sections of a railway network; telephone tokens allowing a user to take part in a telecommunications network; token ring tokens, which serve as a channel access method in certain computer networks; or stamps, which give access to the postal system. Closely related are tokens used for identification, such as ID cards and passports, QR codes, or the citizen tokens used in the *kleroterion* in ancient Athens (e.g. Wilding (2017); Crisà (2019a); Schmandt-Besserat (2019)). One of the most studied types of token are those providing some sort of incentive or reward; these serve as reinforcement mechanisms in token economies (e.g. Bonfonte (2020), Ivy (2017), Doll (2013)). Such tokens may be tangible: gaming chips, coins, tickets, stickers, marbles, or stamps (McLaughlin & Williams, 1988). They may also be intangible, like checkmarks or points given by teachers or managers. The value of these tokens depends upon the availability of the rewards for which the holders have indicated they are willing to work (Doll et al., 2013). Other tokens used for incentivizing, rewarding, or honoring and showing appreciation and affection include sobriety tokens, knight's tokens, coronation tokens, love tokens such as flowers (Valin, 2019), and greeting cards, and business cards (Shank, 2004).

The most widely used type of token, however, is money. Some of the earliest forms of money were shells and beads (e.g. Mellor (2010), Sehra (2018)). Other forms that emerged later were commodities with an intrinsic value like coffee, tea, salt, sugar, cigarettes, jewels, or arrowheads (Sehra (2018); Camp (1995)). The form of money used most today probably first emerged in China around the year 1,000 CE. Such fiat money or currency (paper money, coins) issued by banks only has value as legal tender by governmental declaration (Mellor, 2010; Sehra et al., 2018). This form of money evolved from cash (physical token money) into checks (physical transfers of notational money) to credit and debit cards (electronic transfers of notational money), and these later forms have built a fundamental relationship to identification, recordkeeping, and data mining (Camp (1995), Lauer (2020)).

Over the past millennia tokens shaped the cultural, societal, and cognitive aspects of human lives and civilizations (Crisà et al., 2019b) and hence have played a crucial role in the development of human societies. And tokens—both physical and now digital—are clearly still relevant today.

3.2 Crypto Tokens and Blockchain

With the growing interest in blockchain (Zeadally and Abdo (2019); Dabbagh et al. (2019), Firdaus et al. (2019)), crypto tokens have become a topic of interest, as they can be used as currencies, validation incentives, usage incentives, funding instruments, or as tools for accelerating network effects, governance, asset ownership, and for profit sharing (Oliveira et al., 2018).

Cryptographic tokens are thought to have a significant effect on the economy and might even give rise to a new "token economy" or "tokenomics." In the token economy, a community's revenue can be allocated not only to the actual content producers and service users who create value but also to new token-based ecosystems and business models (Lee (2019); Tönnissen et al. (2020)). Tokens can be network goods with the characteristics of public goods, and can drive inter-organizational value creation while reducing transaction costs (Sunyaev et al., 2021). Furthermore, tokens may accelerate the disintermediation of some markets and also provide opportunities for new intermediators, such as oracle and wallet providers, to enter the market (Jørgensen & Beck, 2022). Much research around cryptographic tokens has focused on their role in enforcing incentive mechanisms. Cryptographic tokens can be used to incentivize the adoption and use of something, or for on-boarding new users or customers (Mougayar, 2017). Moreover, they can be financial incentives to grow a platform but may under certain circumstances become hindrances requiring maintenance and further development after deployment (Drasch et al., 2020).

Hence, crypto tokens have the potential to fundamentally change existing markets and economies, which is why a holistic analysis of crypto tokens and supporting systems is necessary. Prior literature has used varying terms for classes of tokens, mainly driven by the industry or application area within which they occur. Prior studies present taxonomies and classifications of tokens (Freni et al., 2020) with a focus, for example, on tokens for ICOs and crowdfunding (Fridgen et al., 2018). Oliveira et al. (2018) develop a taxonomy where they identify three main classes of tokens: cryptocurrencies/coins, tokenized securities, and utility tokens. Increasingly, there is a consensus around this three-part division into payment, asset, and utility tokens. These are the archetypes for crypto tokens that we consider in this research as well (Lo & Medda (2020), Lee (2019).

4 Text Analytics

In our first analysis, we identify relevant token types in blockchain whitepapers. The terms “token” and “tokens” show up more than 20,000 times in 450 of the 506 whitepapers, indicating that tokens in general are a highly relevant topic in these sources. We use the R package *tm* (Feinerer & Hornik, 2020; Silge & Robinson, 2017) to pre-process the texts by converting all words to lower case; stripping white spaces; and removing punctuation, numbers, stop words, and words with fewer than three letters. Then, we specifically analyze bi- and tri-grams containing the term “token,” which yields terms such as “asset token” and “basic attention token.”

Next, we use an LDA approach to calculate different topic models to detect categories and hierarchies of crypto tokens. LDA builds on latent semantic analysis (Deerwester et al., 1990) and probabilistic latent semantic analysis (Hofmann, 2001). Applied to corpora of documents, this generative probabilistic approach models each document as a finite mixture of a set of underlying topics. Each topic is represented as an infinite mixture over an underlying collection of topic probabilities which explicitly represent a document (Blei et al., 2003). We employ LDA with Gibbs sampling, a Markov chain Monte Carlo algorithm, and the variational expectation maximization (VEM) algorithm using the package *topicmodels* (Grün & Hornik, 2011). To find an appropriate number of topics to model, we employ the criteria provided by the function FindTopicsNumber in the package *ldatuning* (R Core Team, 2020). This function is based on the works of Griffiths and Steyvers (2004) (their metric is only defined for the Gibbs-based model), Arun et al. (2010), Cao Juan et al. (2009), and Deveaud et al. (2014). We calculate the metrics for between two and 40 topics given that for a higher number of topics some of the metrics become unstable. Moreover, we detect similar but more repetitive topics for some higher topic numbers that we tested to ensure the robustness of our findings.
We find that the different criteria we calculated do not converge on a specific topic number to be preferred. However, the topic models for the most preferable topic number candidates for the Gibbs- (i.e., 22, 31, and 37) and VEM-based (i.e., 36 and 39) LDA models (cf. **Fig. 1**) indicate that tokens are a highly relevant theme in the whitepapers. Moreover, they point to that asset tokens, payment tokens, and utility tokens are archetypical subtypes of crypto tokens.

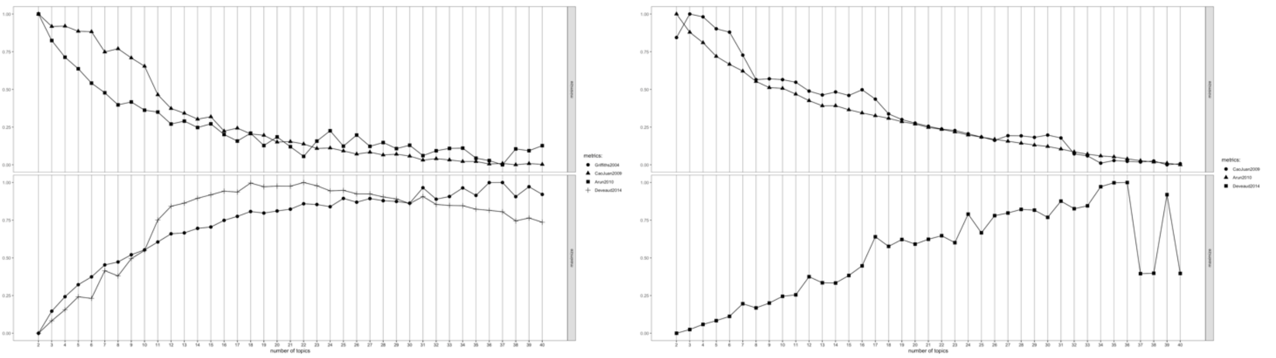

Fig. 1 Metrics for estimating the most preferable number of topics in Gibbs-based (left) and VEM-based (right) LDA topic models

For example, in the Gibbs model with 31 topics, we find that eighteen topics are highly relevant to the subject of tokens. Some of these topics deal with general aspects of tokens such as token sales, platforms, and networks. However, each of the other topics reflects one of the main token types identified in the SLR: utility tokens, payment tokens, and asset tokens. There are three topics which relate tokens to terms like “energy” and “grid”, “health” and “medical”, as well as “game”. As

utility tokens deal with topics such as healthcare, energy, and gaming, these topics indicate that utility tokens are an important topic within the whitepapers and thus the blockchain community. The LDA algorithm also found a relationship between terms such as “token,” “payment,” “cryptocurrencies,” and “financial”; accordingly, we interpret this topic as related to payment tokens. This collection also hints that payment tokens are connected to cryptocurrencies and are thus indeed an important token type.
In two other topics, the terms “exchange,” “exchanges,” “trading,” “transaction,” and “order” as well as “investment,” “investor,”, and “market” are both grouped with the terms “asset” and “token,” suggesting that asset tokens are also a major token type within the whitepapers. The occurrence of financial terms such as “liquidity,” “trading,” and “investor” also indicates that asset tokens are strongly related to the fields of finance and investment, which suggests that investment and security tokens could be seen as major subtypes of asset tokens.

For the VEM-algorithm-based version of the LDA topic modelling procedure with 36 topics we discover 25 topics containing the term “token” among the ten most relevant words. Two topics relate cryptocurrencies and payment tokens to words such as “exchange,” “card,” “wallet,” “money,” and “market”, underlining the monetary and payment features of cryptocurrencies and suggesting payment tokens as an overarching type.
Asset tokens are the theme in four topics, relating the terms “token,” “asset,” “exchange,” “exchanges,” and “trading;” “token,” “assets,” and “exchanges;” “token,” “investor,” “investments,” “market,” and “crypto;” as well as “asset,” “assets,” “market,” and “token,” respectively. This suggests that assets and their tokenized forms (digital and crypto assets) might be linked to the act of investment and investment tokens.
The theme of utility tokens is reflected in several word groupings. One of the topics suggests health and medicine as a relevant topic and that health-specific utility tokens seem to play a role (“health,” “healthcare,” “medical,” “patients,” and “token”). In another topic, the terms “energy,” “grid,” “power,” and “token,” are grouped. Even though the term “utility” is not found to be related to the term “token” in any topic, in the specific contexts of energy and health, corresponding tokens and concrete examples for such tokens do seem to be related. Therefore, the VEM method LDA approach also supports the conclusion that utility, asset, and payment tokens are major token types.

Finally, we run a seeded version of LDA topic modelling using the R package *seededlda* (Lu et al., 2011; R Core Team, 2021a; Watanabe & Zhou, 2020).
Using the italicized words as inputs, we receive the following groups of words. For *token, asset*, we receive network, transactions, nodes, block, transactions, blockchain, node, consensus; for *token, payment*, we receive platform, market, blockchain, users, exchange, cryptocurrency, contract, price; and for *token, utility*, we receive data, blockchain, platform, network, users, smart, system, technology. These results are not of great use in identifying relationships among token types. Only the link between payment, token, and cryptocurrency provides support for a connection between cryptocurrencies and payment tokens.

5 Crypto Token Classification and System Taxonomy

5.1 Crypto Token Classification

Figure 2 provides a structured analysis of token types based on our mixed methods research approach. Asset tokens are *crypto tokens* that are linked to physical or digital assets (financial and non-financial). They can represent security and investment tokens as well as digital registries.

Security tokens provide ownership rights to a percentage of potential profits, such as dividend or revenue shares (Kranz et al., 2019). Investment tokens promise investors future financial benefits and/or rights in relation to the project they are attached to (Ferrari, 2020). Digital registries or digital assets, in turn, are assets that are registered on a blockchain and thus are already confirmed, allowing for faster exchange and transactions (Swan, 2018). *Payment tokens* are crypto tokens used for making digital payments; the term mainly refers to cryptocurrencies, which are a specific form of digital currency built upon ledgers (Chuen et al., 2017). Some central bank digital currencies (CBDC) are built upon ledgers, even though most are account based (Bindseil, 2020). Tokens that provide a certain utility to users (such as access rights, membership rights, or identification and authentication), or that serve as rewards, fall into the category of *utility tokens*. A prominent example of utility tokens are basic attention tokens which are tokens for decentralized advertisement exchange (Brave Software, 2021). However, there are also many *hybrid tokens* that combine attributes of multiple archetypes. As illustrated in **Fig. 2**, identity tokens can be regarded as a combination of asset and utility tokens, as they are used to register identity-related information on a blockchain while simultaneously verifying information in transactions or smart contracts to grant access to services or rewards (Guseva, 2021). Stablecoins are a hybrid of asset and payment tokens as they can be either asset- or currency-based (Jørgensen & Beck, 2022). Hybrids of payment and utility tokens include network and platform tokens. These can serve as a means of payment as well as providing access tools to networks and platforms (Cong et al., 2019; Hülsemann & Tumasjan, 2019).

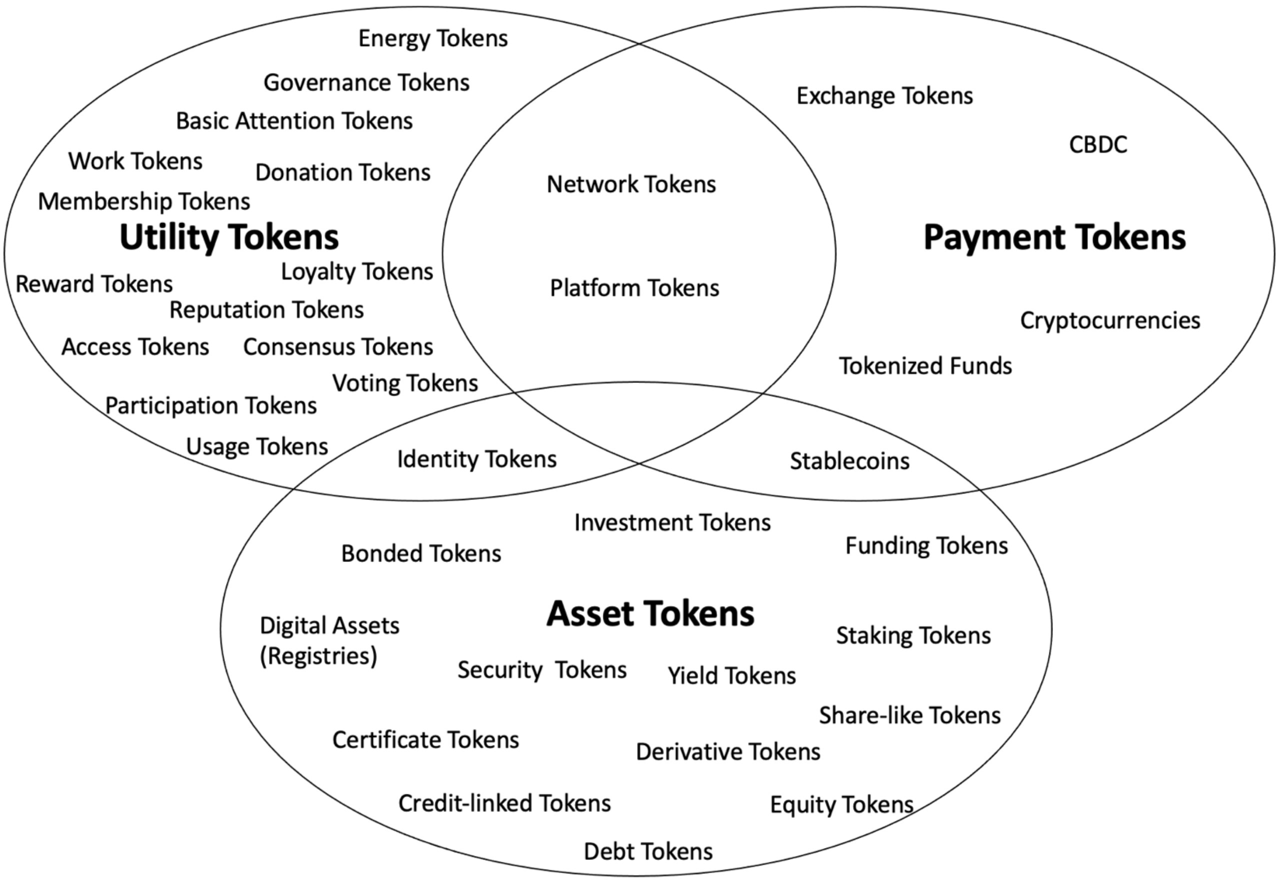

Fig. 2 Classification of crypto tokens along the archetypes of asset, payment, and utility tokens

5.2 Crypto Token System Taxonomy

Table 1 Crypto tokens exist only in the context of a DLT system, which defines who can use them and what can be done with them. The crypto token system itself again is nested in a wider political, economic, social-cultural, technological, legal, ecological, and geographical environment (Perera, 2017). Therefore, analyzing the potential of crypto token systems requires not only to describe and characterize crypto tokens but also to consider their DLT system. Both the token and its supporting DLT system have an architectural (i.e., technical) component as well as a governance (i.e., socio-economic) component. The architecture dimension can be split into *data*, *processes*, and *networks* (Zachman, 1987). *Data* defines fundamental, technical features of the token and hence crypto token system. *Processes* refers to features describing the integration of a token into a DLT system and impositions of the system on the token. Lastly, *network* defines architectural features of the DLT system relevant to the crypto token system. The governance dimension can be considered in terms of *decision rights*, *accountability*, and *incentives* (Weill, 2004). *Decision rights* define who is allowed to make decisions and how decisions are made. *Accountability* identifies who is held accountable for what actions. Finally, *incentives* govern the mechanisms encouraging certain actions within a crypto token system. The use of the lenses of architecture and governance allows to simultaneously perceive and understand the various technical and socio-economic levels of a system and how they interact and has been applied on digital platforms (e.g., Tiwana, 2013; Tiwana et al., 2010) and blockchain systems (Paik et al., 2019) before.

Taking the dynamics between crypto tokens and crypto token systems explicitly into account is a key contribution of this research. In total, we identify 22 distinct characteristics relevant when defining, describing, and explaining crypto token systems. These features build the foundation of our taxonomy. However, new crypto tokens with new features enter the market on a daily basis and thus any taxonomy would need to be adjusted as new archetypes may emerge.

We will begin by looking at the taxonomy of tokens, which is divided into architecture and governance dimensions. When looking at the data level of token architecture, we find seven characteristics describing crypto tokens: *archetypes*, *representation*, *fungibility*, *divisibility*, *spendability*, *expirability*, and *burnability*. The crypto token *archetype* classifies tokens into asset, utility, and payment tokens (or hybrids of these). *Representation* is a property shared by all tokens, whether physical, digital, or crypto: they *represent* something. In the case of crypto tokens, what they represent can be either digital or non-digital. (In the latter case we call the token a digital twin (Tao et al., 2019).) Another feature of crypto tokens is *fungibility*, which describes whether a token is interchangeable or unique. NFTs are a special group of unique tokens that can serve as collectibles (Popescu, 2021). *Divisibility* refers to whether a token can be divided into smaller units, as in the case of payment tokens such as Bitcoin (Barber et al., 2012). *Spendability* describes whether a token is dispositional or can be spent (Oliveira et al., 2018). Certificate tokens can be categorized as non-spendable, whereas cryptocurrencies are spendable. Another differentiating feature is a crypto token’s *expirability*. For instance, some access tokens grant access only temporarily before expiring, while others (e.g., Bitcoins) cannot expire (Oliveira et al., 2018). Finally, some crypto tokens can be *burnt*, i.e., taken out of use within a system in a non-recoverable manner. A typical way of doing this is sending a token to an inaccessible address (Cong et al., 2019).

The token governance dimension consists of decision rights which comprises the characteristic of *ownership*. There are two models for managing token ownership: A token can be owned by an individual entity or in a shared manner (Müller et al., 2018). As crypto tokens form their own decentralized economies (i.e., token economies) in which they represent digital assets, ownership over tokens goes along with power (Sunyaev et al., 2021). Individuals or collectives owning tokens can gain both decision power over the DLT system (e.g., in the case of governance tokens) and economic power (tokens such as cryptocurrencies as digital objects that can be exchanged for other physical or digital objects) (Lee, 2019; Sunyaev et al., 2021).

Next, we consider the system layer. The system architecture dimension is divided into processes and networks. On the process level, there are three relevant characteristics. *Quantity* describes whether there is an up-front limit to the supply of tokens. The supply of Bitcoin or Ripple's XRP is capped, whereas the supply of Ether or Monero is not (Ciaian et al., 2018). *Activation* describes whether a token is in use within a system. All burnt tokens are considered inactive. *Wrapping* can refer to the minting of a new token from an existing one, i.e., the (re-) tokenization of a token, or it can refer to burning. These are ways of creating and destroying tokens that enable interoperability between different DLT systems (Caldarelli, 2021; di Angelo & Salzer, 2020).
On the network level, the *origin* characteristic describes the genesis of a token within a DLT system by distinguishing whether a token is native or non-native to that system. Non-native tokens are created on top of an existing chain and are typically part of the protocol in currencies like Bitcoin or Ether (Y. Chen, 2018). The *chain* characteristic describes how the DLT system is created—whether by building a new chain or forking from an existing one, using either new or existing code (Oliveira et al., 2018).
The system governance dimension has three main divisions: *decision rights*, *accountability*, and *incentives*. The decision rights level has five characteristics. The *system scope* describes whether the access to validations of token transactions is permissioned or permissionless and whether the access to token transactions is public or private (Beck, 2018). When creating a DLT system, the *functional role* or *purpose* of the token matters. Like other tokens, crypto tokens can serve as means of value exchange, information storage or asset representation, authentication or verification, and access. In addition, they can be incentive mechanisms, currencies, or financial instruments (Crisà et al., 2019a; Freni et al., 2020). The *instantiation* of a token transfer within a system can be done either automatically via specific token contracts, or manually, without the involvement of third parties (T. Chen et al., 2019). The fourth characteristic, *tokenization*, describes how the token is created. One way is minting, i.e., deriving a new token from an existing one. The other possibility is called coinage and refers to the creation of an entirely new token. Finally, tokens provide their holders with certain *rights*. They are strongly associated with both property rights that can be owned and transferred with the token (Swan & De Filippi, 2017) as well as obligations which require that the holder of a token trusts its issuer (Freni et al., 2020).
On the accountability level, the different *system roles* and their accountabilities are defined. DLT systems involve four basic roles. *Developers* include the core protocol, client, application, and external systems. *Administrators* consist of the foundation, company, consortia, and open-source community. *Gateways* are composed of gatekeepers, oracles, custodians, issuers, and exchanges. Finally, *participants* are auditors, record producers, lightweight clients, and end-users (Rauchs et al., 2018).
The incentive level comprises three characteristics. *Supply* refers to the frequency and regularity of the supply of tokens. It distinguishes between rule-based enforcement such as schedule-based supply of tokens, and ad hoc discretionary token supply (Oliveira et al., 2018). The *distribution* of crypto tokens can be done in different ways. Payment tokens can be distributed in ICOs, initial exchange offerings (IEOs), or decentralized autonomous initial coin offering (DAICOs) which is an autonomous way to conduct an ICO. Security tokens might be distributed in the form of security token offerings (STOs) or digital security offerings (DSOs) (Myalo, 2019). Lastly, there is an *incentive system* in place in every DLT system. Tokens can be used to encourage the creation, implementation, use, or termination of a platform (Oliveira et al., 2018).

6 Discussion

6.1 Crypto Token Systems

A token is a physical or digital object that can be owned and transferred; it represents something of value but does not necessarily have any value itself. Its features, useability, and value depend upon the system within which it exists. In other words, its function is restricted to the specific community or system using or issuing it. Crypto tokens are no different, as they are hardwired to DLT systems and only useful within the associated DLT communities. These communities create the token, define its functional scope, and can exchange it for some other physical or digital asset hence creating economic value. However, crypto tokens are not only affected and shaped by the community or system but also shape the profile and nature of the underlying systems in return, in a dynamic and reciprocal way. They attract users to the system or push them away and determine the way and form interactions between community members take place. This interplay between a token and its supporting system defines the *token system*.

The creation and maintenance of communities or systems is an important part of keeping tokens functional (Crisà et al., 2019a). However, token systems are themselves outcomes of a broader socio-technical discourse defining the architecture of the token system as well as its governance. The *socio-technical transition* (Geels, 2005) from physical to digital and now to cryptographic token systems, is in fact the product of constant interaction between tokens, their surrounding systems, and their environment. This transition has also spurred the formation of more radical DLT system innovations (Beck & Müller-Bloch, 2017), including advances in privacy-ensuring cryptography and the optimization of data storage (Zheng et al., 2017), digital assets in supply chains (e. g. Eljazzar et al., 2019), and identity management such as self-sovereign identity applications (e. g. Mühle et al., 2018). These innovations would not be possible without crypto token systems. The transition is also shaping new philosophical decentralized considerations and economic models for networks (Koens & Poll, 2019).

One of the distinct properties of crypto token systems is their integrated memory. They store information regarding token transactions such as the sender, the receiver, the transferred token's amount and price, as well as a timestamp on ledger. In general, crypto token systems are much more capable of working autonomously than other token systems. This is because they can enable forms of algorithmic governance and decision making (Dupont, 2017), via smart contracts, dApps, and DAOs, as well as the automatic transfer of crypto tokens from one address to another.

Taking a closer look at our taxonomy in **Table 1**, it becomes apparent that many features of crypto token systems resemble and might be inspired by physical and digital token systems. On the token architecture level, physical or digital token equivalents can be found for most of the characteristics. For instance, stock certificates, a knight's token, and a dollar coin are physical forms of asset, utility, and payment tokens, respectively; a digital train ticket is a digital token representing a physical train ticket and hence a digital twin. In the token decision rights level, all ownership structures listed can be applied to certain physical and digital tokens as well. The same applies to the system layer: In the system architecture process level, for instance, quantity restrictions (e.g., a limited number of digital tickets to a concert) and an activity status (e.g., currently valid currencies such as the Euro and invalid currencies such as the D-Mark) can be found in physical and digital token systems too. On the system governance decision-rights level, neither how tokens are instantiated (automatically or manually) nor the fact that they can provide obligations and property rights is specific to crypto token systems. Even though many crypto token systems' characteristics are similar to digital token systems' features, their design, implementation, and use often have certain specificities. NFTs linked to DLT systems have given rise to specific economic and socio-cultural phenomena, especially when it comes to certain art- and game-related NFTs such as CryptoPunks or CryptoKitties (Wang et al., 2021).

Table 1 Taxonomy of crypto token systems containing 22 characteristics

Crypto Token System Characteristics										
Token	Architecture	Data	Archetypes	Asset Token	Utility Token	Payment Token				
			Representation	Digital Twin	Digital					
			Fungibility	Fungible	Non-Fungible					
			Divisibility	Divisible	Non-Divisible					
			Spendability	Spendable	Non-Spendable					
			Expirability	Expirable	Non-Expirable					
			Burnability	Burned	Non-Burned					
	Governance	Decision Rights	Ownership	Solo Ownership	Shared Ownership					
System	Architecture	Processes	Quantity	Limited	Unlimited					
			Activation	Active	Non-Active					
			Wrapping	Mint	Burn					
		Networks	Origin	Native	Non-Native					
			Chain	New Chain, New Code	New Chain, Forked Code	Forked Chain, New Code	Forked Chain, Forked Code			
	Governance	Decision Rights	System Scope	Permissioned Private	Permissioned Public	Permissionless Private	Permissionless Public			
			Functional role / purpose	Value Exchange	Information Storage/ Asset Re-presentation	Authenti-cation/ Verification	Access	Incentive Mechanisms	Currency/ Money	Financial Instrument
			Instantiation	Automated	Manual					
			Tokenization	Coinage	Minting					
			Rights	Property	Obligations					
		Accountability	System Roles	Developers	Administrators	Gateways	Participants			
		Incentives	Supply	Rule-based enforcement	Ad hoc Discretionary					
			Distribution	ICO	IEO	STO/DSO	DAICO			
			Incentive System	Create system	Implement system	Use system	Terminate system			

Our taxonomy also comprises several characteristics which are unique to crypto token systems and the blockchain economy at large—for example burnability (the process through which tokens are destroyed by being sent to an inaccessible address). This characteristic differs from digital and analog tokens: even though a burnt crypto token still exists and is still valid, and its location is perfectly known, it cannot be retrieved and thus loses its value. Closely related to this token characteristic are the system features of wrapping and tokenization. Via minting, a token can be transferred to another DLT system. This enables the creation of a new crypto token system based on the original one, making multiple crypto systems interoperable.

Decisions regarding the origin and chain of the DLT system have a tremendous impact on crypto tokens. By designing a non-native token either using a new or forked chain, the system designers significantly increase the complexity of the token system. This is because creating a crypto token on an existing DLT system with its own native tokens leads to a new token system and hence a system of a system (Boardman & Sauser, 2006). This nesting of crypto token systems means that events on the underlying system also affect the new token system, as can be seen in price and sale co-movements such as the price shocks in Ether that are correlated with a decrease in the number of active Ethereum-based NFT wallets (Ante, 2021). Co-movements can be found between different payment tokens such as Bitcoin and Ether, which indicates that there might be dependencies between different crypto token systems on a more general level as well (Katsiampa, 2019).

The scope of crypto token systems is defined very rigidly by the scope of the foundational DLT system. The system designers decide whether they want to grant full writing access to the DLT system (permissionless) or limit it (permissioned). They also decide whether everyone should be granted read access to and the right to create new transactions within the DLT system (public) or whether they restrict these rights (private). These trade-offs between security and speed, as well between transparency and privacy (Drescher, 2017) funnel through to the way tokens can be handled (e.g., who can hold and transfer tokens) in the crypto token system.

The fact that in DLT systems all token transactions are stored in an immutable and time-stamped manner makes auditing much easier in crypto token systems than in others. Lastly, there are specific distribution mechanisms for tokens in crypto token systems such as ICO . However, ICOs have been found to be so risky that they endanger the whole crypto token system and need to be conducted carefully (Zetzsche et al., 2018).

The strong interwovenness of the different architectural and governance characteristics makes crypto token systems highly complex socio-technical systems. They undergo constant changes and can run in part autonomously. Therefore, the rise of crypto token systems brings possibilities as well as risks, and a deep analysis of crypto token systems is needed to mindfully develop strategies and risk mitigation instruments.

6.2 Limitations

Our topic modelling findings are highly dependent upon the 506 whitepapers used in the analysis. Using other or more ICO whitepapers, might have generated additional insights. Also, although we considered seeded and non-seeded LDA topic models we did not employ correlational topic modelling (Blei & Lafferty, 2007) approaches. Such approaches could have led to further insights as well as generating different topic groups. Using document metadata from the whitepapers and a structural topic modelling approach could also have generated more insights from this data source (Blei & Lafferty, 2006). A general problem in LDA topic modelling is coming up with a reasonable number of topics up front; selecting more or fewer topics could have led to different outcomes. In the seeded LDA version, our findings are strongly related to the number and content of the word groups that we set up. Modelling different word groups would also have impacted our ultimate findings.

6.3 Contributions

Our research makes several contributions relevant to both the field of IS as well as blockchain researchers and practitioners. By incorporating a historical perspective on physical and digital tokens we are able to identify universal characteristics of tokens and improve the understanding of cryptographic tokens. We find that tokens always exist within a foundational system of some kind, and that they interact symbiotically with this foundational system to build a token system. Crypto tokens are no exception: in their interplay with underlying DLT systems and the wider environment, they form socio-technical systems. These cryptographic tokens have an architectural as well as a governance dimension which are both human-made. This view of crypto tokens as socio-technical systems allows for a much deeper and interconnected analysis that hopefully will guide and inspire other researchers.

Furthermore, the crypto token classification and system taxonomy that we derived through an extensive analysis of sources drawn from academia as well as practice are also highly relevant for practitioners such as system designers and regulators. The insights can be used to improve both standardization and regulation in the context of blockchain and DLT and to provide guidance to auditors.

7 Conclusion

Tokens have played an important role in human history. The most contemporary form of tokens, DLT-empowered cryptographic tokens, have raised much attention and awareness for their potential in different application areas. In our research, we find that crypto tokens can be classified into: asset tokens, which are linked to physical or digital assets; utility tokens that provide their users with a certain utility such as rewards or access rights; and payment tokens which are used for making digital payments. Through their reciprocal relationship with their underlying DLT systems, crypto tokens form socio-technical systems comprised of humanely designed governance and architecture dimension. Our findings are highly relevant for IS and blockchain scholars as well as organizational decision makers, DLT system designers, regulators, auditors, and others tasked with making mindful decisions regarding crypto token systems. These findings will be particularly helpful in the context of blockchain standardization, regulation, and design, where they will help demystify and illuminate some of the complex and dynamic phenomena happening in the new blockchain world.

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Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author on request.

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