UNIVERSITY OF UTRECHT

MASTER'S THESIS

A framework for designing self-sustaining ecosystems

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Declaration of Authorship

I, Swayam Shah, declare that this thesis titled, "A framework for designing self-sustaining ecosystems" and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
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Abstract

Game and Media Technology
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A framework for designing self-sustaining ecosystems

by Swayam Shah

Blockchain is a foundational technology where the idea of a distributed database and trust is established through mass collaboration and smart contracts. It is being perceived as the next major sociotechnical advancement after the invention of the Internet. Its unique features such as provenance, distributed consensus, and transparency, make it appealing to a wide range of industries like supply chain, finance, heath-care, gaming, and media technology. This study focuses on designing a framework which can be used by blockchain leaders for better understanding of elements and parameters required for engineering and scaling-up their blockchain projects while aiming for a self-sustaining ecosystem. The critical building blocks of the framework are value exchange mapping, determining an evolutionary distributed ledger technology architecture, governance modelling, and token economics modelling, which are all co-dependent variables for designing a self-sustaining ecosystem. The ultimate goal of the framework is to achieve a Minimum Viable Ecosystem which is self-sustaining in itself while having a default market and mechanism design to establish positive-sum game. The positive-sum game is an essential component for any ecosystem to attract and retain network effects. The end goal of Minimum Viable Ecosystem results in a complex adaptive system which requires tools to breakdown the complexity such that it is attainable. For designing the framework, the research employed design science and multivocal literature study along with multiple case studies to evaluate the proposed artefact. The case-studies were aimed at blockchain projects from different fields of work such as academia, startups, and community-driven projects revolving around gaming ecosystem. The results of the case-study were positive and evident of the need for such frameworks to help blockchain leaders to think strategically, critically and precisely.

Keywords: Distributed ledger technology, Blockchain, decentralization, token engineering, digital assets, self-sustaining ecosystems, sociotechnical system

Contents

Chapter 1

Introduction

1.1 Problem Statement

Open-source communities have witnessed unprecedented growth in the last two decades and are becoming the source of driving next-generation innovations (Riehle, 2019). Additionally, the technology giants like Microsoft, Alphabet, Apple etc are investing and promoting open-source projects at large scale, for example, the TensorFlow project by Google Brains have benefited largely from the online community. The open-source projects tend to become platforms for innovation, for example, Linux, Android, Apache Hadoop, Java et. al are some of the prominent foundational technical stacks which have enabled new ecosystems and commercial markets. Especially, for the decentralized ecosystems like Bitcoin, Ethereum and most other DLT platforms, the open-source communities have been the sole driver for research and development (Lindman, Tuunainen, and Rossi, 2017; Bian, Mu, and Zhao, 2018).

Blockchain projects have been easy to bootstrap although when it comes to next step, for going beyond a proof of concept and scaling up while attaining the network effects, numerous blockchain-based projects have failed or substantially devalued. At times, the reason behind the failure is lack of in-depth understanding of intricacies of blockchain systems and availability of right tools to help them navigate, through the all the required parameters to engineer a technically as well as commercially sound product or service. Many blockchain startups or communities lack a well defined revenue model which makes it difficult for them to raise funding. There are instances, where projects decide to completely discard tokenization as it increases complexity in the system, but it backfires as the project loses an important component which can actually help in achieving network effects, scope for monetization strategy and boosting valuation of the project. Also, the DLT projects are generally complex which makes it further difficult for projects to operate at an optimum level. (Hurder, 2020; Panetta, 2019).

The self-sustaining ecosystem has an ingrained capability to operate itself with negligible interference from the outside world. The value is created, distributed, maintained, exchanged and stored within the ecosystem and follows the principles of anti-fragile systems proposed by Taleb and Douady (2013). We discuss our aim for the research in the subsequent section.

1.2 Introduction to Blockchain

Blockchain technology is an establishment of asynchronous communication of a network of thousands of independent nodes with simple and predefined algorithmic rules to accomplish a multitude of functions on the network which might be in the form of transactions or execution of smart-contracts. Blockchain can be perceived as the socio-technical infrastructure (Beck, 2018) aimed to achieve fairness in the system through a distributed consensus mechanism. On the other hand, there are leisurely applications that the blockchain technology is envisioned by Chohan (2017), but research on this is still in its early stage.

Moreover, it is an economic system rather than just a technical infrastructure. When a user needs to transfer a digital title of ownership without a central authority, the infrastructure needs a ledger that records these changes in ownership, so that these changes cannot be refuted or altered by malicious activity. Blockchain offers a highly safe and secure infrastructure to build such ecosystems.

Blockchain, from a holistic perspective, is an interdisciplinary ecosystem which comprises of System Engineering, AI optimization and control theory, Computer science and cryptography, Psychology, design science, Philosophy, Law and Ethics, Economics and Game Theory, Political science and Governance, Operation research and Management science (Risius and Spohrer, 2017). Blockchain is an interesting philosophical ideology (Sfetcu, 2019) and a source of inspiration for developers, but it also has practical applications many of which are already out there and open for start using them (Swan, 2015).

It is widely being experimented for numerous use-cases within gaming and media platforms (Xu et al., 2017), for example, the use of blockchain for keeping track of collectables within a gaming environment as well as using tokens to represent in-game assets which can be traded with other in-game assets or exchanged for cryptocurrencies and further, fiat currency in secondary markets (Attaran and Gunasekaran, 2019). The market for in-game collectable is believed to be of 50 billion dollars according to WAX (2018).

Similarly, media industries are using blockchain infrastructure to resolve the issues of license infringement of intellectual property by recording transaction history with respect to ownership of the digital media asset (Tsai et al., 2017). Therefore, media-attribution is an important task, as it is crucial to resolve the problem of intellectual property while adequately incentivizing (Satchwell, 2005; Burns, 2018) and acknowledging the creator of the content. Along the same line, international media services provider, Spotify had recently acquired the MediaChain startup which is helping them solve the problem of Music-Attribution [1].

In this research, we study, the aspects of blockchain or DLTs to enable SSE and propose a framework which can enable SSE. *To note, there is an ambiguity between DLTs and Blockchain. It should be noted that a distributed ledger is a broad term describing shared databases, hence, all blockchains technically fall under a wider umbrella*

[1]https://techcrunch.com/2017/04/26/spotify-acquires-blockchain-startup-mediachain-to-solve-musics-attribution-problem/

of shared databases or distributed ledgers. However, all blockchains are fundamentally distributed ledgers, all distributed ledgers are not necessarily a blockchain.

1.3 Aims and Objectives

These problems concerning open-source communities and issues for scaling-up blockchain projects and discarding of tokenization due to high complexity, demands to design a framework leveraging the governance, token economics and fair consensus mechanism of DLTs. This can lead to satisfying needs of each stakeholder participating on the network, for recognition and fair incentives while creating a value chain or a marketplace, thus, paving a road for attaining self-sustenance where the value is created, distributed, maintained, exchanged and stored within the ecosystem while having the resilience to external factors.

In this research, we propose a framework, which can help SSE designers (blockchain leaders) to navigate through the intricacies of DLTs and make sound decisions. Further, the framework offers tools to think about consortium modelling and monetization strategies based upon token engineering which is essential for any enterprise-first DLT solution. Moreover, it opens up a wide range of possibilities for in-app marketplaces where digital assets like gaming collectables can be traded, exchanged, gifted or creating new ones without any mandate from the central entity. Therefore, we evaluate the proposed framework by conducting case-studies with multiple blockchain projects working around the gaming ecosystem. Moreover, to the best of the author's knowledge, this is the first attempt towards a framework that is focused on critical elements of blockchain project which assists in carrying out strategic thinking while establishing a precise project roadmap with the aim to attain self-sustenance in the form of a Minimum Viable Ecosystem(MVE).

This research project has the goal of determining design elements of self-sustaining ecosystem(SSE) where 'design' is the purpose, planning, and intention that exists behind the SSE which can be determined by the framework. The framework can be leveraged by SSE designers for effective and efficient strategizing of their blockchain project to scale-up and establish a Minimum Viable Ecosystem(MVE) which is self-sustaining in itself.

1.4 Research Questions

The research question is focused on designing SSE for each and every stakeholder of the community with default mechanism for recognition and incentives. The 'self-sustaining' indicates network equilibrium, where its utility is fully optimized and the network is in balance. Such ecosystems can be extended to every other set of open-source communities where contributors come together to build something they care for and eventually might generate value out of the creation.

The research question addresses a practical problem and is addressed by following the Design Science Approach (Hevner and Chatterjee, 2010)

RQ Main: ***How can a framework be created for designing self-sustaining ecosystems?***

As discussed in previous section, self-sustaining ecosystems(SSE) designers who might be blockchain leaders encountering numerous road blocks when it comes to scaling up DLT based solutions (Croman et al., 2016; Hurder, 2020). We propose a framework such that SSE designers have right tools to determine critical elements for designing SSE with DLTs.

To further structure this research the main question is further sub-divided into three sub-questions.

- **SQ1:** ***What are the core aspects of DLTs for designing self-sustaining ecosystems?***

  This is the most essential part of research as it determines the key design elements for SSE and the importance of using DLTs. We looked into every aspect of DLTs starting from consensus mechanisms, functions of cryptocurrencies, digital assets and token engineering which are all crucial parameters for designing SSE.

- **SQ2:** ***What steps does SSE designer need in order to design a self-sustaining ecosystem?***

  After building the knowledge base with SQ1, we propose set of tools and steps in terms of a framework which makes it easy to consider complex elements such as value exchange mapping, DLT architecture, governance and token economics for any SSE. Further, it can be used by blockchain leaders to make sound and strategic decisions for their projects.

- **SQ3:** ***How can the proposed framework be evaluated?***

  The proposed framework was evaluated rigorously through multiple case-studies from gaming ecosystems. The detailed explanations is covered in following chapters.

1.5 Research Scope

1.5.1 Scope of Research

Our primary focus in this research is to study the role of DLTs in building anti-fragile ecosystems and going in-depth of incentive models enabled by DLTs in the form of the token economy. Antifragility is a property of systems that increase in capability to thrive as a result of stressors, shocks, volatility, noise, mistakes, faults, attacks, or failures (Taleb and Douady, 2013). We aim to propose a framework which satisfies SSE system requirements. Such framework would serve as a blueprint for SSE designers to facilitate the development of SSE. Further, we go ahead and validate the framework through multiple case-studies.

1.5.2 End-Users

The design of SSE is focused for SSE designers(blockchain leaders) envisioning self-sustenance. Moreover, for the evaluation part of this research we use multiple case-studies which are aimed to be conducted with academic and business leaders preoccupied with blockchain projects revolving around gaming and media technology which demands integration of token engineering to attain the state of self-sustenance.

1.6 Overview to the thesis

The overview of the overall thesis is summarized in the figure 1.1. The first chapter talks about the problem statement and the need for SSE along with research questions. The following chapter is aimed at explaining the research methods used for conducting the research. Chapter 3, talks about the intersection of blockchain and gaming along with the case-study of CryptoKitties, signifying the capabilities of representing digital collectables in form of tokens and thereafter, creating marketplaces out of it. Chapter 4, we dive into the intricacies of Blockchain and how they can enable SSE. Chapter 5, we propose the framework along with subsequent frameworks or tools for the respective steps. Chapters 3, 4 and 5 are mainly derived as a result of multivocal literature study. Chapters 6 and 7, are the discussion of case-studies and their results along with the evaluation and evolution of the framework. In the end, chapters 8 and 9, forms the overview of the thesis with discussions, future work and conclusion.

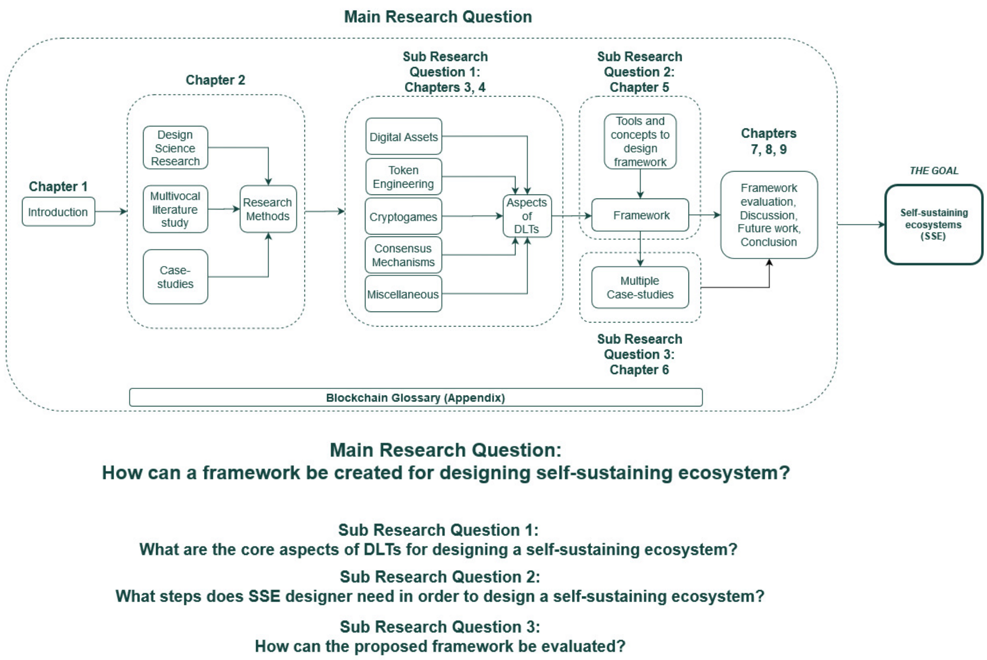

FIGURE 1.1: Overview of overall thesis

Chapter 2

Research Methods

Explaining the research process elaborately is necessary to allow other researchers to assess whether derived results and conclusions are scientifically relevant and reproducible (Bhattacherjee, 2012). This chapter details the research methods followed in this thesis with specific research methods and techniques.

First, the decision to follow the Design Science Research(DSR) (Hevner and Chatterjee, 2010) approach is elaborated, entailed by an explanation of its implications and processes.

Further, the use of the two main research methods are described:

(i) Multivocal literature study (Garousi, Felderer, and Mäntylä, 2016) prior to the framework design.

(ii) Multiple case studies to evaluate framework.

2.1 Design Science Research

Design Science Research offers relevant approach to study the identified problem for the requirement a fair SSE. Moreover, lack of understanding and tools available on the topic of digital assets and token engineering are limited, therefore, by designing a meaningful artefact in the form of a conceptual framework that captures the dimensions and layers of blockchain governance coupled with token modelling. The ultimate goal of this study is to design and evaluate decentralized framework focused on token modelling which can facilitate the creation of SSE. This artefact is envisioned to be a tool for assessing and parameterizing precise requirements for the development of self-sustaining ecosystems using DLTs.

To achieve this, DSR methodology was put to practice. This approach is relevant as the artefact being designed is aimed at improving real world problems (Hevner and Chatterjee, 2010; Wieringa, 2014). As stated by Henver and Chatterjee, design science research should not be confused with design research. As, Design Research primarily focuses on the design of an artefact, Design Science Research also values the generation of new scholarly insights resulting from the process of designing. The artefact produced as part of Design Science Research can have various different outputs as per the guidelines by Hevner and Chatterjee (2010). The goal of this research is in line with the criteria of design science.

Method	SQ1	SQ2	SQ3
Multivocal Literature Review	✓	✓	
Multiple Case-studies	✓	✓	✓

TABLE 2.1: Research methods used to answer the SQs

The DSR research cycle in figure 2.1 was adopted in order to create a scientifically sound artefact of high quality. Moreover, the table 2.1, summarizes the research methods corresponding to the research questions.

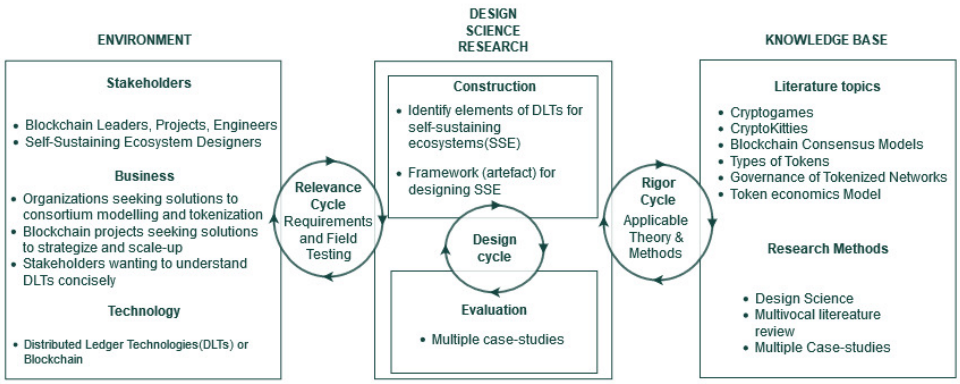

FIGURE 2.1: The Design Science Research Framework applied to this study, adapted from (Hevner and Chatterjee, 2010)

2.1.1 Artefact design and evaluation

Design Science Research can be perceived as combination of two main phases. The first phase entails designing of a new artefact while the second phase deals with the evaluation of the proposed artefact. The phases of design and evaluation are iterated number of times until the artefact is considered ready for the evaluation (Hevner and Chatterjee, 2010).

Figure 2.1 illustrates the Design Science Research Framework adapted to this study. The theoretical foundation of this research is grounded in the multivocal literature revolving around blockchain, digital assets and token economy to establish broad range of topics.

2.1.2 Multivocal Literature Study

A literature review assist in developing fundamental knowledge base in the blockchain space. Furthermore, it helps in identifying gaps in the research, and facilitates to focus on specific area for the research (Wohlin, 2014) which can yield fruitful results for academia and industries.

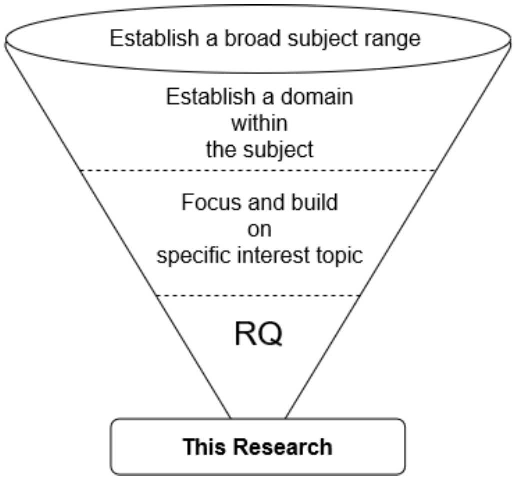

FIGURE 2.2: Literature Study Funnel

Additionally, the research incorporates, a literature study funnel inspired by the visualisation of the funnel method by Hofstee (Hofstee, 2006) along with the snowballing approach (Wohlin, 2014) illustrated in Figure 2.3.

The primary research for the literature study began with a broad range of subjects pertaining to blockchain. These subjects are the state-of-the-art publications such as Bitcoin (Nakamoto, 2019), Ethereum (Wood et al., 2014), Blockchain beyond bitcoin (Crosby et al., 2016), Blockchain: Blueprint for a new economy (Swan, 2015) et. al. The next was to establish a domain within the blockchain which included decentralized autonomous oganization (DAO) (Buterin et al., 2014), blockchain governance and smart contracts (Alharby and Van Moorsel, 2017; Reijers, O'Brolcháin, and Haynes, 2016; Beck, Müller-Bloch, and King, 2018) and Cryptogaming (Kraft, 2016; Attaran and Gunasekaran, 2019). A step further, we narrowed down the research on specific interest topics such as token economics and digital assets(Davidson, De Filippi, and Potts, 2016) that served in answering the research questions. Although, the academic research in these specific areas of digital assets and token economics have been limited due to recent advancements. On the other hand, the grey literature (GL) from open-source communities and platforms have been rampant, in contributing and driving the research in the field of distributed ledger technology. As a result, an academic and GL review was necessary to fill any gaps in knowledge left by the lack of academic literature.

As per the previous research in GL by prominent papers (Adams, Smart, and Huff, 2017; Lawrence et al., 2012), can bring in different perspectives into scholarly conversation to increase its relevance and impact. This statement applies directly to the goal statement of this study. To incorporate both academic and GL into the literature review, the guidelines for conducting an MLR presented in (Garousi, Felderer, and Mäntylä, 2019) were followed which describes MLRs as a form of a Systematic Literature Review which includes GL and published literature. The use of such guidelines improves the design of the artefact by ensuring only credible literature is used and reducing the effects of research bias (Kitchenham, 2004).

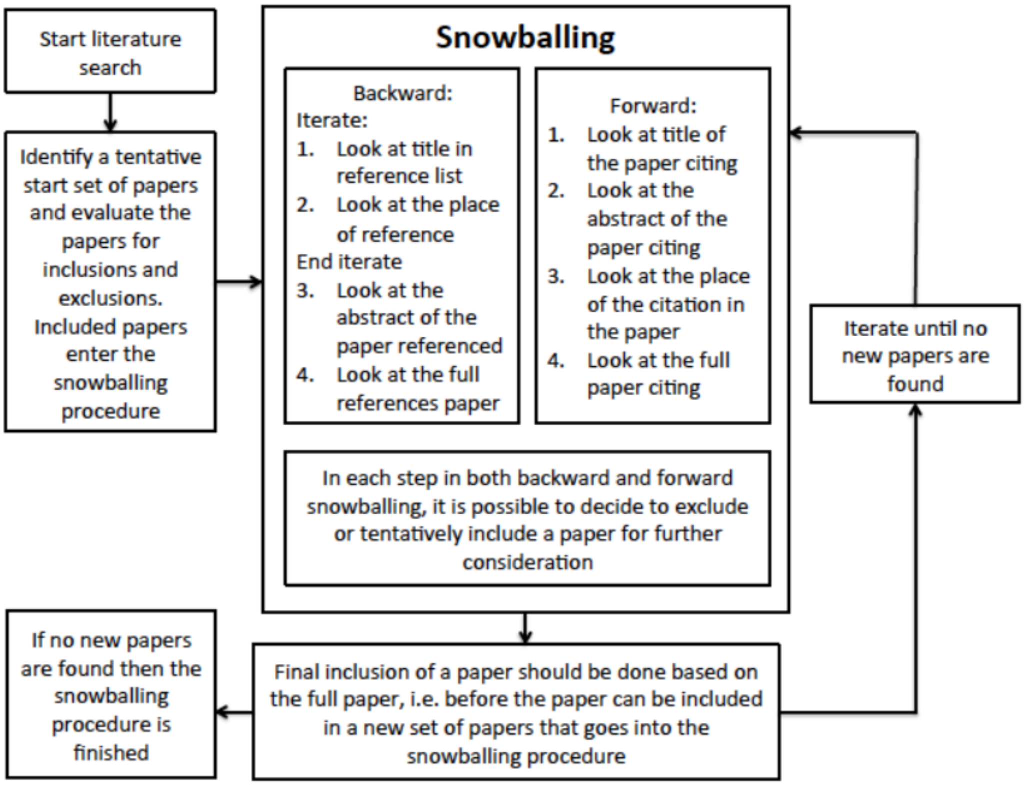

FIGURE 2.3: Applying snowballing technique (Wohlin, 2014)

To answer the research questions, we make use of several research methods where we start with a multivocal literature study which contributed to answering the need for DLTs, token engineering, digital assets, and aspects of DAO for designing anti-fragile ecosystem. Further, we use design science to solidify our findings from the literature study. At the end, for the evaluation, we conducted multiple case-studies with existing projects which can utilize our proposed framework in their current state of work where DLTs and token engineering play an important role.

After completing the literature reviews, we built a knowledge base regarding the topic of blockchain related token economics and digital assets which further assisted in proposing a relevant decentralization framework.

2.1.3 Framework Design

In DSR, the artefact design can be viewed as an inherently creative process (Hevner and Chatterjee, 2010). The decentralization framework is the set of tools which can be applied to any blockchain project which intends to attain self-sustenance state.

First, we start by identifying the relevant decentralization concepts while performing the literature review. There has been a good amount of research in the technology and governance aspects of blockchain although token engineering which enables incentive modelling for the stakeholders on the blockchain network is fairly new domain for the research. Therefore, the decentralization framework proposed would be having more elements of token engineering along with governance and technology as a support elements.

Further details on the design process, including a rationale behind design decisions, is explained after completing the first iteration of design in Chapter 5.

2.1.4 Framework Evaluation

Artefact evaluation is an important task of Design Science Research. Failing to conduct a strict evaluation of the created artefact, the outcome might remain an unconfirmed propositions (Shrestha, Cater-Steel, and Toleman, 2014). A rigorous evaluation of the artefact is key in order to make to deliver a high quality artefact. The Design Science Research Framework by (Hevner and Chatterjee, 2010) provides useful guidelines that describes the intricacies and well functioning of DSR as a whole, however, it lacks the depth on aspects of evaluation strategies, and reporting of the outcomes. Therefore, to accurately report the artefact evaluation, we follow the DSR evaluation reporting structure proposed by (Shrestha, Cater-Steel, and Toleman, 2014).

This structure presents a combined overview of: (i) the inputs in terms of the artefact to be evaluated and the evaluation strategies followed, (ii) a discussion of outputs in terms of the evaluation process, and (iii) the impacts from the evaluation including both immediate findings, their discussion and future impacts. An adapted version of the DSR evaluation reporting structure is illustrated in Figure 2.4.

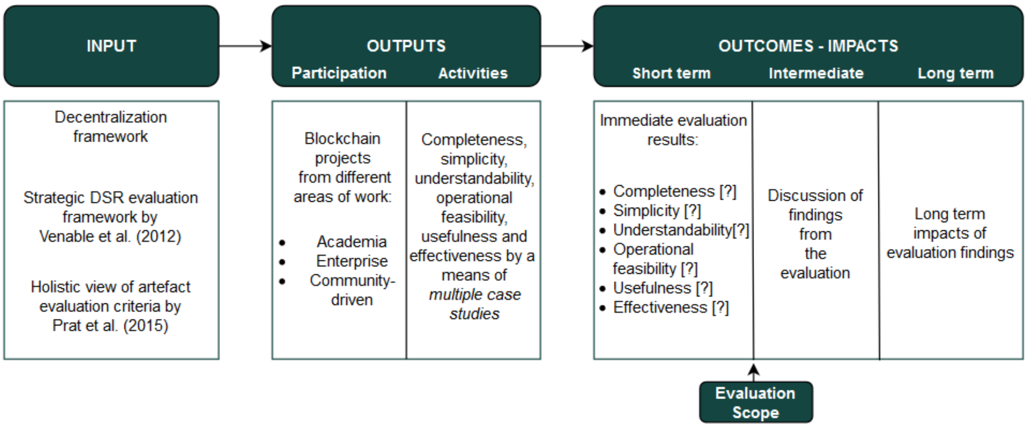

FIGURE 2.4: The DSR Evaluation Reporting Structure applied to the evaluation followed in this study, adapted from Shrestha, Cater-Steel, and Toleman (2014)

2.2 Case-studies

A case study is an observational evaluation method which can be used to study the designed artefact in depth in its intended business environment. Moreover, The use of case studies within the DSR methodology supports the goal of evaluating the effectiveness of an artefact's design Hevner and Chatterjee (2010). This research is evaluated by using a holistic multiple case study approach taking inspiration from the work of Yin (1994), referring to a design with more than one case but only one unit of analysis. The holistic multiple-case study is conducted

Evaluation	Evaluation setting	Evaluation method	Evaluation focus	Evaluation instruments
Design product (Artefact)	Ex-post, Natural	Case study	Effectiveness of model in real life assessment	Taxonomy of Evaluation Methods from Prat, Comyn-Wattiau, and Akoka (2015)
Design process (Research method)	Ex-post, Artificial	Alignment with design science and MLR guidelines	Design Science methodology and MLR method	Guidelines for Design Science from Hevner and Chatterjee (2010) and guidelines for conducting a MLR by Garousi, Felderer, and Mäntylä (2019)

FIGURE 2.5: Evaluation strategy protocol, based on the research by Prat, Comyn-Wattiau, and Akoka (2015)

Criteria	Definition by Prat, Comyn-Wattiau, and Akoka (2015)	Adapted definition for this study	Evaluation Scale
Operational feasibility	Evaluates the degree to which management, employees, and other stakeholders, will support the proposed artifact, operate it, and integrate it into their daily practice.	To what degree do the experts involved in the case-study see the framework being used by other blockchain projects in practice?	5 point LikertScale
Ease of use	The degree to which the use of the artifact by individuals is free of effort and intuitive.	What is the degree of difficulty associated with gathering the information required to answer the assessment questions?	5 point LikertScale
Completeness	The degree to which the structure of the artefact contains all necessary elements and relationships between elements.	To what degree does the model assess the necessary aspects of a framework and contain the questions needed to adequately assess the aspects?	5 point LikertScale
Usefulness	The degree to which the artifact positively impacts the task performance of individuals.	To what degree does the assessment questions extract insightful information for designing self-sustaining ecosystems?	5 point LikertScale
Effectiveness	The degree to which the artifact achieves its goal in a real situation.	To what degree do insights gathered portray the applicability of framework in ongoing projects?	5 point LikertScale

TABLE 2.2: Evaluation criteria and definitions

to demonstrate application of the decentralization framework and to evaluate the influence and effectiveness when applied in the analysis of blockchain projects from different areas of work and having a common aim to attain an anti-fragile state for their ecosystem. This aligns with the study's goal statement as case studies allow researchers to analyze the use of the artefact in depth in its intended real-life environment (Hevner and Chatterjee, 2010). The research entails multiple case studies as it assist in better understanding the intricacies of decentralization framework from different perspectives between the cases. The number of cases were limited to three because it enables the researcher to increase the time and and depth of analysis spent per single case (Gustafsson, 2017). As reported by (Yin, 2013), a case study design can have multiple validity concerns which are discussed in the following section.

Further, the guidelines for conducting case studies from (Runeson and Höst, 2009) have been used and can bee seen in Figure 2.6.

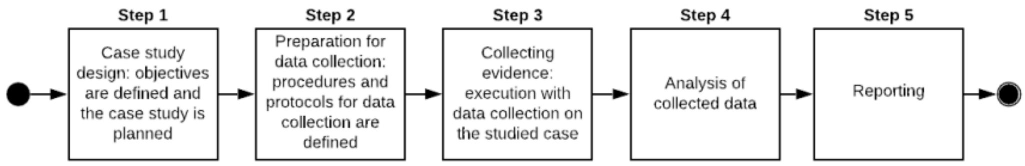

FIGURE 2.6: Case study steps, extracted from (Runeson and Höst, 2009)

2.2.1 Case Study Selection Criteria

The case-study is aimed at blockchain projects from different fields of work such as academia, community-driven projects and startup. The common requirement for the project is that it should be having 'self-sustenance' as a long term goal where digital assets and tokenization are vital elements.

The case-study subjects were selected based upon nature of their project revolving around gaming ecosystem and close to the vision of SSE. In the following chapter, we explicitly explain reasoning behind choosing projects from blockchain gaming(cryptogame) ecosystems. Moreover, while reviewing the projects, an important parameter was if the project is having trouble understanding the fundamental requirements and token economics for scaling up the project to acquire network effects. The total number of case-studies conducted were limited to three due to constraint of time.

Case-study Steps:

Step 1: As discussed previously, the research takes leverage of multiple case studies, where three case studies were carried out to allow comparison of the differences and similarities between them. The ultimate goal is to perceive the influence of the proposed decentralization framework on blockchain projects where the aspect of token engineering is critical. The decision to limit the study to only three cases, is primarily due to the time constraints of this study. The objective of the study is aimed at determining the effectiveness of the decentralization framework as described in table **??**.

Step 2: To prepare for the gathering the data needed to determine effectiveness, an ethical protocol is developed. The protocol contains elements addressing: Informed consent, review board approval, confidentiality, handling of sensitive results, inducements and feedback (Runeson and Höst, 2009). A draft of this protocol was peer-reviewed and piloted prior to sending to the prospective blockchain projects, ensuring the wordings and instructions of the document along with preciseness. Once an agreement has been reached with the project, a list containing needed information is sent. Additionally, there were two rounds of meetings/discussion scheduled, first at the starting of the case-study and next at the end of the case-study. The overall duration of case-study was three to four weeks. Nevertheless, the projects were allowed to ask questions or schedule an additional meeting, if required.

Step 3 and 4: The discussions were recorded and further converted to transcripts to extract necessary information for reporting. This was done with proper consent form, respecting the privacy of the participants. Moreover, some information that could violate confidentiality or are not meant for public knowledge were not reported, respecting the terms and conditions.

Step 5: At the end, the report contains all the perspectives and insights along with critical comments from the study. Also, the analysis and scoring as per the guidelines were reported.

The goal of Case Study: *The most relevant outcome of each case-study would be if the framework, assisted in giving the project a well-defined direction along with all required parameters such that it can aim for self-sustenance.*

For detailed case-study protocol, refer to C.

2.2.2 Threats to Validity

In this section, we discuss, threats to validity as mentioned by (Wohlin, 2014) and (Runeson and Höst, 2009) in their study, which boils down to four major threats, construct validity, internal validity, external validity, and reliability.

Construct validity refers to the degree to which this study measures what it claimed to measure. This threat was mitigated by peer-reviewing the protocol and piloted prior to implementation. Additionally, the use of multiple cases studies for evaluation improve this threat. Another significant improvement is through the tracebility that is naturally part of the thorough MLR process.

Internal validity is the extent to which a piece of evidence supports a claim about cause and effect, within the context of this study. As per (Johnson, 1997), the researcher is metaphorically termed as a 'detective' for conducting Internal validity where the researcher searches for the evidence about cause and effects. For this research, the strategies used are 'Data triangulation' where we utilize multiple data sources along with 'Theory triangulation' which is further coupled with 'participant feedback' to help understand the influence of the framework. Through internal validity, we aim to reduce the complexity of blockchain powered ecosystems by understanding each aspect of the infrastructure.

External validity is degree of which the conclusions of this study can be applied outside of its context, across other situations, people, stimuli, and times. As the framework, is aimed to be tested at three different levels of blockchain projects, community-driven project, enterprise level project and a startup level project. It provides a foundation for expanding its depth of coverage, creating a catalyst for the potential to be applied in other situations.

Reliability is concerned with to what extent the data and the analysis are dependent on the specific researcher. As the lack of academic literature on token engineering, digital assets and decentralization framework design was identified in the preliminary research phase of this study. The need for including GL in the literature review to understand the dynamics of these topics and the process in which it can be streamlined in terms of usability was required. This need was also validated by answering questions for determining the necessity for a MLR presented in (Garousi, Felderer, and Mäntylä, 2019). The steps taken in the MLR have been clearly detailed in Section 3.1.2 and records kept enabling traceability of the decisions made throughout the study. Nevertheless, the protocol for the MLR states that at least two researchers should conduct the quality assessment and code the literature (Garousi, Felderer, and Mäntylä, 2019). This was out of the scope for this research as it was conducted by only one researcher. This can be perceived as a source of researcher bias in the literature selected and following assessments during the MLR.

Chapter 3

Research Context

3.1 Blockchain and Gaming

The cryptocurrency specifically Bitcoin, in the previous decade has been a growth machine while attracting attention from various of stakeholders across various demographic regions, academia and areas of businesses which has significantly contributed to its network effects. The network effects is defined as a phenomenon whereby increased numbers of people or participants improve the value of a commodity or service (Katz and Shapiro, 1994). Moreover, some authors have also perceived Bitcoin as game and further compared it to the genesis of Game Studies (Kavanagh, Miscione, and Ennis, 2019).

The blockchain technology is believed to be one of the most forthcoming and disruptive technology which has widespread range of applications starting from FinTech, HealthCare, Supply-Chain, Internet of Things(IoT), Social Media, Telecommunication, Gaming and media technology et. al (Swan, 2015).

Subsequently, the global state of online gaming industry is exploding in the entertainment space. According to the multiple reports by Newzoo [3], which is the leading research firm in the gaming industry, at the turn of the century the gaming market and the global music industry in the global film industry was about the same size but over the last two decades the gaming market has witnessed unprecedented growth. In 2025, it is expected to be a 300 billion dollar market.

This section is result of multivocal literature study as suggested by the guidelines of Garousi, Felderer, and Mäntylä (2019). This chapter justifies our choice for using blockchain gaming projects as a subject of our case-studies.

3.2 Current state of Gaming ecosystem

Gaming ecosystem as a whole as per the revenue and audience engagement, is larger than the film and music industry combined together. Moreover, the number of total gamers in 2020 is expected to be atleast 2.6 billion. The noteworthy thing about games is that as more and more people around the world are playing on pcs, consoles and smartphones. The highest number of gamers tend to play games through their smartphones due to portability and convenience. These crucial factors which have significantly contributed to the gaming ecosystem and

[3]https://newzoo.com/insights/trend-reports/

this has further motivated game developments within mobile devices.

The gaming has always been at the bleeding edge of new technologies, right from personal computing, the Internet, CD-ROMS, AI, cloud computing and evidently the mass-adoption of smartphones and social networks. Moreover, as of today in 2020, the same phenomenon can be extrapolated for Augmented Reality(AR), Virtual Reality(VR) and Mixed Reality(MR) where gaming is leading the research and development in these technologies which is directly contributing to market conversions. The adoption of new technologies such as 5G, Edge computing and enhancement of hardware equipments coupled with new state-of-the-art graphics algorithms are going to assist in engineering of more immersive gaming experience which can fuel up the rise of gaming ecosystem as it attracts more stakeholders in the coming years (Meijer, 2015).

The peculiar thing about gaming ecosystem is that it has given rise to new third-party marketplaces and scope for new digital economy. With an increasing adoption of gaming space, *a step-function innovation of digital collectables is becoming prominent(Stini, Mauve, and Fitzek, 2006)*. It is gaining quick popularity and influence in the gaming community. The digital in-game assets have been an important source of revenue models for gaming studios. According to an article by TechCrunch [4], the estimated global digital collectible market is expected to be 370 billion dollars. Additionally, there are some outliers like expensive baseball cards that sell for millions of dollars like the 'Honus Wagner' card which was auctioned for approximately 3 million dollars [5]. The scarcity of digital collectables makes them valuable and source of value storage.

3.2.1 Problems within the gaming ecosystems

There are several platforms which facilitates trading of gaming accounts, for instance, the online portal of GamerMarkt [6], facilitates buying and selling of entire gaming accounts for games such as Fortnite, League of Legends, Clash of clans and many more. For instance, a user plays a game of 'world of warcraft' for few days and builds up the profile with required in-game assets and right gears that is perceived valuable by the game community and then there are several subreddits, where the user can go to and sell the entire account with the login credentials with password to another player. Nevertheless, the trading of digital game assets is still limited with some dark web portals. In most of the cases, these portals for gaming accounts and digital assets have found out to be unreliable due to numerous scams and frauds. These instances lead to an unfair gaming ecosystems which is not fun for gamers as well as the gaming studios as they encounter losses in revenue. Adding to it, there is no remediation if a user gets cheated out of their money and most game studios hate this as it creates a customer support nightmare as well as it creates room for security vulnerabilities in the game.

[4] https://techcrunch.com/2020/03/25/the-future-of-collectibles-is-digital

[5] https://www.forbes.com/sites/davidseideman/2019/05/30/iconic-honus-wagner-card-sells-for-1-2-million-in-private-sale/2734afe79554

[6] https://www.gamermarkt.com/en

On the other hand, the global state of the game industry provides many reasons to be critical of them, one of such instance is when the Blizzard's End UserLicense Agreement [7] is an example of denying players' ownership of in-game assets.

The rise in this space is expecting more people to join gaming industry in near future. The gaming offers opportunities for gamers and game developers to earn living but the probability to make it as a professional gamer is too thin as the space is joined by increasing number of gamers.

Moreover, the game crunching is a serious problem affecting community of game developers as they experience a great deal of exploitation and disparity due to the 'crunch culture' which is the point at which the team is thought to be failing to achieve milestones needed to launch a game on schedule which at times results at the end of their employment (Larsson, 2018; Dyer-Witheford and De Peuter, 2006). In the recent times, this has been a major issue at major gaming studios [8] which puts the gaming industry under the spectrum of judicial activities.

At this confluence of opportunities, risks, issues and centralized control of gaming studios, *blockchain opens up door for next major revolution within the gaming ecosystem and specifically this is focused on economic revolution within gaming as it perfectly aligns with the digital nature of games (Attaran and Gunasekaran, 2019)*.

To take note of, the academic literature as of now is very limited as discussed in previous chapter, therefore here many references rely on journalist publishing, media coverage, and dApps analytic data.

3.2.2 Intersection of Blockchain and Gaming

Digital Assets and Ownership

The DLTs are already upending these odds and opening up new opportunities for gaming ecosystem. Now let's shed some light on digital ownership on blockchain. Bitcoin invented a way for a user to truly own a digital asset which is not dependent on the government or any other private financial institution to authenticate and validate their ownership of asset. Another important element is provenance, which is the complete history of a digital asset from its origins and followed by, the safe and secure way to do peer-to-peer transactions without depending on any intermediaries (Nakamoto, 2019).

Digital ownership for in-game purchases of virtual items is a business of multi-billion dollars and a large share of revenue for game studios is dependent on in-game purchases of assets (Grimes and Feenberg, 2009).

[7] https://www.blizzard.com/en-us/legal/fba4d00f-c7e4-4883-b8b9-1b4500a402ea/blizzard-end-user-license-agreement

[8] https://www.businessinsider.nl/video-game-development-problems-crunch-culture-ea-rockstar-epic-explained-2019-5

A thought experiment:

To illustrate the present scenario, let's imagine a Batman costume in the 'Fortnight' game cost few bucks which can be purchased by player as the limited time edition. Now, after a while, the player is no longer using the costume and wants to sell it to another player that might have missed the sale of special editions. But in the present scenario, there exist no in-game marketplace to facilitate such trading. Also, the players don't own the license to a digital copy of this asset. Now a feasible option that opens up is the option to use peripheral markets where players can buy and sell entire game accounts because as discussed previously, they can't actually own the items and trade those items. This method has its own flaws and security implications. Further, if the Batman costume was on a public blockchain, it would be the equivalent of going to a Halloween costume shop and buying a Batman suit which can be traded, gifted, or whatever the player intends to do with the asset. If the player intends to sell the costume, the transaction is peer-to-peer which is safe and secured as compared to transactions in deep web. Further, with the help of smart contracts, an escrow can be created which can assist in avoiding scams, frauds or any kind of disputes between players.

Nevertheless, with ingrained provenance, effectively every item has a history and background that basically makes the asset 'scarce' in itself. So even if a game has a million swords or if the 'Fortnight' sells the same Batman costume in the same color, each skin is ultimately different because each asset is linked to the unique experiences of that particular player. This gets more interesting from the perspective of owning an unique digital asset which has long and heroic history entailed that is adding a real and verifiable value to it. Moreover, the aspect of immutability is equally important as it means that if the game ever dies, the digital assets will be permanent.

So, when blockchain technology is applied to gaming in the right manner, it unlocks the real ownership for digital assets, capabilities of in-game marketplaces and creates residual value for virtual items as well as in certain cases turn digital purchases into investments (Min et al., 2019).

A step further, these digital assets can be represented in the form of tokens. Generally, tokenization is the representation of assets in a blockchain, making their ownership flexible and programmable (Hargrave, Sahdev, Feldmeier, et al., 2019).

Along the same lines, the research conducted by Sultan, Ruhi, and Lakhani (2018) proposes a matrix with an intersection of blockchain scope and blockchain access, where the gaming is at the sweet spot as depicted in the figure 3.1. Additionally, a research conducted at McKinsey Digital (Carson et al., 2018) for the feasibility analysis of blockchain in various field of work, 'Technology, media, and telecommunications' category was at the forefront while specifically highlighting importance of 'Digital Assets'.

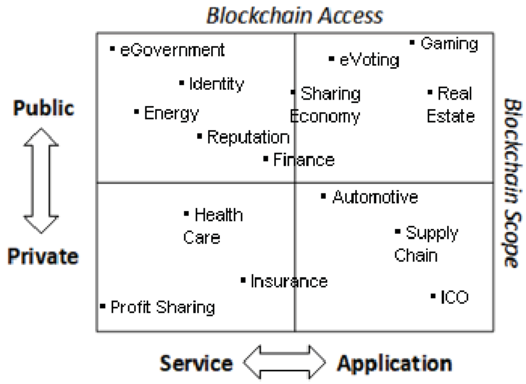

FIGURE 3.1: Blockchain Access-vs-Scope Matrix by Sultan, Ruhi, and Lakhani (2018)

Tokenization

Tokenization can be leveraged for company shares, software licenses and video game items, anything that is already digital can easily be tokenized.

The tokens can enable the use of same digital asset in another game. In this manner, the utility value of the content goes up. A lot of video game platforms are supporting the integration of tokenization of the digital assets that have historically been purchased or earned via gameplay. The ease with which games are able to attract and sustain significantly large user base, most innovation in the tokenization space is the contribution from the gaming sector (Qiao, 2020).

These aspects of digital ownership provenance as well as peer-to-peer trading or internalizing in peripheral markets creates a new form of community economics right inside of a game so imagine that there is a version of an in-game marketplace like 'Ebay [9]' where players can buy and sell the virtual goods, an in-game 'Etsy [10]' where creators and artists can create new skins and costumes which can directly be plugged into gameplay, an opportunity for digital artists to envision new assets and sell them and something like a 'TaskRabbit [11]' where users can find another player and hire them to help them accomplish tasks in a particular game.

Blockchain technology unlocks the possibilities for gaming enthuse to become creators, entrepreneurs and service providers and best of it can be done along with preparing for world-class or professional eSports athlete as well as the players involved with entertaining through streaming live games to earn living from gaming industry.

The game developers can configure their smart contracts to take a cut of every transaction, this can significantly increase revenue over a period of time for gaming studios and while relying on cryptographically secured technology.

The potential impact on the DLT landscape, is quite profound. Businesses already present in the collectibles market have new offerings, demographics and

[9] https://www.ebay.com/
[10] https://www.etsy.com/
[11] https://www.taskrabbit.com/

economic impacts to take into account, for example, the platform of 'Gamedex [12]' which is a digital collectible marketplace built up on blockchain, offers similar prospects. To grab the opportunity, even household brands of gaming studios are acknowledging significance of blockchain technology and building strategies around it (Baikal, 2019). Moreover, to validate this study we went further to set up a detailed case-study with a Digital Collectibles startup from Switzerland.

Moreover, digital games are often regarded as an industry where technological innovations first gets tested and adopted, it is logical to assume that also DLTs would also find its way within the arena of digital games. As of April 2020, according to 'State of the DApps', which is the online data analytics platform for DApps.

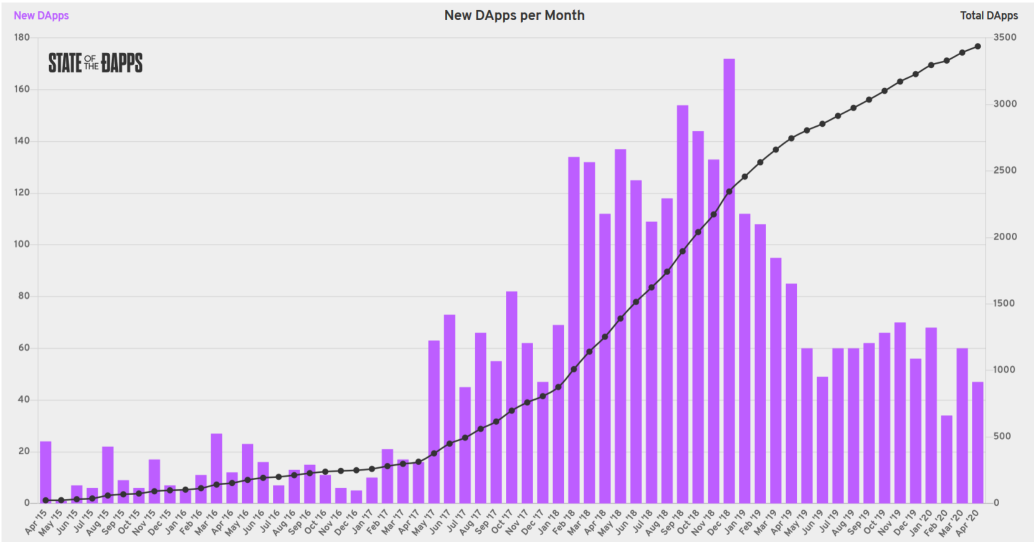

FIGURE 3.2: State of the DApps: Total number of DApps

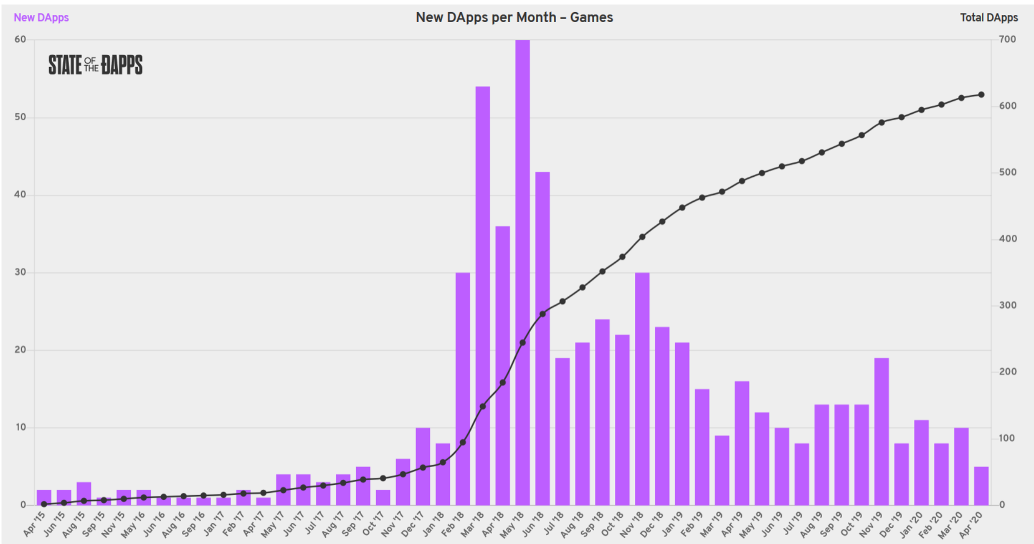

FIGURE 3.3: State of the DApps: Total number of Cryptogames

[12]https://www.gamedex.co/

The figure 3.2, depicts the overall scenario for total number of DApps across DLT platforms over the period of time and subsequently, figure 3.3 depicts the overall scenario for total number of Cryptogames that are rising and adding to the ecosystem across DLT platforms. This makes it is quite evident that there are approximately 600 cryptogames out of approximately 3500 DApps where cryptogames are at the forefront for blockchain technology. Additionally, these games are not inclusive of gambling games which are again one of the leading domain under blockchain applications.

Further, analytics services such as DappRadar(2020)[19] *infers that blockchains are mainly used for two types of games:* ***online casinos and collectibles.*** Although, only a small minority of these games, have a stable player bases and are able to bring profits to their owners (Serada, Sihvonen, and Harviainen, 2020).

Multilevel analysis has enabled a grounded discussion on the opportunities and business potential of blockchain based game design (Attaran and Gunasekaran, 2019). Ludic aspects of blockchains are especially visible in the cryptogames. There are several examples of existing cryptogames such as Cryptopunks, Decentraland, MyCryptoHeroes, HyperDragons, Gods Unchained, and Etheremon etc.

Although, one of the most talked about blockchain game is the CryptoKitties. It is generally used as an important and required case-study to dig into digital assets and Cryptogames (Serada, Sihvonen, and Harviainen, 2020).

3.3 CryptoKitties: Digital Asset Case-study

In December 2017 during the peak of cryptocurrency market value, CryptoKitties [13] gained unprecedented popularity amongst the hype. CryptoKitties is an online multiplayer game developed by Dapper Labs, Canada. It is built upon the blockchain platform called Ethereum network. In the global context, it is generally perceived as the benchmark example when it comes to the operations of digital assets enabled by blockchain as the platform gamified the idea of digital collectables in a comprehensible manner (Scholten et al., 2019). The CryptoKitties became the first distributed application based on smart-contract to reach the mainstream audience where it showcased some fundamental concepts of smart-contract (CryptoKitties, 2018).

Goal:

Our goal here is to investigate CryptoKitties as an example of blockchain-based gamified digital assets and cryptogame in itself.

There are three major reasons. First, blockchain technology is considered to be the disruptive technology which is going to influence multiple domains such as financial services, smart contracts, business models, logistics, secure communication, and governance models. Second, CrptoKitties highlighted some crucial limitations of blockchain technology amidst its hype. Third, the most

[19] https://dappradar.com/ranking
[13] https://www.cryptokitties.co/

important aspect with respect to the scope of this research, economic ramifications of digital assets which might be in the form of non-fungible tokens (NFTs).

We use CryptoKitties as a case-study to go in-depth of the possibilities and limitations of digital assets.

Introduction:

CryptoKitties is a digital asset trading game, where the game offers three functions to players, first the ability to purchase and sell individual virtual cats through the CryptoKitties marketplace, second the ability to breed two virtual cats to produce an offspring and third is the function to collect unique virtual cats in the form of digital intangible asset. Each virtual cat has an unique genetic code, denoted by a 256-bit unsigned integer that is immutable based upon the properties of blockchain and further governed by the intricacies of smart contracts. In this manner CryptoKitties, exemplify the concept of non-fungible tokens, because every virtual cat is unique, immutable, and may contribute to high market demand because of its uniqueness as result of being a scarce asset. Therefore, they are particularly suitable for digital collection games where the purpose is to acquire the rarest possible items. As blockchains ensure the validity of blocks by resisting the modification of data by design, they enable the kind of artificial scarcity of digital goods that forms the basis of online economies.

Gameplay:

Breeding and trading virtual cats, are the two most vital activities from the perspective of gameplay, and the player's motivation lies in the possibility of increasing the in-game and out-of-game value of these virtual cats. For the game to be successful while attracting new players, in economic terms, there should be clear and precise incentives for the player both to take part in the multiplayer game which is the possibility to own an unique cat and to be able to prosper through their ownership that when they can trade the unique digital cat on in-game or peripheral market.

Blockchain-based tokens and assets are stored in players' wallets and they are tradable as an open market exists for them. *Player-owned content is often perceived as one of the core values of cryptogames.*

Taking a closer look at the gameplay of CryptoKitties, players can breed, develop, and beautify virtual cats. If the cat resulting from breeding has some rare attributes they can trade the cat to the highest bidder on the in-game marketplace. Due to its mechanics relying on the Ethereum blockchain, each cat is unique and can only be traded by the owner unless the current owner explicitly grants permission for an Ethereum transaction. Even the game developers of CryptoKitties don't hold any control over the ownership of virtual cats. Nevertheless, new genes are rarely introduced, as they are meant to be scarce, and there is a limit to them hardcoded into the game system.

For the first time, the non-fungible digital tokens (unique virtual cats), purchased with fungible tokens Ether which is the operational currency on Ethereum network, with each cat only able to be produced by breeding a specific combination between two parent cats. The resulting image of the cat, that determines it's appearance, is executed completely server-side and front-end having no role to play. At the end it is just an unsigned 256-bit integer.

Analysis:

The value creation within CryptoKitties is dependent on three parameters, first, by analysing, the functions of blockchain as the basis for the valuation, second, significance of rematerialization in the gameplay, and lastly, the ownership of tokens or digital asset is tied to its value in cryptogames.

The most fascinating aspect of Cryptogames and digital assets is the possibility to interoperability. For instance, a recent collaboration between CryptoKitties and Gods Unchained (Labs, 2019), in which the players of both games can acquire unique items to add to their digital collections and now, with the interoperability these digital assets can be traded with each other and shared as assets in both the games universes. If this can be extrapolated to the traditional gaming, the gamers of 'Fortnight' owning a specific gun artefact, can now use the same gun in the 'Counter Strike' and moreover, they have an option to trade them in-between games in the same marketplace which is reliable and safe.

On the other hand, there are several limitations in the intricacies of CryptoKitties which can be extended to as being the fundamental issues in the underlying network of ethereum on which it is developed (Bez, Fornari, and Vardanega, 2019). For example, each activity in CryptoKitties costs money although they only cover the costs of mining for newly minted cats and do not generate any profits for the game developers or game studio. Developers claim that the new virtual cat minted is the most demanding aspect of the game from the perspective of the computing power on the blockchain, and this is also the reason why the birthing fee is drastically high (Serada, Sihvonen, and Harviainen, 2020). Simply put, this is the fee paid to miners in the form of transaction costs or technically known as 'Gas' which is paid out in the form of native cryptocurrency(Ether for Ethereum) of the particular platform, for computing new blocks or smart contracts(here, virtual cats) in the blockchain. Also, the game mechanics of cryptogames entirely depends on the intricacies of the underlying distributed ledger technology upon which they are built.

The fee or gas is established on the basis of an auction, where each player sets their gas limit which is the maximum amount of units of gas the player is willing to spend on a transaction. The transaction fee itself consists of this gas limit times the gas price that the player sets to pay per unit of gas. The price the player is willing to pay influences the mining time of the transactions required (Wood et al., 2014; Lamison-White, 2019).

Thus, this can lead to disparity in the network where wealthier players can pay relatively more to speed up transactions, while players who are less keen to spend their cryptocurrency on gas. Moreover, there are at times events where the player needs to wait for hours for a basic transaction in the game to resolve. Also, the fee increases with the total number of simultaneous transactions in the game, which means that the game is simply unfair for less wealthy players especially during major in-game events. In the worst case, the whole Ethereum network gets overwhelmed with the number of transactions which is the most critical problem in terms of scalability (Lamison-White, 2019). The CryptoKitties became the first dApp to have launched and caused serious distress where all transactions were slowed down or even halted regardless of amount of gas being offered to miners (Chengevelyn, 2017).

Therefore, the money spent is in the form of transaction cost on blockchain network, this includes giving away a virtual cat for free or cancelling its sale. This is because the checking of transactions in distributed peer-to-peer networks is relatively slow, so any transaction in the game, from a trade to simply cancelling the trade, can take from seconds to several days that is directly dependent on the fee and network load. The other critical hurdle is the expertise required to perform these operations on in the game. These downsides of blockchain technology makes it inapplicable for the design of most popular game genres such as first-person shooters or real-time strategy, although there are several attempts being made in that direction, for example, EOS Knights and Epic Dragons.

The aspect that it is not possible, as of now, is to generate profit from in-game activities and further distribute them to game developers or the studio. This is a clear downside of a digital game based on blockchain technology. This is where we can play around token economics as a part of decentralization framework that works seamlessly (Serada, Sihvonen, and Harviainen, 2020).

The solution to overcome these challenges lies in using different consensus method at the bottom stack or using layer-2 scaling techniques (Hafid, Hafid, and Samih, 2020). The most talked about and being considered for Ethereum network is Proof-of-Stake as it gives new opportunities for token engineering. In addition, the technology is making noteworthy strides in the smart contracts domain. However, the DLT stack is fairly recent and algorithms of value creation tend to go askew when they encounter the limitations of the real-world economy. Nevertheless, the research and development is significant within the blockchain space and working towards a overcoming these issues.

The significance of blockchain in this way can be theoretically associated with the rise of digital distribution systems of games, the erosion of boundaries between players and developers, and the growing importance of user feedback in building sustainable gaming infrastructures. This study, proposes a framework which can be used to further study, the possibilities to build better economic system for future cryptogames. Moreover, the research focuses on the possibilities and challenges motivated by the intricacies of blockchain and digital assets in the gaming arena, to further design SSE which thereby can push forward the industry and innovations. Moreover, the combination of blockchain and digital-assets would assist in for the incorporation of a value chain for incentivizing stakeholders while preserving and respecting their intellectual property (Rae and Thorwirth, 2017) through tokenization.

The resultant framework provides the design to unlock the true economic and creative endeavours to pursue within a DLT project.

Chapter 4

Distributed Ledger Technology

4.1 Introduction

A critical difference between a distributed ledger and blockchain is that a distributed ledger does not necessarily consist of blocks of transactions to keep the ledger growing. Rather, a blockchain is a specific type of shared database that is comprised of blocks of transactions. An example of a distributed ledger that does not use blocks of transactions is Hashgraph (Baird, 2016). Hashgraph is a distributed ledger which is developed to record and manage agreements, in the form of a Directed acyclic graph(DAG).

On the other hand, more widely known blockchains like Bitcoin and Ethereum make use of blocks to update the shared database on a distributed ledger which is distributed among its participants and spread across demographics. This type of ledger can be either private or public. In next section, we explain types of DLTs.

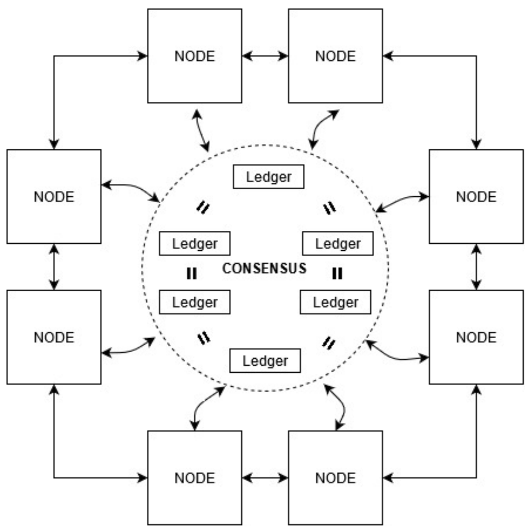

FIGURE 4.1: Blockchain Model

The DLT is a database that is spread across several nodes or computing devices across the world. DLTs offers a compelling paradigm shift, first ideologically and thereafter technically. It is an opportunity to re-evaluate our existing approach to build hierarchical societies and ecosystems which are highly inefficient and tends to cause a disparity in the system (Rajan and Wulf, 2006). Blockchain is one form of distributed ledger technology. It employs a chain of blocks to provide a secure and valid distributed consensus. Blockchain technology is termed as one of the most potent technology to revolutionize applications and redefine the outlook of digital economy (Underwood, 2016). The blockchain is bringing in the shift from centrally operated applications to decentralized applications(dApps). The advantage of dApps is that they are not owned or controlled by a single entity (e.g. banks, governments, and private corporations). This makes it uncensored and a community-driven technology following a peer-to-peer approach. Blockchain is also perceived as a 'trustless network' which can be interpreted as there are consensus mechanisms in place by which all entities in the system can reach a consensus about the truth. Power and trust are distributed or shared among the nodes of the network which makes it distributed network of trust rather than concentrated in a single individual or entity. Here, the nodes are the stakeholders of the network which can be developers, miners, and other users. Moreover, the blockchain is *immutable* as the data in a blockchain cannot be altered. Each block of information, such as transaction details or any message, proceed using a cryptographic function which is a hash value. The goal of a distributed consensus algorithms is to allow a community of users who are demographically spread across the globe for coming to an agreement on the order in which the users generate transactions, where no user is trusted by everyone. On a distributed ledger, entire network records and validates each transaction. In this perspective, it is a system for generating trust, when individuals do not already trust each other (Swan, 2015).

4.1.1 Tiers of Blockchain Technology

The evolution of distributed ledger technology over the last decade has been incredible. The evident blockchain revolution started with the prominent platform of Bitcoin (Nakamoto, 2019) which is perceived as **Blockchain 1.0** by the community. Bitcoin is a peer-to-peer technology facilitating digital transactions eliminating intermediaries such as financial institutions and government organizations. Bitcoin is all about digital money well-known as cryptocurrency. The feature of micro-transactions enabled by bitcoin is one of the most fascinating features because of its ability to influence day-to-day transactions as well as giving rise to new business models. However, the bitcoin network has a limited spectrum of applications, mainly pertaining to cryptocurrency transactions. Thereafter, there have been unfathomable applications of blockchain technology to a greater extent of DLTs (Swan, 2015).

Furthermore, the evolution of **Blockchain 2.0** was the rise of the concept of smart contracts, dApps and decentralized autonomous organizations (DAO) which enhanced the level of applicability of DLTs. These transformations are supported by the widely used, Ethereum network. The smart contracts are autonomous computer programs that execute without human intervention with predefined facilitation, verification or enforcement of the performance of a contract. The feature of immutability in blockchain makes it infeasible to hack or tamper smart contracts. The idea of smart contracts originated with Nick Szabo, who described the concept in 1994 (Szabo, 1994). In this context, a smart contract is code that is stored, verified and executed on a blockchain (Christidis and Devetsikiotis, 2016). Similarly, DAOs are built leveraging smart contracts where a set of participants interact with each other according to a self-enforced protocol. The major bottleneck realised was the scalability issues which hampered the mass-adoption of these dApps (Gervais et al., 2016).

The next evolution, **Blockchain 3.0** was all about over-coming scalability issues and development of new platforms with different consensus mechanisms like Directed Acyclic Graph(DAG) which is another form of DLTs. Hashgraph (Baird, 2016), IOTA (Divya and Biradar, 2018), and NANO (LeMahieu, 2018), are some of the platforms redefining the intricacies of DLTs while using DAG. Simultaneously, the rise of private and permissioned blockchain is significant as it uses DLT fundamentals having a centralized consensus mechanism such as Hyperledger, R3 Cordo and Quorom. These are mainly leveraged within private institutions including banks and governments. These private networks often have high throughput as they run internally with limited participants and transactions.

Over the time, the blockchain technology has seen major upgrades in terms of technological advancements as well as adoption among private institutions and influencing governments, space program like NASA to start experimenting with the technology across various use-cases (Mital et al., 2018; Brambilla, Amoretti, and Zanichelli, 2016). As the technology is massively upgrading, there are numerous use-cases such as financial institution using blockchain for transaction records, auditing, asset management, healthcare where medical records are being recorded on blockchain and supply chain giant like Maersk (Lal and Johnson, 2018) is using it to trace import-export deliveries using DLTs.

Similarly, the technology can be crafted as a registry to record authorship and keep track of each activity for protecting copyright infringement of any code-base or digital media artefacts (Dutra, Tumasjan, and Welpe, 2018). Moreover, over the period of time the network can attain the state of self-sustenance.

4.2 Types of DLTs

There are several types of DLTs. They can be classified on basis of their functionalities and capabilities. Primarily, they are combination of private, public, permissioned and permissionless. Private can be defined as a ledger where direct access to blockchain data is limited to predefined or registered users. Thus, selected users have access to blockchain platform. Contrarily, public blockchain has no restrictions on reading blockchain data. Thus, everyone on the public blockchain is authorized to access, append and update data. Moreover, Permissioned blockchain is where transaction processing (mining) is performed by predefined users. Thus, a node requires authorization to mine blocks and contribute to the chain. Similarly, Permissionless blockchain is where there are no restrictions on the identities of processors. Thus, every node can mine blocks and contribute to the chain. Although, best categorization of various blockchain or DLTs can be perceived through 4 quadrants where each platform can be categorized under Public-Permissioned, Public-Permissionless, Private-Permissioned and Private-Permissionless (Friebe, 2017).

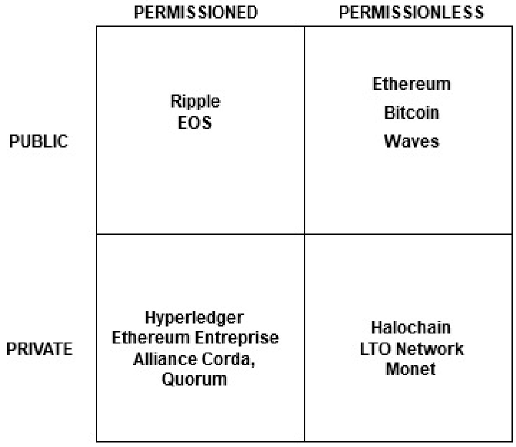

FIGURE 4.2: Public-Private-Permissioned-Permissonles

Private / Permissioned: Private / Permissioned network offers limited scope for decentralization. Only predefined users can read the transactions and only authorized users among them can validate transactions. The applications deployed in production, and the network nodes running those application, must be invited to join the network and meet certain criteria or provide a form of identification. Any party can also be removed by central authority. Hyperledger, Ethereum Entreprise Alliance, Corda and Quorum are some of the examples of Private/Permissioned DLT.

Private / Permissionless: Permissionless Private Blockchain setup allow businesses to collaborate without the need of creating a consortium or resort in sharing information publicly. Requires that applications deployed in production to be invited to join the network and can be removed without warning at any time. The nodes which constitute the network and run applications are free to anonymously join and contribute, typically in exchange for a network's native cryptocurrency. Only predefined users can see data. But every predefined user can validate transactions. This is more of a hybrid approach to DLTs like a private instance of public DLTs. Halochain, LTO Network and Monet are few examples of Private/Permissionless DLT.

Public / Permissioned: Every user can read the transaction data, but only predefined users can validate transactions.. Allows applications to be deployed in production or removed, without having to notify anyone, reveal their identity, or meet any application criteria requirements. The nodes which constitute the network and run applications must be invited to join the network. Ripple and EOS are two examples of Public/Private DLT.

Public / Permissionless: Every user can read and validate the transaction. This type of network is the most decentralized. Applications can be deployed in production or removed, without having to notify anyone, reveal their identity, or meet any application criteria requirements. Additionally, the nodes which constitute the network can freely and anonymously join and contribute, typically in exchange for a network's native cryptocurrency. Ethereum, Bitcoin and Waves are few examples of public/permissionless DLT. A truly self-sustaining ecosystem is possible with this kind of DLTs. For example, Ethereum which is public/permissionless platform offers capability of creating a DAO which can further be designed to fulfill the purpose and requirements of SSE.

4.3 Properties of DLTs

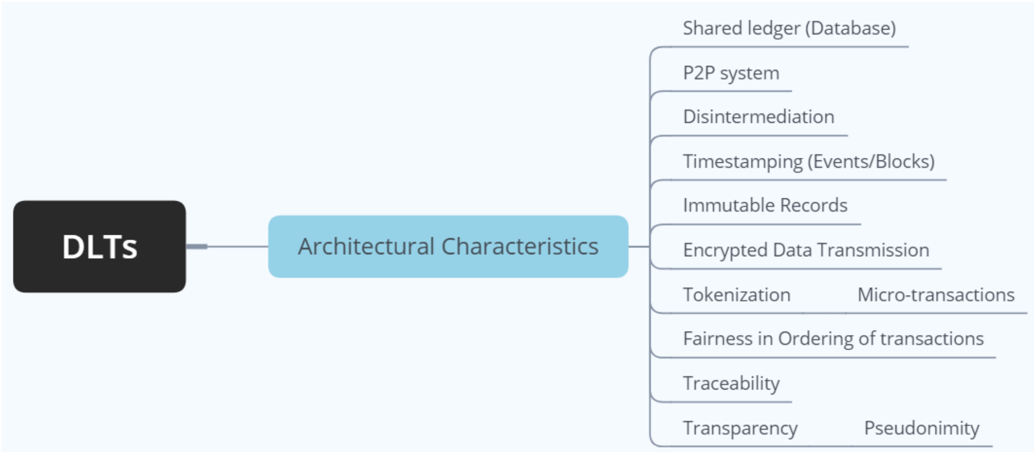

FIGURE 4.3: Properties of DLTs

Distributed ledger is a consensus of replicated, shared, and synchronized digital data demographically spread across the globe. There is no central administrator or centralized data storage (Tasca and Tessone, 2017).

The **P2P architecture** is inherent to blockchain technology, allows Bitcoin and other cryptocurrencies to be transferred worldwide, without the need for intermediaries nor any central server. Also, anyone can set up a Bitcoin node if they want to participate in the process of verifying and validating blocks. So, there are no banks or central entity processing or recording transactions in the Bitcoin network. Instead, the blockchain acts as a digital ledger that publicly records all activity (Tasca and Tessone, 2017). Basically, each node holds a copy of the blockchain and compares it to other nodes to ensure the data in the ledger is accurate. The network quickly rejects any malicious activity or inaccuracy. Full nodes are the ones that provide security to the network by verifying transactions against the system's consensus rules. Each full node maintains a complete, updated copy of the blockchain allowing them to participate in the collective work of verifying the true state of the distributed ledger. It is also worth noting, that all full validating nodes are not miners. Among the most important is the fact that P2P networks offer greater security than traditional client-server arrangements. The distribution of blockchains over large numbers of nodes renders them virtually immune to the Distributed Denial-of-Service(DDoS) (Yaga et al., 2019) attacks which is threat to distributed systems. As a result, the distributed peer-to-peer network, paired with a majority consensus requirement, gives blockchains a relatively high degree of resistance to malicious activity. The P2P model is one of the reasons blockchain was able to achieve **Byzantine fault tolerance(BFT)** (Castro, Liskov, et al., 1999).

Beyond security, the use of P2P architecture in cryptocurrency, blockchain also renders resistance to censorship by central authorities. Unlike traditional bank accounts, blockchain wallets can't be frozen or drained by governments. This resistance also extends to censorship efforts by private payment processing and content platforms. **Cost reduction and disintermediation** is the primary advantage of blockchain based services over traditional intermediary or audit based systems where substantial value is lost in the process (Rockart and Leventer, 1976). By distributing transaction ledgers across large networks of nodes, P2P architecture offers security, decentralization, and censorship resistance.

Blockchain based systems resort on specific **netowork topologies** to create a peer-to-peer network that determines the validation process where centralization and decentralization refer to levels of control over the network in a distributed system.

Moreover, blockchain provides infrastructure with ingrained **transparency**. Records are auditable by a predefined set of participants, particularly in the case of public ledgers, the records are open to anyone audit. The records are transparent and **traceable**. Moreover, participants to the network can exercise their individual rights to update the ledger. Participants can also pool together their individual weighted rights, for instance, in Proof-of-Stake, the participants have an option to proxy stake to another user who can further use the right to vote. Although, permissioned networks can manage the level of transparency as well as rights about updating the ledger. The blockchain transactions are verifiable because they can be traced back to the origin but at the same time it continues to hide the entire details, therefore, it is also **pseudo-anonymous**. Additionally, zero-knowledge proofs(ZKP) (Feige, Fiat, and Shamir, 1988) are by some blockchain platforms such as ZCash (Hopwood et al., 2016), ZKP enhances the control over sharing and transparency of the data. Transparency could also be in the form of fair ordering of events or blocks. Applications such as Stock Market and Online Auctions requires that the consensus order of transactions similar to the actual order in which the transactions were received by the network. In any circumstances, it should not be possible for a single party or group of users to prevent the flow of transactions into the network nor influence the order of transactions in the eventual network consensus. DLTs such as hashgraph ensures all fair access, fair timestamp and fair ordering which are important elements of SSE.

Blockchain is a shared, tamper-proof replicated ledger where records are irreversible and cannot be forged due to one-way cryptographic hash functions. Private keys are used to generate a signature for each blockchain transaction a user sends out. This signature is used to confirm that the transaction has come from the user, and also prevents the transaction from being altered by anyone one after it has been issued. Therefore, blockchain in entirely wrapped into cryptographic functions which increases its security although its not completely resistant to cyber attacks (Lin and Liao, 2017).

Blockchains function under the principle of **non-repudiation and immutability** of records. Blockchains are immutable because once data has been recorded in the ledger, it cannot be secretly altered ex-post without letting the network know it, therefore, the data is tamper-resistant. This is also termed as persistence. In the blockchain context, immutability is preserved using hashes a type of a mathematical function which turns any type of input data into a fingerprint of fixed size, that data called a hash. If the input data changes even slightly, the hash changes in an unpredictable way. Each block includes the previous blocks hash as a part of its data, creating a chain of blocks. Hence, it becomes difficult for an individual or any group of individuals to tamper with the ledger, unless these individuals control the majority of voters (Yaga et al., 2019).

A blockchain structure can be deduced as a tree that is continuously pruned as it grows. This pruning is essential to keep the branches of blocks from outgrowing and to ensure the ledger consists of just 'one' main chain of blocks. The performance of Proof-of-Work based blockchains cannot be enhanced without impacting their native security (Baliga, 2017).

In a blockchain, as blocks are intended to form a single, long chain. If two blocks are created at the same time, the network nodes will eventually choose one chain to continue and discard the other one which is termed as 'Soft Forking' where a growing tree that is constantly having all but one of its branches chopped off but there are events in the community which arise due to technical glitches where the community decides for 'hard forking' after which the networks are divided into two distinct networks. The 'Hard Forking' in blockchain highly affects the network effects, hampering the growth of platform(e.g. Ethereum and Ethereum Classic, Bitcoin and Bitcoin Cash).

Therefore, characteristics such as distributed ledger, peer-to-peer system, elimination of intermediaries, transparency with enforced security and immutability along with fairness in access, time-stamping and ordering of transactions are all critical aspects for building a SSE.

4.4 Consensus Mechanisms

The consensus mechanisms in DLTs can be summarized as depicted in the figure 4.4. These parameters are fundamental and essential building blocks for any DLT platform. *Each of these mentioned parameters, signifies important decision making element while designing SSE.*

4.4.1 Network Topology

Consensus Network Topology is the type of interconnection between the nodes. The network topology is categorized to three types, centralized, decentralized and distributed. Centralized topology is the fundamental design solution for hierarchical systems. This topology ensures efficiency which makes it a commercially viable option. The efficiency comes in the form of drastically reducing cost of system operations such as configuration, maintenance and throughout. On the other hand, they are prone to security attacks due to central points of control which lowers the reliability and increases infrastructure risk. To avoid the single point of failure, these centralised systems can be extended into hierarchical constructs which exhibit larger scalability and more redundancy, while keeping the communication efficient. Although, in a centralized system, control is exerted by just one entity for example, a person, an organization or an enterprise which makes them critical risk point. The reflection of this can be seen in the traditional socio-economic systems like banks and governments (Atzori, 2015). For instance, a ATM machine installed by a bank is easy to break into while if the ATM machine is result of decentralization, it would be more safe and secured as the 'trust'

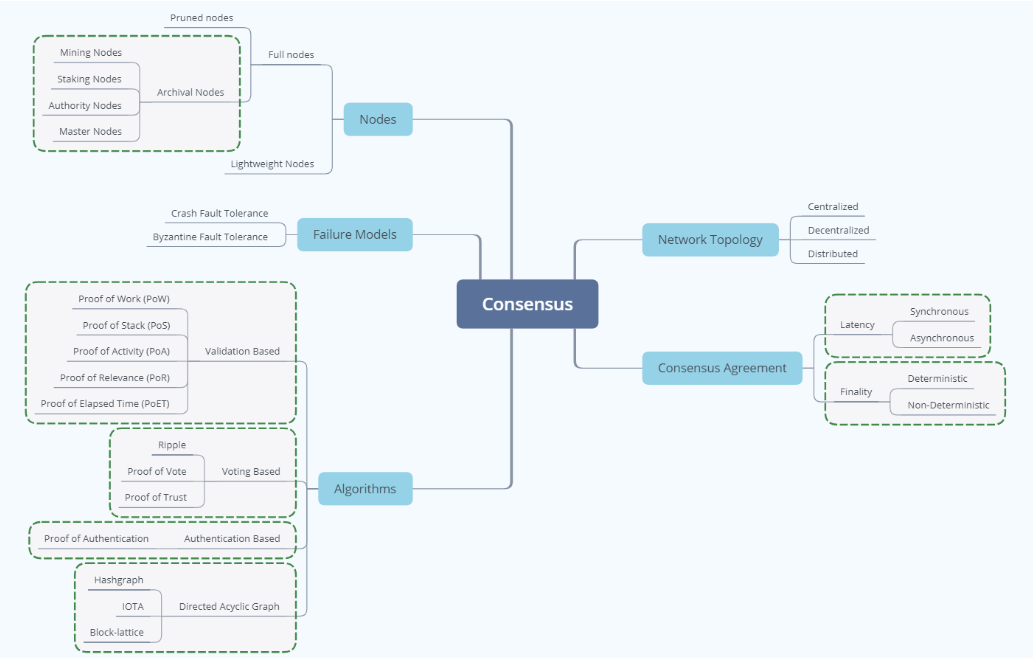

FIGURE 4.4: Consensus Mechanisms

is decentralized. Since the growth of the Internet, technical systems have witnessed a transition towards decentralised arrangements (Wright and De Filippi, 2015) where all the nodes have fair authority, therefore, the trust is distributed and not concentrated at one place which reduces the risk and increases reliability.

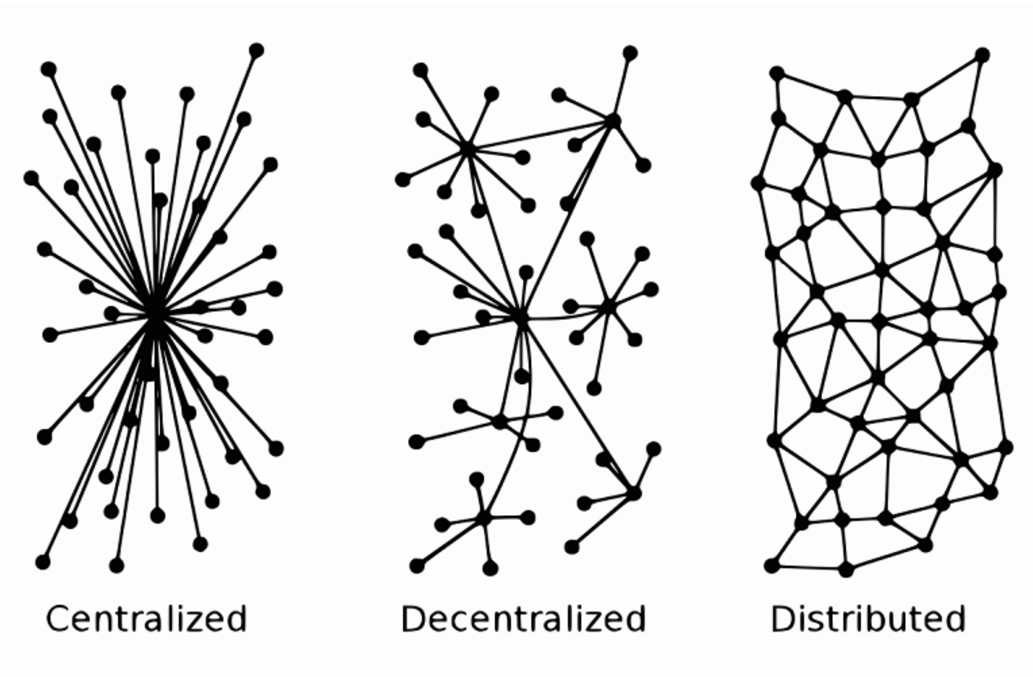

FIGURE 4.5: Centralized-Decentralized-Distributed

4.4.2 Consensus Agreement

The consensus agreement is directly dependent on two critical factors, first, the latency and second, finality.

The **latency** is the time the transaction takes from the genesis until the initial confirmation of it being accepted by the network. Throughput and latency have a direct relationship in the way they work within a network. **Throughput** is transactions per second and latency is time taken by single transaction to reach finality. Throughput of a protocol is an important characteristic for designing a SSE as it determines the scaling factor for the network, therefore, low latency is crucial for SSE. Moreover, latency could be synchronous or asynchronous. Systems which set upper bounds on 'process speed interval' and 'communication delay' such that every message arrives within a certain known, predefined, time-interval are called synchronous and vice-versa, the systems which does not set upper bounds on 'process speed interval' and 'communication delay' such that every message can take an indefinite time to arrive are asynchronous (Tasca and Tessone, 2017).

The **finality** is the property that once a transaction is completed, there is no way to revert or alter it. It is the moment when the participants involved in the network comes to an agreement or consensus over a transaction. Finality can be deterministic or probabilistic.

Probabilistic or Non-Deterministic finality occurs when a transaction's finality increases as more blocks are added to the blockchain but it never reaches to conclusive probability of 'one' that the transaction is confirmed. That is, as more blocks are added, the transaction is further referenced in the blockchain and becomes increasingly difficult to revert or alter as a result. For most protocols providing probabilistic finality, there is a recommended number of blocks to be added following the transaction until it can be considered complete. For example, it is recommended that one wait until six additional blocks have been appended to the Bitcoin blockchain before considering a transaction to be final. The majority of cryptoassets offer probabilistic finality. Probabilistic finality causes security threat to the system as there is scope for a double spend attack. A double spend attacks is when an attacker or group of attackers trying to spend their tokens twice (Lin and Liao, 2017).

Deterministic finality occurs when a transaction is immediately considered to be final once it is added to the blockchain. For this to happen, a node must propose a block to be added, and then a specified portion of validators must approve it. Deterministic finality is less common and is provided by Practical Byzantine Fault Tolerance-based (PBFT) protocols and asynchronous Byzantine Fault Tolerance (aBFT). Members of authority cast finality votes, and when enough votes have been cast for a certain block, the block is deemed final. In most systems, this threshold is 2/3. Blocks that have been finalized by such a mechanism cannot be reverted without external coordination such as a hard fork (Berger and Reiser, 2018).

4.4.3 Consensus Fault Tolerance

The consensus fault tolerance mechanisms ensures reliability and security of a network, there are typically two mechanisms crash fault tolerant and byzantine fault tolerant.

Simple fault tolerant system or crash fault tolerant (CFT) is the type of mechanism that prevents the network from network partitioning and failing when the nodes crashes or goes offline. It does not provide security against the nodes behaving maliciously or arbitrarily. A CFT is not useful in an uncontrolled environment which is a default state of any public blockchain. Although, CFT is commonly found in a permissioned or private networks such as Hyperledger (Androulaki et al., 2018) powered by kafka (Kreps, Narkhede, Rao, et al., 2011) and RAFT (Ongaro and Ousterhout, 2015) which are based on Paxos (Lamport, 2005). PBFT is currently used in Hyperledger fabric along with the Kafka ordering system. Kafka provides crash fault tolerance and finality. But it is important to note that while Kafka is crash fault tolerant, it is not Byzantine fault tolerant, which prevents the system from reaching agreement in the case of malicious or faulty nodes.

In a decentralized distributed system, like blockchain, the participants often communicate with each other in an uncontrolled, open, and permission-less system. Their action may vary based upon their individual interests and can be malicious. In such scenario, **Byzantine fault tolerant (BFT)** system is capable to ensure network operations in the case if the nodes fail or are malicious.

4.4.4 Types of Nodes

In general, every participant on the network could be perceived as a node. There are different kinds of nodes although each of them require specific hardware in order to participate on the network. There are two main kinds of nodes, full nodes and light nodes. Nodes are coupled with wallet functions. The full nodes are responsible for maintaining a copy of blockchain ledger, including all blocks whereas, light nodes which are also known as Simple payment verification(SPV) nodes or light wallet which only downloads headers of blocks. These types of nodes communicate with the blockchain while relying on full nodes to provide them with the necessary information. As they don't store a copy of the chain, they only query the current status for which block is last, and broadcast transactions for processing. Lightweights nodes are convenient although it comes with trade-off in terms of security.

The **full nodes** act as a server in a blockchain infrastructure. Their main tasks include maintaining the consensus between other nodes and verification of transactions. They also store a copy of the blockchain, thus being more secure. The full nodes can further be divided into pruned and archival full nodes.

Pruned nodes, download blocks from the beginning and once it reaches the set limit, deletes the oldest ones, retaining only their headers and chain placement. For example, if size limit is set at 1GB, it will store all the latest blocks that can fit in that hard drive space, but in order to get to that state, it would first validate entire blockchain, hence, pruned nodes can verify transactions and contribute to the consensus.

On the other hand, archival full nodes is a server which hosts the full blockchain in its database. Their main task is to maintain consensus and validate blocks. The difference between pruned and archival node is the amount of hard drive space they take up on server.

Archival nodes can further be sub-categorized into a two subtypes, first, that can add blocks to the blockchain and second, ones that are unable to add blocks.

Miners Nodes aim to prove that they completed the required work to create a block. Hence the consensus name 'Proof of Work'. To complete the task, as I mentioned above, miners need to either be an archival full node themselves or receive data from other full nodes on the network to know the current status of the blockchain and the required parameters for the next block in line.

Participants in the process employ hardware components like CPUs, GPUs or ASICs to solve a cryptographic problem. The first node to complete the task broadcasts his results to the network so it can be verified by full nodes and once consensus is achieved and that node is granted the right to add a block to the existing blockchain. For their work, miners are rewarded a pre-defined amount of incentive in terms of tokens in addition to any transaction fees for the block. This set reward amount is called coinbase or a coinbase transaction. Considering it's the first transaction in the block, it's free of charge, as the miner itself created the block and included it.

Advantages for employing miner nodes is that it makes easy to understand and track the work done by the nodes which increases transparency and trust in the system. Moreover, the miners can work in a mining pool with other miners to increase the rate of receiving rewards. On the contrast, the process of mining requires high amount of energy and using ASICs for mining can actually cause disparity in the network as they possess capability to mine more blocks in short amount of time when compared to CPU or GPU. Moreover, to start contributing to the network initial cost is high with uncertain returns.

Staking Nodes buy coins and hold them, while in return they receive an interest back as a reward. Staking is a game of chance, which while with a lower barrier to entry, offers less certainty compared to mining. To be able to stake, full archival node is required such that it downloads the core wallet for the coin and keep the entire blockchain on the node. Staking nodes have important variables such as coin age, maturity period, network weight and total weight. Coin age refers to the time period the coins have been in an address(wallet) while the maturity period is the number of confirmations needed before the node is eligible to start staking. When node successfully stake coins or move them from one address to another, coin age is reset to zero and the node needs to wait for the maturity period again. Network weight refers to the sum of coins which are mature enough, while total weight refers to the sum of mature coins total. The primary advantage of staking nodes is that it offers low barrier to join the network and it relatively consumes less energy and disadvantage is that the rewards are random and not 'work' based.

Authority Nodes are integral part of permissioned network like Hyperledger. All authority nodes requires permission from the network to join the network. The task of these nodes is, as with full nodes, is to create and validate blocks, while at the same time distributing information to users on the network. Networks that make use of such algorithms need to define a fixed number of authority nodes. Consensus algorithms which requires authority nodes are Delegated Proof of Stake, Delegated Byzantine Fault Tolerance, Proof of Authority and others. The advantage of such nodes is that it increases speed of transactions and no storage requirements. Even mobile device can be used as a wallet. There are few drawbacks to this approach and the solution involves employing some level of centralization which lowers the level of trust and hence, the network is more vulnerable to attacks.

Compared to full nodes, **masternodes** cannot add blocks to the blockchain. Their only purpose is to keep a record of transactions and validate them. Nevertheless there are added benefits to run a masternode, as it secures the network but can earn a share of the rewards for services. These services can be in the form of responsibility for network budgeting, treasury, enhanced privacy of transactions, voting rights and instant sending of funds. The voting rights are for the proposals for modifications in the consensus process, altering the block size or reward and other network-wide changes. The primary advantage is that it gives authority in the network with rewards and although on the downside, masternodes are difficult and expensive to setup.

4.4.5 Consensus Algorithms

Choosing the right consensus model for a particular network, various parameters needs to be taken into consideration such as nature of the network, types of stakeholders, the relationships between them, and other functional as well as non-functional aspects. There are different kinds of consensus mechanism algorithms which work on different principles such as validation based, voting based, authentication based and directed acyclic graph(DAG) (Alsunaidi and Alhaidari, 2019).

Some of the validation based consensus algorithms are proof of work(PoW), proof of stake(PoS), proof of activity(PoA), proof of relevance(PoR) and proof od elapsed time(PoET).

The **Proof of Work (PoW)** is a common consensus algorithm used by the most popular networks like bitcoin, ethereum and litecoin. It requires a participant node to prove that the work done and submitted by them qualifies them to receive the right to add new transactions to the blockchain. It uses miner nodes to validate blocks and add them to the main chain. The downsides are it is slow, high consumption of energy and have scalability issues (Nguyen and Kim, 2018).

The **Proof of Stake (PoS)** is another common consensus algorithm that evolved as a low-cost, low-energy consuming alternative to POW algorithm. It involves allocation of responsibility in maintaining the public ledger to a participant node in proportion to the number of virtual currency tokens held by it. Each PoS system may implement the algorithm in different ways, but, in general, the blockchain is secured by a pseudo-random election process that considers a node’s allocation and the allocation determining the commitment of the participant to ensure the network.

Similarly, there are other consensus algorithms like **Proof of Activity (PoA)** is a hybrid consensus mechanism combining PoW and PoS to strengthen each other's weaknesses (Saini, 2020). This consensus mechanism only gives online nodes a chance to propose the next block. Numerous other consensus mechanisms have been proposed of which some are currently used in blockchains. Examples include Proof of Burn, Proof of Relevance, Proof of Elapsed Time, Proof of storage , and Proof of Existence (Saini, 2020; Alsunaidi and Alhaidari, 2019; Nguyen and Kim, 2018).

The other kind of consensus algorithms are based on **Proof of Voting (PoV)** based where the distributed nodes controlled by participants could reach consensus and come to a decentralized arbitration by voting. PoV separates the voting rights and bookkeeping rights with the essential idea of establishing different security identities for network nodes. Contrary to the third-party intermediary or uncontrollable public awareness, the production and verification of PoV blocks are decided by the voting results among the core participants of the network. The primary difference compared to proof-based consensus algorithms, which nodes are often free to join and withdraw from the verifying network. Also, in voting-based consensus algorithm, besides maintaining the ledger, all the nodes in the network would have to verify together the transactions or blocks. They will communicate with others, before deciding to append their proposed blocks to their chain or not. Although on the downsides, nodes require permission to join the network which brings down the number of nodes responsible for executing consensus. Moreover, its more it bring in elements of centralization which lowers the trust in the network Nguyen and Kim (2018). Some of the examples of platforms using PoV are Ripple (Armknecht et al., 2015), Hyperledger (Androulaki et al., 2018), R3 Corda (Brown et al., 2016), Quorum with Raft (Baliga et al., 2018) and Stellar (García-Pérez and Schett, 2020).

Further, **Proof of Authentication (PoAh)** is proposed for resource constrained infrastructure. PoAh has cryptographic authentication mechanism to replace PoW for resource constrained devices, and to make the application-specific blockchain. PoAh is suitable for private as well as permissioned blockchains. Further, PoAh not only secures the systems, but also maintains system sustainability and scalability. PoAh is mainly targeted for fast and scalable private blockchain for large-scale Internet of Things(IoT) frameworks (Puthal et al., 2020).

The next generation consensus algorithms are in the form of **Directed Acyclic Graphs(DAG)**. DAG are the type of DLTs although they are blockchain as they do not have data structure supporting blocks. In DAG, transactions are added parallely, each transaction confirming a number of previous transactions. This makes DAGs inherently scalable. Therefore, they offer high scalability, speed, energy efficiency and finality. Some of the examples of platforms using DAG are Hashgraph (Baird, 2016), IOTA (Divya and Biradar, 2018) and ByteBall (Churyumov, 2016).

4.5 Tokenization

Tokens are the digital representation of value or assets on a blockchain and the Tokenization is the process of turning an asset, right, reputation or digital goods into an interchangeable unit to power an ecosystem whereas the purpose-driven **tokenization** is leveraging the exchange of value through tokens to drive behaviours of an ecosystem towards a particular goal. A token is not limited to one particular application. **Tokenomics or token economics** is the study of the emerging field of the design of crypto tokens and related digital assets using economic incentives, game theory, mechanism design, market design, cryptography and computer science. **Token engineering** is the practice of using tokens as the foundation for designing value flows and ultimately economic systems (Dhaliwal et al., 2018).

4.5.1 Benefits of Tokenization

The application of DLTs in tokenization may deliver efficiency gains through the transfer of value without the need for trusted centralised intermediaries or through the efficient automation of processes, resulting in faster, potentially cheaper and steady transactions driven by disintermediation and automation. The use of smart contracts reduces the cost of issuing and administering tokens or securities, further reducing the cost of transactions, increasing speed of execution and streamlining transactions.Smart contracts can facilitate corporate actions like coupon issuing, dividend payments, voting, escrow arrangements, fund allocations and collateral management. Smart contracts provides automation in the issuance, distribution, management of securities but also around securities servicing and corporate actions while reducing costs throughout the transaction lifetime, benefiting issuers and investors at the same time (OECD, 2020).

Additionally, DLT-based token registries provides increased transparency and a clear record of beneficial ownership with certainty at any point in time. DLT enables a transparent, immutable, time-stamped repository of each transaction and detailed provenance.

The benefits of tokenization could be received by stakeholders with the possibility of fractional ownership of the asset(tokens) or in the terms of fractional interests received from the assets. Tokenization of assets allows for the slicing up of assets, dividing ownership into smaller claims with possibility of joint-ownership and co-ownership. For instance, a publicly issued share of an organization on a DLT, could have the possibility to joint or co-own it as well as this could be a micro amount as it becomes viable to own fraction of share which could be sliced up for the ownership. But this would only be possible for fungible tokens and not non-fungible tokens as they do not have the property where it can divided or sliced-up.

4.5.2 Cryptoeconomics and Tokenomics

Cryptoeconomics refers to the blend of cryptography, computer networks and game theory which provide a secured and decentralized infrastructure exhibiting some set of economic incentives and disincentives. Cryptography is used to prove properties established in the past, such as account balances, identities and ownership that is provenance. Digital representations of economic value become possible, accessible to all, assignable, exchangeable and immune to censorship, able to be relied upon in the future.

Cryptoeconomics comprises of three major parameters; provenance through cryptography (past), financial incentives at any particular given time determined by game theory and mechanism design (present) and desired system properties to be relied upon is determined by token design (future). In the following chapter, we discuss token design in detail (Tan, 2019b).

Whereas in the case of **tokenomics**, it is the study of functions of cryptocurrencies within the broader ecosystem. This includes token distribution as well as incentive models for positive behaviour in the network. Moreover, tokenomics is the subset of cryptoeconomics, only dealing with financial incentives of present and system properties of future to be relied upon (Tan, 2019b). It can be leveraged for creating new economic models and theories that exploit the possibilities offered by blockchain (Kampakis, 2018).

Tokenomics is an overlooked aspect of blockchain infrastructure. However, while tokens are a huge part of it, tokenomics is still a discipline that has not been studied in depth. A google scholar search for “token economy blockchain” returns only 13,600 results whereas "blockchain" returns 257,000 results as of July 2020.

4.5.3 Token Ecosystem and Velocity

Tokens are value creation and exchange mechanisms that allow network stakeholders to participate in, and/or manage the system. They ensure that nodes operate effectively and actors participate in a coordinated manner without the need of any special communication which is termed as Schelling Point (Potts, 2008) which is to have an equilibrium in the network with zero communication or coordination. Therefore, tokens play an important role in aligning the incentives in a ecosystem.

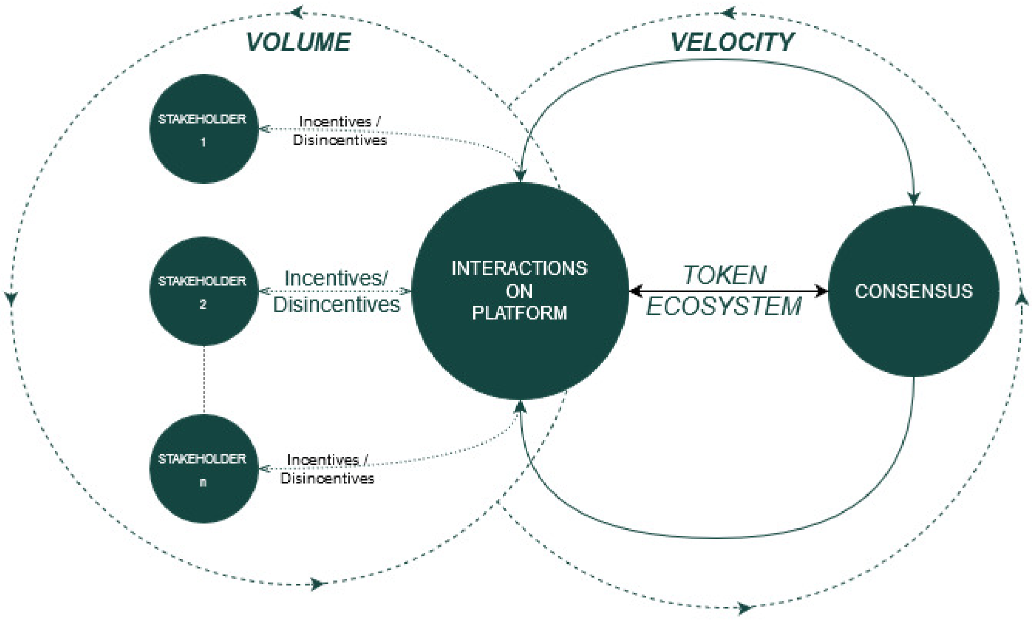

FIGURE 4.6: TOKEN ECOSYSTEM

The Token Gravity is the understanding flow of tokens within a network, as incentive tools affect the likelihood and frequency of transactions between stakeholders (Dhaliwal et al., 2018). The token gravity have two main variables velocity and volume.

Velocity = Total Transaction Volume / Average Network Value

Hence,

Average Network Value = Total Transaction Volume / Velocity

Velocity is one of the key levers that will influence long-term, non-speculative value which is an important element while designing SSE. To maintain the token gravity in the ecosystem, it is crucial to engineer market and mechanism design where there is balance between holding of tokens and trading/distribution of tokens. Hence, protocol designers will be well served to incorporate mechanisms into their protocols that encourage holding, not just usage. The volume of transactions in the network is depends on the number of stakeholders on the network. The volume and velocity together can encourage more stakeholders to join the ecosystem which eventually reflects the network effects.

4.5.4 Classification of Digital Assets

The tokens or crypto-assets can be categorized into two categories, fungible and non-fungible tokens. A detailed overview for the classification of tokens is depicted in figure 5.6, it is the result of MLR (Pereira, 2018; Srinivasan, 2017; Euler, 2020; Mueller et al., 2018; Goldin, 2017; Haseeb Qureshi on, 2020; Oliveira et al., 2018; Bo, 2019; Mersch, 2018; Drasch et al., 2020; Euler, 2019)

Fungible Tokens are identical, interchangeable and divisible. Tokens of the same type with identical specifications. Moreover, tokens can be interchanged for another with the same value. These tokens are divisible into smaller portions. Therefore, the fungible token have a property of being joint-owned, co-owned and sole-owned. The fungible tokens can be further sub-categorized into three categories. First, store of value tokens, which are generally used to store value as they possess speculative nature along with network effects. A good example for, store of value is the Bitcoin. In terms of token gravity, the bitcoin has higher volume(network effects) and lower velocity(users tend to hold the tokens and not use them) which decreases the usage of token. The bitcoin is utility token functioning as store of value. The **utility tokens** are meant to access the platform or applications. In some protocols, like Ethereum, the Ether which is utility token is required to use the network. Therefore, utility tokens could also be perceived as 'fuel' for the network. Another, interesting application of utility tokens are the stablecoins. The stablecoins are generally backed by other valuable assets like fiat currency(Dollars, Euros), digital currency(Bitcoin, Ether), and commodities(Gold, Silver). There is another type of stablecoin which is termed as Seignorage share, it is not backed by any other assets. Its operating mechanism is a fixed value is established (for example: 1 cryptocurrency = 1 euro), if the value deviates from the established price, the community that represents the currency issues or buys the coins in circulation, so that the stablecoin returns to its established price. The token curated registries(TCRs) are recent research work into token engineering. TCRs have been proposed recently as an approach to create and maintain high quality lists of resources or recommendations in a decentralized manner (Asgaonkar and Krishnamachari, 2018). The figure 4.7, represents consequences of different utility tokens with respect to the variables of token gravity.

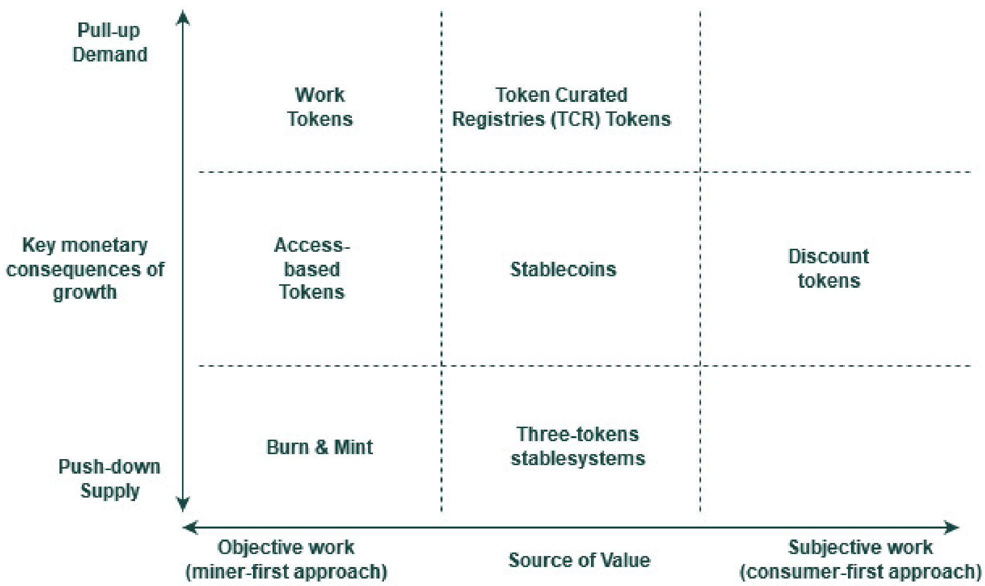

FIGURE 4.7: Key monetary consequences of increased usage (Y axis) and the source of the value they accrue (X axis) by Pereira (2018)

Another type of fungible tokens are **security tokens** where the tokens are regulated and compliant to the legal jurisdiction. This increases trust in the tokens as they are backed by the governance policies. The security token could be backed by equity, asset, debt, derivative or a hybrid.

Non-Fungible Tokens are unique, non-interchangeable and non-divisible. Each token has unique information and attributes, therefore, it can also be not interchanged. These tokens are linked to user's identity and unique experiences which is not divisible. All the in-game assets fall under this category of cryptoassets.

4.6 In Summary

The DLT elements such as types of nodes, network topology, consensus mechanism which determines access management, algorithms, and type of consensus agreements along with data privacy and security analysis forms the basis for designing the proposed framework 4.8 in the following chapter which covers each critical aspect of DLT and helps blockchain projects to scale-up.

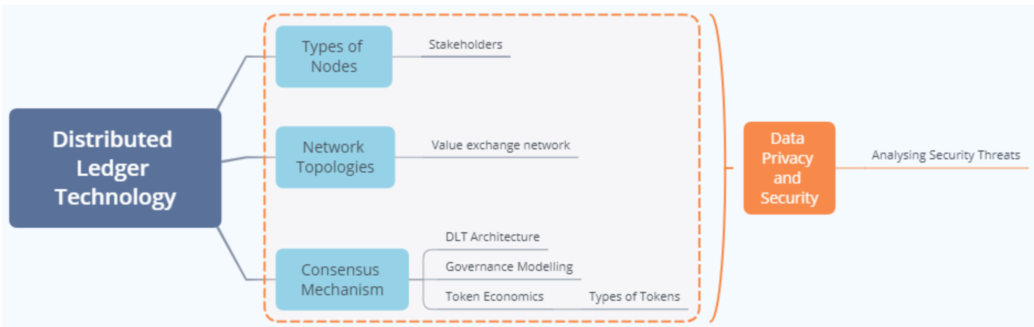

FIGURE 4.8: Conceptual Model for designing the framework

Chapter 5

Framework for Self-Sustaining Ecosystems

5.1 Introduction

This chapter is dedicated to proposing a framework which can assist in strategizing a detailed roadmap to a self-sustaining ecosystem for DLT projects. .

5.1.1 Research design Assumptions

- **System Requirement: Self-sovereign identity(SSI) as a native service of the underlying protocol platform**

  For instance, if the user is able to create multiple user accounts on the network, such network would be prone to infringements and malicious activities which can bring the network to a compromised state. Therefore, we are presuming each stakeholder operating on the network would be registered with a single identity which might be in the form of decentralized identities(DIDs) derived from SSI. The SSI is critical for the authenticity of the ecosystem which directly influences the state of self-sustenance.

- **System Requirement: The regulation and compliance is considered on each step of the framework** The regulations and compliance which are local as well as global needs to be aligned with each decision made for the project. The regulations and compliance have been the major barriers for enterprise applications to scale-up (Hughes et al., 2019) although that part of the discussion is beyond the scope of this research.

5.2 Phases of framework

The phases of this framework are motivated by the work of Dhaliwal et al. (2018). Each phase differentiates between various research stages of a blockchain project. There are three phases proposed, starting with, Discover phase which helps in deciding the purpose and intent behind the project along with determining potential stakeholders and type of relationship between them in the ecosystem. It also consists of finding relevant DLT architecture for the project. The second phase is the Design phase, which is the most critical and important phase for any blockchain project as it assists in establishing fundamental parameters to establish governance and incentive models which are foundational to attain self-sustenance state. Incentives and rules need to be aligned so that ecosystems can produce robust outcomes and are resilient to externalities such as collusion.

The last phase is the Deploy, which is about 'testing and optimization' for the assumptions made in the design phase followed by 'incubation and validation' which is the actual deployment step on the mainnet. The ultimate goal of the framework is to achieve a Minimum Viable Ecosystem which is self-sustaining in itself while having a default market and mechanism design to establish a positive-sum game. The positive-sum game is an essential component for any ecosystem to attract and retain network effects.

Design and Deploy are iterative phases until self-sustenance is reached which might be in the form of a Minimum Viable Ecosystem(MVE).

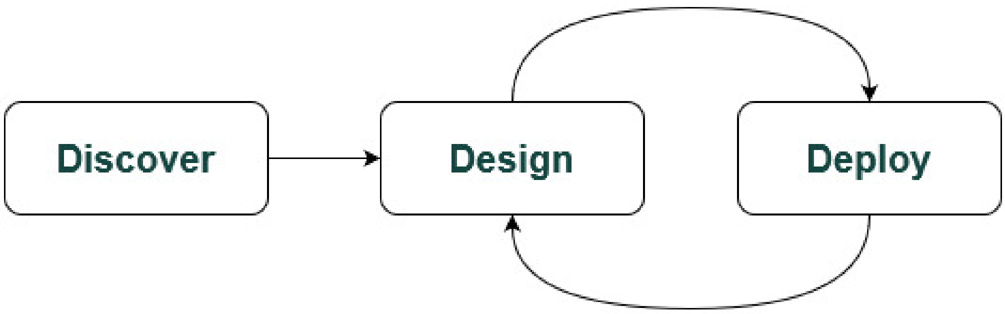

FIGURE 5.1: Three phases of the framework as proposed by Dhaliwal et al. (2018)

We go over each phase and discuss its importance along with previously researched artefacts and/or concepts which can accomplish that phase. The token classification artefact is the result of MLR.

5.3 Discover

The 'discover' phase is to determine the particular characteristics of the ecosystem and the purpose behind the ecosystem followed by its stakeholders and mapping of value exchange between them. The discover phase aims to prepare blockchain leaders with a series of questions while laying out the context, criteria for success, the scope of solution space, and constraints that need to be satisfied. Secondly, determining DLT architecture for the project is equally critical as there are key elements to consider such as required level of on-chain transparency, need for provenance, platform access rights, data sharing policy, issuing of digital assets and tokenization. These are a few of the most important considerations required at the beginning of any DLT project. In the first phase of discovery, we recommend tools that help in establishing a solid foundation for the next phases.

This phase is about defining the overarching problem to be solved and understanding the key stakeholders, their requirements and how this value is exchanged between them. It requires a deep understanding of market design. Inputs during this stage, we pull together any existing research or data pertaining to user patterns, consumer behaviours, market data, pricing and other relevant business information. This may include items such as personas, journey maps, customer segmentation, business model canvas, pricing models, and other strategic tools.

A blockchain ecosystem is a highly complex system designed to deliver a socially and economically optimal allocation of resources. It is this complexity that requires structured thinking in order to clearly organize and prioritize an integrated set of challenges. It is critical to deconstruct these challenges into the singular primary problem that is to become the goal of the token economy while defining the constraints of this problem. This kind of problem-solving demands the ability to perceive a problem from multiple and holistic perspectives even though there may be initial challenges with presumptions.

5.3.1 Stakeholder and Value Exchange Mapping

The first step is to discover the purpose and intent for the blockchain project that is problem structuring. There are tools available which can help in narrowing down the requirements. These tools are generally in the form of a business canvas, for answering critical questions. Nevertheless, business canvases are too generalised and don't help in answering specifically for DLT projects. Moreover, blockchain projects require a new and relevant layout and questions for analysis, as blockchain business value design demands different ideological and market perception and there exist no one size fits all solution, yet (Carson et al., 2018).

Blockchain canvases can enable them to navigate through complexity within the context of the blockchain ecosystem to find the essence of the problem and identify linkages to its sub-issues. These canvases are curated to serve needs of blockchain projects while offering insights into governance and incentive details along with miner fees. Here, is the list(table 5.1) of blockchain canvases which can be utilized by the blockchain leaders or SSE designers. The use of a combination of these available canvases can provide a concrete starting point while figuring out problem structuring, stakeholder mapping, and value exchange between them. The best suitable canvas depends on the nature of DLT project, for example, DAOCanvas is a good option for a public DLT project and other tools incline towards private or permissioned projects. Especially, while designing for a self-sustaining ecosystems, DAOCanvas can help in breaking down complexity and offer insights for the subsequent steps.

It is important to note that these complex systems need to be adaptable but an ecosystem is only as strong as its community, and loss of participants can have detrimental effects on the ecosystem. Therefore, stakeholder mapping and value exchange mapping with each other is critical and can be done using these canvases. Stakeholder mapping helps in getting a clear picture of the network's participants and their respective roles such that they can be individually incentivized to undertake desired activities and disincentivized from stepping beyond boundaries which is an important exercise in designing SSE. Whereas, value exchange maps, focus on capturing and visualizing how value is created, captured and distributed within the SSE which forms the basis for governance and token economics.

Blockchain Canvas	Website
Lean-Blockhain	http://lean-blockchain.com/canvas/
The blockchain canvas	https://theblockchaincanvas.com/
Blockchain Assessment Framework	https://www.krypto-valley.com/en/canvas-2/
DAOCanvas	https://daocanvas.webflow.io

TABLE 5.1: Discover: Blockchain business canvases

5.3.2 Determining Evolutionary DLT Architecture

The DLTs are a work in progress, but research and developments are at its peak amongst the communities. Most of the scientific research studies available to study DLTs and their architectures are limited in number, quality and scope of research but at the same time, the gray literature adds significant value to research resources which are highly peculiar. The architecture determined here is evolutionary as going further for governance and incentive modelling would require the architecture to evolve as per the requirements and constraints. To determine architectures to be considered for the investigation for their relevancy with the required architecture, the **decision support system(DSS)** [14] for DLT architecture designed by Farshidi et al. (2020), is an important step for the phase of 'Discover'. The DSS utilizes the MoSCoW technique (Ahmad et al., 2017) to determine the required architecture. The DSS results in a potential list of possible options for DLT architecture.

Advantages of DSS: The DSS offers, easy and quick approach to perform feasibility check for the required DLT architecture. Hence, it forms a good starting point for the project.

Drawbacks of DSS: However, the current version of DSS is supported by a static database of DLT properties and the database requires continuous upgradation for recommending relevant results. Also, suggested recommendations are single DLT platforms and sometimes as per the requirement of use-cases, there might be a need to use a combination of these platforms to attain a desired architectural solution.

This step is aimed to get perspectives on the nature of DLT architecture required for the particular use-case. Here, DLT architecture mainly pertains to public, private, permissioned and permissionless along with the required consensus mechanisms.

The DSS is a useful tool to perform quick initial feasibility check although recommendations are generic and not specific to particular use-case.

5.4 Design

Design is an emerging concept that consists of building an ecosystem surrounding the market or the business model that an entity is trying to operate in or create via the use of blockchain technology. *It is a complex task, similar to designing and launching a completely new economic structure supported by technical*

[14]https://dss-mcdm.com

infrastructure. The key is to keep the design and the underlying token architecture as simple as possible and minimize assumptions about participants' behaviours because even very simple structures could lead to extremely complex interactions and outcomes. Accordingly, overloading models with assumptions would restrict system capability as well as increase error and affect overall system fragility (Dhaliwal et al., 2018).

The design phase consists of making high-level design choices including, governance structures, the token modelling and its parameters. These parameters are needed to be optimized for stakeholders' incentives and the long term sustainability of the associated ecosystem in order to avoid value leakage.

The primary objective of the network is to optimize its network while helping the project to aggregating different goals of a particular network depending on their relevant importance. Similarly, the model's constraints are an equally important requirement in the design of safe and secure ecosystems.

DLT projects must prioritize issues such as governance, token economics and security analysis in terms of 'Design' importance.

5.4.1 Governance Model

Governance is about collective decision-making, and may be defined as in (Chhotray and Stoker, 2008) as follows: "Governance is about the rules of collective decision-making in settings where there is a plurality of actors or organisations and where no formal control system can dictate the terms of the relationship between these actors and organisations." Note the emphasis on: (i) Rules (ii) The collective scope (iii) The decision-making process, and the (iv) Lack of formal control systems.

The blockchain governance model curated by Pelt (2019), offers high-level view on the formation and context within the intricacies of blockchain governance. As depicted in the figure 5.2, the framework consists of three layers, off-chain community, off-chain development and on-chain protocol. Further, it is divided into five dimensions consisting of roles, incentives, membership, communication and decision making.

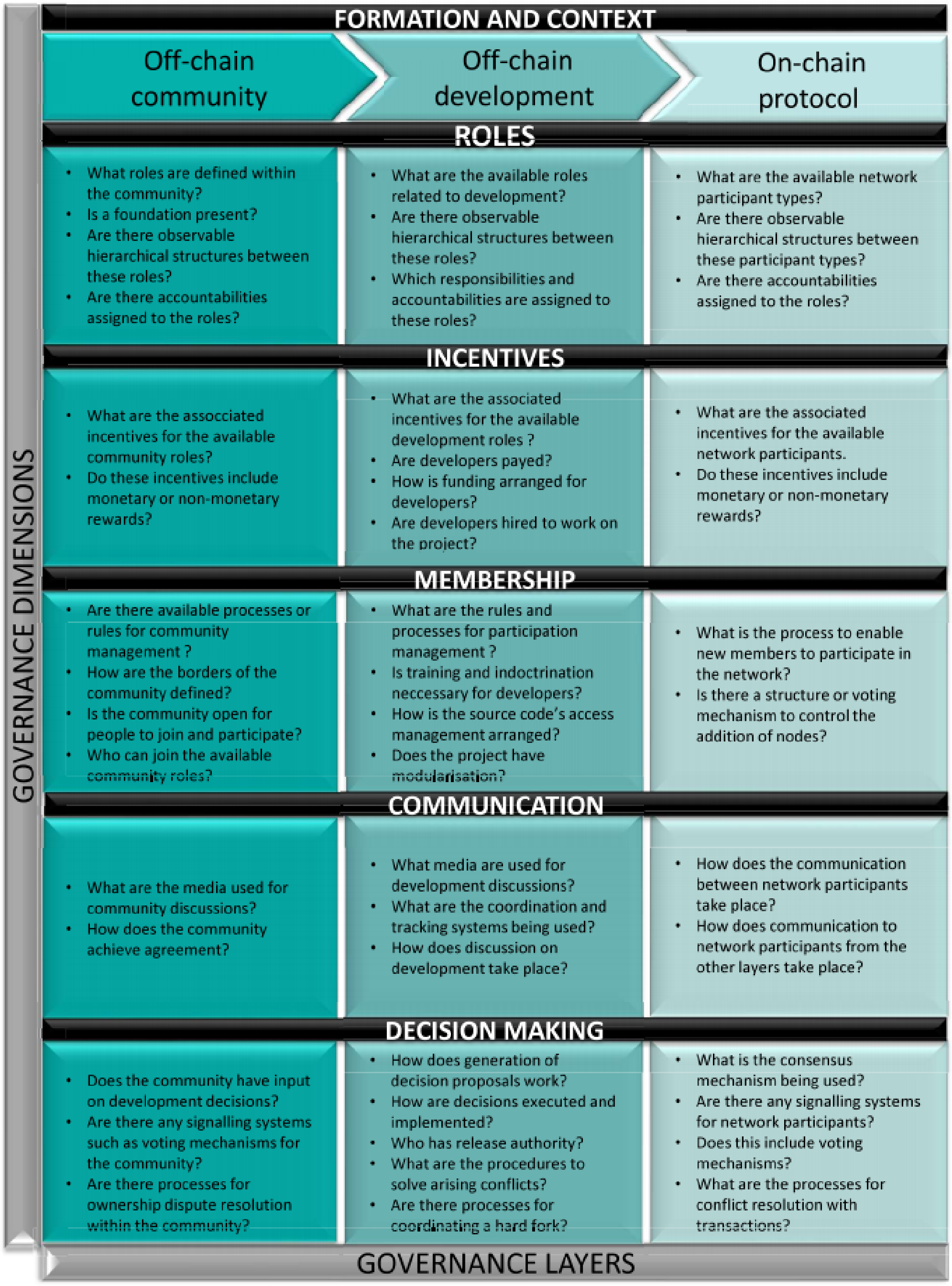

FIGURE 5.2: Blockchain Governance Model Framework by Pelt (2019)

The strength of the framework is that it combines insights from literature into open-source governance, blockchain governance and opinions from blockchain experts in a framework which of added value for various stakeholders in different situations.

The limitation of the model is that it does not provide many insights regarding incentive modelling and token engineering are critical while designing SSE because governance and incentive modelling are co-dependent and simultaneous processes.

Therefore, the next step is the token economics model which includes governance as part of mechanism design.

5.4.2 Token Economics Model

An incentive is something that makes people act in a particular way and is central to the study of economics. In our context, we use it to achieve mutual gains or a positive-sum game when parties have differing motivations.

Token design requires an understanding of the incentives for each participant in the ecosystem, the associated business model, the market structure, and the network structure. The final model leads to a protocol design that allows the network to sustain itself while prioritizing system safety by correctly engineering incentivization and governance mechanisms. There may exist multiple solutions for any given problem but the goal of token design is to try to identify the optimal solution while taking associated constraints into account.

Token-Network fit is analogous to product-market fit. Finding the right token model for the network means creating the right mechanisms that align incentives across the market and ledger layer such that everyone acts in the best interest of the network. It is useful to view the token as the interface between the ledger and the market layer.

The token economics framework consists of the various exogenous and endogenous parameters to be considered when developing the token economics model for the project.

The core elements of token economics are divided into three segments, Market Design, Mechanism Design and Token Design. Market design is the design of the environment which mainly consist of exogenous parameters. Mechanism design is the design of the system from exogenous as well as endogenous for optimizing governance and token economy. Token design is the design specific to the token that will be used in the token economy which consists of endogenous parameters. Here, the discussed token economics model is inspired by the work of Tan (2019a).

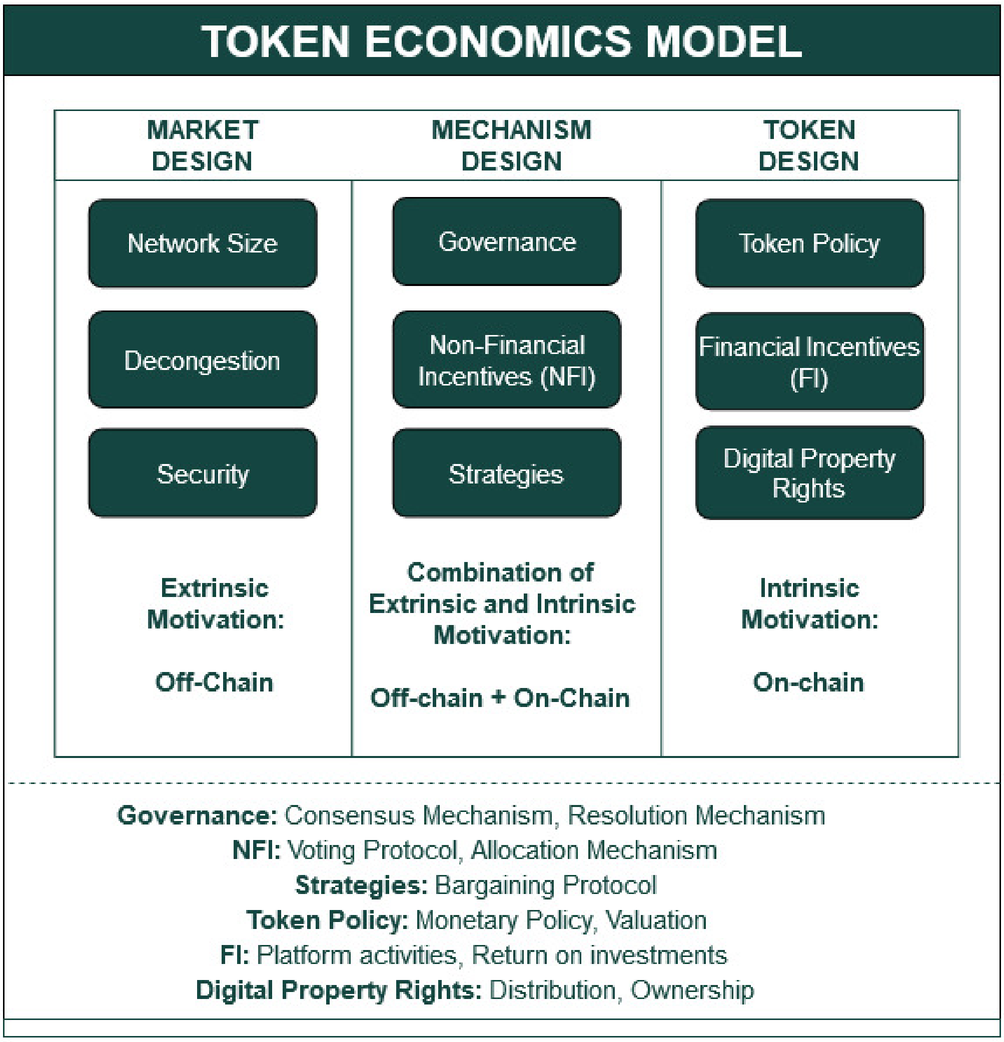

FIGURE 5.3: Token Economics Model inspired from Tan (2019a)

Market Design

Market design defines the environment for marketplaces where users and tokens co-exists so that markets are operated and governed fairly. The purpose of tokens is discussed in-depth in the previous section. It involves designing a market structure to facilitate a set of efficient outcomes. Therefore, it is crucial to design successful market policies that would encourage users to participate in the network, thus, increasing the 'volume' and simultaneously, token velocity, to driving forward network effects in order to achieve self-sustenance. Utilizing token economics model, blockchain leaders can design more efficient networks and applications to provide greater value for participants through sound economics. Market design mainly represents off-chain considerations which further acts as an input to the next steps which are mechanism design and token design.

Markets have to attract enough participants to reach a suitable adoption level and reduce congestion when the transaction occurs. The design of the market needs to allow enough potential transactions to be available at one time so that a particular type of agent does not possess the power to influence the market on its own. Additionally, there needs to be enough time for offers to be made, accepted, rejected, and for transactions to be carried out. Lastly, it should be safe, secured and trusted infrastructure for participants.

The market design begins with identifying stakeholders and bringing them together such that they can transact in a trusted ecosystem. **Network size** becomes an important characteristic as it can impact the efficiency of the network with more participants than the network can manage as well as too low for the network to operate fairly. The capability of the network to deal with overwhelming transactions depends on the underlying platform and consensus mechanism it uses. Moreover, depending on the consensus mechanism, structured incentives can be defined based upon network activities which might be in the form of mining or staking. Mining is mainly concern with incentivizing participants through block rewards, for example, in the case of Bitcoin. Block rewards can also be used to increase early-adopters to incentivize them for early contributions to the network. Whereas, a Staking Mechanism requires a participant to put some tokens in order to perform certain activities on a network. Staking is a useful way to introduce a cost to join the network, and disincentivize undesired behaviours.

On the other hand, for the private entities, network size is the constraint for consortium partners where they can seek to onboard related companies to drive early adoption and bootstrap network effect. Moreover, they can create leverage for customers while offering them security tokens which holds possibilities of co-ownership and joint ownership. Additionally, there can be a model for referral tokens or 'airdropping' to increase the volume of the network. An Airdrop is a token distribution strategy that gives tokens away for free to potential ecosystem participants (Fröwis and Böhme, 2019).

A market is congested if there is insufficient time or resources to fully evaluate all the potentially available transactions. **Congestion** is a particular problem of markets with many heterogeneous matching opportunities. To make sure, the network is running efficiently and resources are allocated are optimal, there can be a mechanism to govern these transactions through grading and prioritizing transactions where low graded transactions could be removed. In some cases, bandwidth throttling could also be useful but while using underlying infrastructure with PoW, they are already meant to slow down the network to avoid unnecessary forking (Nakamoto, 2019). To avoid congestion, there can be a measure to charge transaction fees which might in the form of network access fees or surge fees in case of overwhelming of transactions while in the case of Delegated Proof-of-Stake(DPoS), there are fixed or randomly selected governing validators, for example, EOS (Grigg, 2017) and Hedera Hashgraph (Baird, 2016) uses fixed governing validators while Cardano (Aydinli, 2018) and Dfinity (Hanke, Movahedi, and Williams, 2018) uses randomly selected group of validators. In the case of MakerDAO (Lipton et al., 2020), there are specified super-nodes with authority for consensus. The private platforms such as Hyperledger Fabric (Androulaki et al., 2018) and Corda (Brown et al., 2016), uses Proof-of-Authority for validation.

Security aspects are elaborated in the section of 'Analyzing security threats'.

Mechanism Design

Mechanism Design (Toyoda and Zhang, 2019) is the art of designing the rules of a game to achieve a specific desired outcome. While game theory takes the rules of the game as given and helps us determine outcomes based on them and the strategic interaction of players, mechanism design uses the framework of game theory with incomplete information and asks about the consequences of different rules and chooses the game structure rather than inheriting one. Therefore, mechanism design allows SSE designers to look at the overall design of the network and stakeholders' incentives as a tool to influence the outcomes of the network game in addition to determining the optimal design of the network itself 5.4. Mechanism design plays an important role in understanding the behaviour of the highly decentralized networks, full of selfish nodes or users.

Mechanism design aims to establish a Schelling Point (Potts, 2008) which is to have an equilibrium in the network with zero communication or coordination. It is a concept of game theory in which people will tend to use in the absence of communication because it seems natural, special, or relevant to them.

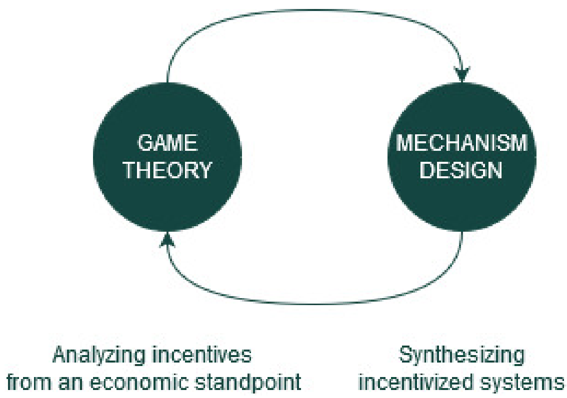

FIGURE 5.4: Game theory - Mechanism Design

To set the rules of the game, the first step is to define the environment and the actors participating in the game, that is, stakeholder mapping and value exchange mapping. This involves describing who the participants are, the scope of potential decisions, the set of and preferences for each participant which is done as the part of 'Discover' phase.

For this exact reason, the characteristics of actors are the main input of the design phase. The utility of a well-designed ecosystem should facilitate powerful incentives that drive activity(volume) in the network.

The governance aspect here can be fulfilled with the consideration made in the governance model 5.2 by (Pelt, 2019). Governance can also be in the form of a precoded set of instructions for resolution mechanisms like smart contracts functioning as an escrow to hold the money until the fulfilment of an activity.

The second aspect of Mechanism design is the Non-financial incentives(NFI) which could be on-chain as well as off-chain. NFI can be coupled with Financial incentive which is the part of the token design. Both NFI and FI are crucial to strengthening the strategy. NFIs could be in the form of the voting protocol where stakeholders are distributed with authority to cast votes. The authority is determined by the nature of underlying infrastructure as well as the type of voting protocol being used. There are various approaches for voting protocols such as commit-reveal, quadratic voting, quorum voting, delegated voting, partial-lock commit-reveal voting and politeia voting (Niemi and Renvall, 1994). Moreover, NFI could also be in the form of Allocation mechanism which is automated by smart contracts and could be triggered on the basis of reputation or other predefined rules.

The third aspect that helps in bringing together with off-chain and on-chain parameters together is through precise strategizing of mechanism design. Strategies could be driven by using bargaining protocols that can be in the form of auction mechanisms and payment mechanism. Auction mechanisms offer a solution to congestion and security issues. It can be with payment system using different auction types such as fixed price, first price, second price, Vickrey-Clarke-Groves (Makowski and Ostroy, 1987) and Dutch auctions (Galal and Youssef, 2018).

Mechanism design serves as an input to the token design which is focused on on-chain token economics entailing token policies, financial incentives and digital property rights. The incentive design is influenced by two sets of inputs, the first is embedded in the code in the form of a smart contract, an automated mechanism and human input which are behavioural rules. The automated mechanism could be smart contracts, voting protocols and auction mechanisms whereas for human input could be influenced with reputation-based protocol, specific curated markets and allocation mechanism.

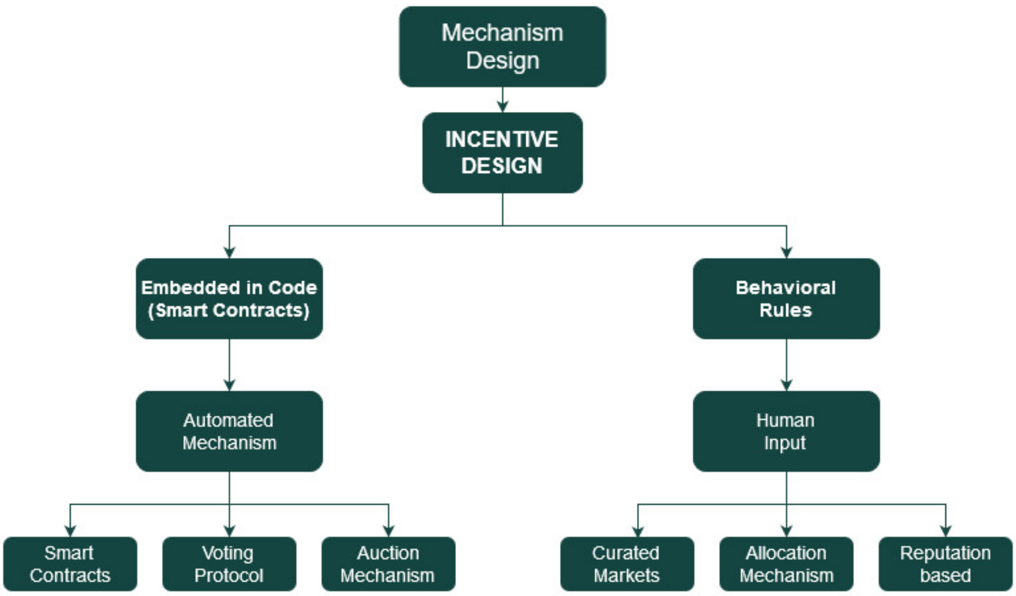

FIGURE 5.5: Incentive Design: To govern and align behaviours of decentralized participants in the ecosystem

Token Design

The last element in the token modelling framework is the token design which directly corresponds to the economic system in the on-chain. The token design consists of purpose of token, token policies, token functions, classification of tokens, distribution of tokens and ownership of tokens. These token design rules are coded or embedded into the decentralised system with smart contracts or oracles. It is important to ensure that participants follow specific behaviours outlined in mechanism design, this could be accomplished by defining financial rewards for the participating stakeholders, followed by the disincentives for bad behaviour (Tan, 2019c).

Token design is a highly variable and complex process, for establishing SSE, tokens require a defined token policy. The token policy mirrors, the traditional monetary economics and monetary policy. It seeks to design how tokens will be managed and governed, unlike mechanisms where it seeks to design how the mechanism is governed and managed. The token policy has different market constraints, based on the objectives of the token ecosystems, such as ensuring price stability, extracting transaction cost from token holders, etc. Unlike monetary policy, the token policy can be extended to use-cases beyond the function of money. The token policy mainly deals with the supply of tokens, the expected growth of money supply, saving function of tokens, inflation/deflation tokens, distribution of token allocation and token velocity. Moreover, token policies entail token valuation along with all required economic variables such as scarcity function, dynamic pricing, growth functions etc. The defined constraints of token policy and established mechanism design help in setting financial incentives. The financial incentives can be in the form of platform activities and return of investments. The platform activities could be transaction fees, onboarding bonus, discount tokens, referral benefits, proxy staking or mining rewards. The return of investment is generally based on potential returns to tokens or equity owned as well as arbitrage trading on secondary markets (Tan, 2019a).

The blockchain architecture along with tokens can help to govern actions through property rights and establish trust through scale economies. Each activity on the platform can be represented by tokens which in turn can have the knowledge of provenance. This is can lead to determining ownership rights, voting rights, authority and governance aspects. Moreover, the distribution of tokens could be managed for allocation and locking-up of tokens for a specific time-period to control the velocity and flow of tokens on the system.

Therefore, market design governs the environment of the network, mechanism design governs the rules of the network. Token design governs the actions of the people on the network through direct incentives. Further, each of them is co-dependent and needs to operate at the optimum level for self-sustenance (Dhaliwal et al., 2018).

5.4.3 Classification of Digital Assets

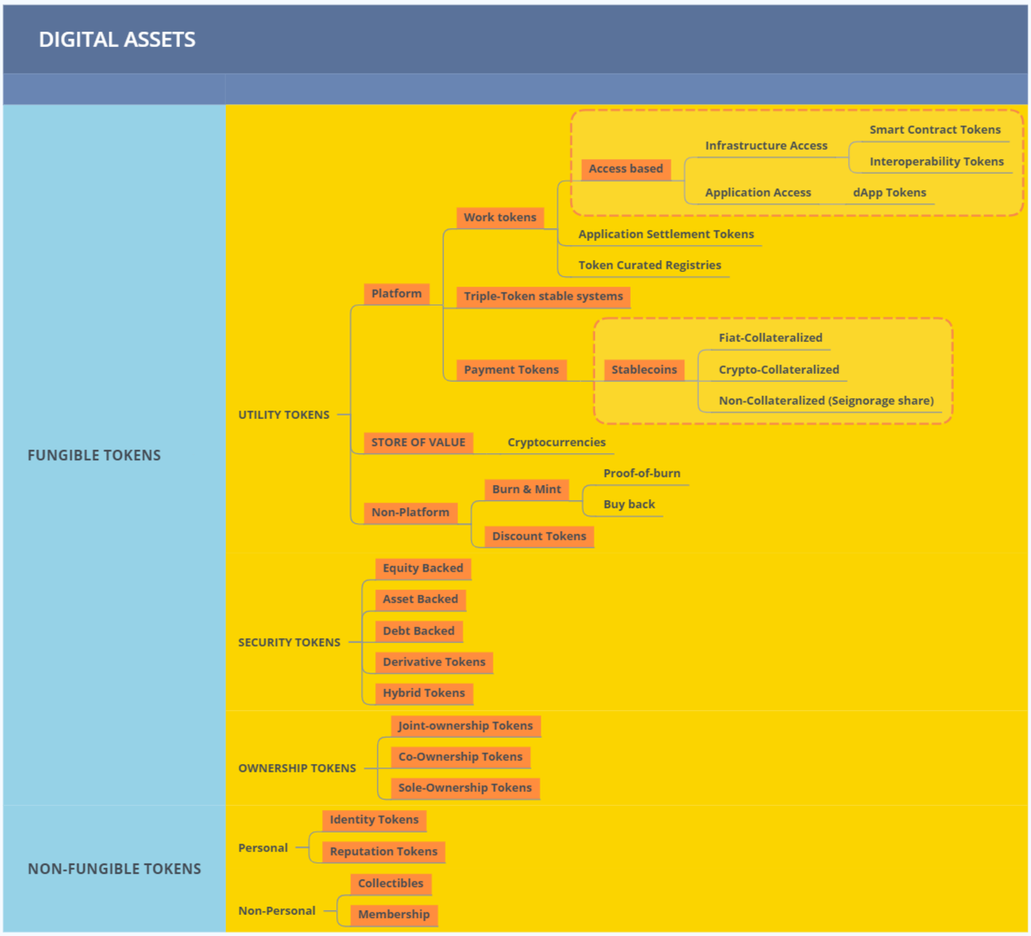

FIGURE 5.6: Token Classification

The details regarding each type of token is discussed in the section of tokenization 4.5.4, chapter 4.

5.4.4 Analyzing Security Threats

In a blockchain-based infrastructure, the security is the critical aspect as the value is created, distributed, maintained and stored within the network. Therefore, it gets immensely important to analyse each vulnerability in the system and possible attacks on them. The attacks in DLT system can be categorized into three categories; attacks on consensus state, consensus strategy, and network topology (Dhaliwal et al., 2018).

Attacks on consensus state are when an attacker changes the consensus state of the system while attacks on consensus strategy are when an attacker persuades other participants to manipulate the state of consensus. Similarly, attacks on network topology occur when an attacker changes the topology of the network of nodes, either by removing or adding new ones.

Consensus state can be altered by a series of attacks, for instance, when an attacker or group of attackers trying to spend their tokens twice which is termed as a double-spend attack. The second type of attack is when the network is made inaccessible to its users while occupying resources in the network by overloading with spam requests, popularly known as distributed denial of service(DDoS) (Rodrigues et al., 2017). The other significant type of attack is forking, this occurs when a deliberate divergence in the state of a blockchain caused by a disagreement amongst blockchain nodes as a result of colluding. Lastly, when there is an attack in order to acquire a majority of the network's mining hash rate or computing power is termed as 51 percent attack (Yaga et al., 2019).

Similarly, there are a series of attacks to manipulate consensus strategy, for instance, offering to rent other participants' to gain control over their strategy, this is called, Bribe Attack (McCorry, Hicks, and Meiklejohn, 2018). Moreover, when an attacker introduces a reward into a coordination game that affects the group's behaviour without causing the attacker to incur any cost, this can deviate from the networks' strategy to establish consensus, this attack is called P+Epsilon attack (Sayeed and Marco-Gisbert, 2019).

The Sybil attacks (Heilman, Baldimtsi, and Goldberg, 2016) are when one node in the network acquires several identities and tries to take over the network, this type of attack is possible on the network topology.

We are not covering security analysis in depth here, as it is out of the scope of this research, although, the research conducted by Debus (2017) offers required insights.

5.5 Deploy

Testing needs to be an integral part of any token design to create the optimal design as well as to build an optimal feedback loop that helps govern and monitor the system. This deploy phase consists of first iteratively testing until all parameters have been optimized with respect to their constraints. The deployment process involves using a combination of mathematical, computer science and engineering principles to fully understand the interactions in our network and its failure points. It is important to note that optimization and testing are present throughout the entire lifecycle in an iterative process, that is, in practice, token models should be continuously optimized for parameters, variable ranges at all stages. There are various methods to test and optimize the network, for instance, regression learning (Huang et al., 2011) could be used to validate the input selection stage. In this process, we are able to identify the variables and parameters of the objective function including trying to pinpoint and optimize each group of stakeholders' utility value on the network. Similarly, Monte Carlo simulations (Swendsen, 1993) and Markov chains (Kemeny and Snell, 1976) that allows quantifying outputs of token gravity to calculate the velocity of the token and its value. Additionally, agent-based modelling (Crooks and Heppenstall, 2012) and evolutionary algorithms (Back, 1996) allow for the model to capture possible future interaction of different use cases and users come on the network. The feedback loop created in this process should relay information to deep learning models comprised of neural networks, this can assist in optimizing the network and maximize the objective function of the network. For the testing and validating purpose, we can utilize tools like Token Utility Canvas and Javelin Board to track activities.

Token utility canvas focuses on the mapping of assumptions, and the token structure to the most viable testing mechanism. For optimization of token economies, we take into account two sets of economics, ledger layer economics and market layer economics which can is termed as layered economics. As the market indulges and exchanges digital services, the ledger layer is where key attributes of each transaction need to be verified and contracts need to be executed. Token Utility Canvas B.2 seeks to outline the utility of a token in its entirety and can broadly be divided into two aspects, Market layer (Business Centric Factors) and Ledger Layer (Network Centric Factors) (Drasch et al., 2020) as per the depiction 5.7.

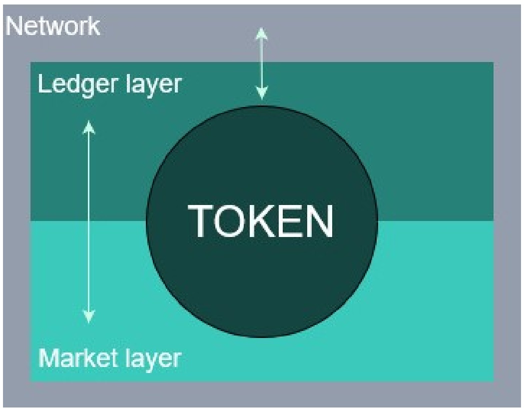

FIGURE 5.7: Token: Market layer and Ledger Layer

The market layer, the economics of the ecosystem are designed to align the distribution of value in order to achieve a more efficient market that also benefits from powerful network effects. The token is used as an incentive or disincentive to participants to behave both in their best interests and those of the greater good of the ecosystem at large. This layer generally represents a dApp token. Tokens represent an atomic element of a network's business model. Whereas, the main goal of the ledger layer is to drive the costs of verification to as low as costless possible while ensuring security and maintaining the integrity of the network. This layer is generally represented by protocol tokens.

A **Javelin Board** B.3 is helpful to track and validate assumptions and ideas and is broken up into two sections. All model assumptions are listed on the left-hand side of the board. To the right of this column, we track the experiments and tools testing our assumptions.

Refer B for the Token Utility Canvas and Javelin Board.

The end goal of the proposed framework 5.8 is to achieve Minimum Viable Ecosystem which is self-sustaining in itself.

5.6 Proposed Framework - draft version

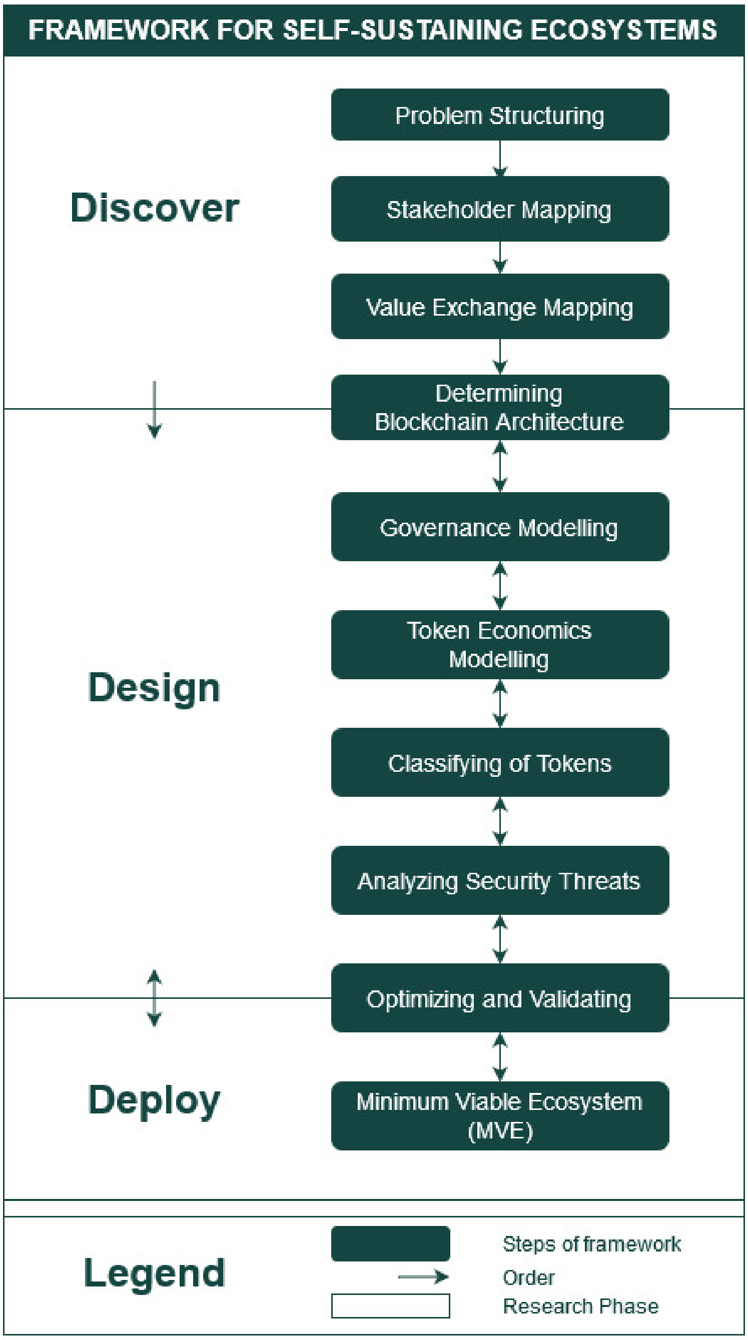

FIGURE 5.8: Proposed framework for self-sustaining ecosystems

Chapter 6

Case Study Description

The previous chapter discussed the proposed framework resulted from the multivocal literature review. The purpose of the framework is to assist blockchain leaders to scale-up and establish strategic project roadmap. In this chapter, we present the outcomes of the ex-post design product evaluation, following the evaluation strategy as defined in Section 2.1.4. This evaluation is structured around the application of the framework in a holistic multiple case studies. For the followed case-study process refer to Multiple Case-study in 2.2 and further, for the protocol followed during the case-studies refer to Appendix C.

The case-studies were conducted in two rounds, where the first round was focused on understanding the nature of project along with its struggles and helping them to strategically think using the proposed framework to pinpoint the pain points which may be technical or ideological. Further, the second round was particularly focused on evaluating the framework and getting insights into where it could be improved. Moreover, each of the case-study partner was provided with case-study reference materials during the first round which included the proposed framework and other supporting models. In the duration between two rounds which was one week, it was expected that they would be spending time along with their team to brainstorm about their project using the framework such that we have more perspectives to evaluate the framework. A detailed overview of case-studies can be found in the table **??** with case-study partners, their field of work, type of their project, criteria they satisfied for the selection purpose and identifiers which would further be used for discussion in following sections. Moreover, the case-studies were aligned with the suggested case-study protocol by Yin (1994) and further, the framework was evaluated on the basis of Operation Feasibility, Ease of Use, Completeness, Usefulness, and Effectiveness as recommended by Prat, Comyn-Wattiau, and Akoka (2015).

The case-study partners were selected on the basis of satisfying at least two of these criteria:
(i) The blockchain project is relevant to gaming ecosystem
(ii) The blockchain project is relevant to the characteristics of SSE
(iii) The blockchain project involves a requirement for token engineering

The next sections further define the objectives and followed process.

6.1 Ex-post evaluation objectives

The process of evaluation can be divided into two activities, namely demonstration and evaluation (Peffers et al., 2007). A demonstration is a light version of

Casestudy	Field of work	Type of Project	Satisfying Criteria	Identifier
Eclesia	Startup	Digital Collectables	i, iii	IE-1
Lisk Casino	Community driven	Online Casino (Gambling)	i, iii	IE-2
SecureSECO	Academic Research Project	Self-Sustaining Software Ecosystem	ii, iii	IE-3

TABLE 6.1: An overview of the conducted evaluation multiple case-studies

an evaluation that demonstrates the use of the artefact to solve an instance of the problem. The evaluation activity is more formal and evaluates how well the artefact performs. By means of an ex-post evaluation we aim to evaluate the Operational feasibility, Ease of Use, Completeness, Usefulness and Effectiveness of the framework (Prat, Comyn-Wattiau, and Akoka, 2015). In our ex-post evaluation the researcher takes the role of an investigator of the framework while conducting case-study with different partners and therefore it is executed in an artificial setting. The goal is to apply the artefact to the real-world blockchain projects from gaming ecosystem which are in a naturalistic setting. Summarised, the objectives of the ex-post evaluation are twofold: (i) demonstrating the application of the framework to a problem situation while making sure the partners are challenged to think in a new paradigm concerning different and important blockchain elements (ii) evaluate the framework on the basis of 5 points mentioned in the table **??**.

6.2 Data collection and analysis

The proposed framework was used as the basis for questions and criteria for data collection. The data collected is qualitative in nature. The source of the data are the recordings and transcribed notes from the two rounds of each case-study. The collected data is analysed following thematic analysis (Braun and Clarke, 2012) along with Data triangulation where we utilize multiple data sources along with Theory triangulation which is further coupled with participant feedback to help understand the influence of the framework. Further, we used deductive reasoning approach, the themes for data analyses emerge from the case-study. The designed artefact is thus used as a thread to conduct and report on the analysis, demonstrating its practical use. Wherever applicable we aim to provide tables and figures as they provide the reader with a rich presentation of evidence, making the case more reliable (Gustafsson, 2017).

The most discussed part of the framework in all case-studies was the 'Discover' and 'Design' elements and specifically stakeholder and value exchange mapping. 6.1.

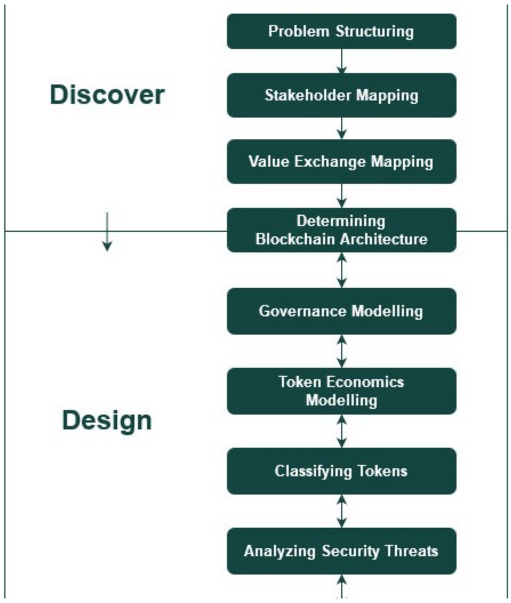

FIGURE 6.1: Part of the framework which was rigorously evaluated

6.2.1 Case Study 1: Eclesia - Digital Collectibles Startup

Eclesia [15] is a digital collectable startup based out of Switzerland. The project has successfully accomplished a proof-of-concept. The primary reason to select it as a case-study partner was its operation into digital collectables with the tokenization aspects which satisfies the first and third criteria for the selection. Moreover, the person leading the startup has experience of four years into the blockchain domain and overall thirty years of experience as a technical architect which was important for the evaluation of the framework.

Nature of project:

Eclesia is a decentralized marketplace built on the concept of a Radical Market (Posner and Weyl, 2018). Eclesia provides tools to digitally claim the ownership of any off-chain as well as on-chain collectables while managing them in a secure and independent manner. Moreover, it reflects aspects of a community market where one can interact and share with the trusted network of collectors while buying and selling collectables for recommended and fair prices. Each of these collectables is entailed with proof of ownership and the provenance of collectable. They are further cryptographically secured and represented as non-fungible tokens which makes them related to the gaming ecosystem similar to that of Cryptokitties discussed in chapter 3.

The primary stakeholders of the collectable startup are the local or regional collectors. The startup aims to build a smart and dynamic marketplace for such collectors where they can collect digital assets such as in-game assets or media records. Moreover, even off-chain collectables could be represented in the form of digital assets.

[15] https://www.thecollectors.world/

Problem:

The main concern for the startup is to define a strategic project roadmap to scaling-up which can make it appealing to a wider audience and help in achieving required network effects. But to attain network effects and appeal to a wider audience it becomes critical to have a predefined governance and incentive models in place that reflects the positive-sum game. Moreover, being a blockchain startup it is difficult to attract external investments as the project does not have a promising revenue model. The other option is to conduct an Initial Coin offering(ICO) but as ICOs are not regulated and doesn't provide any sort of security to the investors, it is at times perceived as a scam (Venegas, 2017).

Solution:

A better way to define a path to scaling-up blockchain projects is to define precise governance and incentive model for the project. This can help in creating initial motivation for the stakeholders to join the marketplace as well as to retain them. This can generally be done using incentives and disincentives to motivate the right behaviour on the network. To further think along these lines, the framework was introduced to them. In this particular case-study, the framework was perceived as highly relevant and applicable as the framework follows the discover, design and deploy phases which are an integral part of lean and digital innovations (Nicoletti, 2014) used for scaling up startups. The framework resonates with existing process model which makes it adaptable to startups as they don't need to change their existing strategy to use this model, in fact, the framework integrates and makes the process more concise with each important parameters of DLT project. Further, the framework was rigorously evaluated. Specifically, the 'discover' and 'design' phase were critically analyzed and discussed in-depth. The deploy phase was analyzed but was limited to where it could be improved upon. The most interesting element of the framework discussed was the value exchange mapping which lead us to discuss governance and token economics in-depth.

6.2.2 Case Study 2: Lisk Casino project

Lisk[15] is an open-source project focused on blockchain accessibility. The lisk community already had a working proof-of-concept for the casino project with its Roulette project[16]. The gambling applications on the blockchain are the most used dApps having the highest number of transactions and users (Gainsbury and Blaszczynski, 2017) which makes it obvious to consider the project for the evaluation of the framework and see if the Lisk Casino benefits from the framework and helps the project to think strategically.

Nature of project:

The Lisk Casino is a community-driven project which built upon lisk platform. The community-driven projects tend to use public ledgers with different consensus mechanisms. The lisk project employs Delegated proof-of-stake(DPoS) as a default consensus mechanism. DPoS requires a project to decide on the

[15] https://lisk.io/
[16] https://roulette.delegate.moosty.com/

number of validation nodes which are generally between 21-101 (Alsunaidi and Alhaidari, 2019). These nodes can be divided into different groups of validators as per the requirement of the project such it makes it difficult for these nodes to collude or act maliciously. For instance, with Lisk Casino, project, the total number of validation nodes is 101, which can be further sliced up into different groups of stakeholders who would be responsible for the network. These stakeholders could be a group of legal and government bodies with 30 out of 101 nodes who are responsible for the jurisdiction for the gambling market, the other group could of competitors in the same market having 30 nodes as it would not be of interest for them to collude as well as maintain a high level of security, the last group could be from the lisk community itself, with 41 nodes representing the interests of the whole community.

Problem:

While using the public network with DPoS consensus it gets critical to establish governance policy amongst the validating nodes, ensuring interests of the community. Another, crucial element in public blockchain projects is the fund allocation and management as well as to attain the breakeven point for the network's operational cost from ongoing transactions which could be in the form of maintenance fees. Similarly, there needs to be a defined incentive model to ensure operations of the network along with keeping the stakeholders of the network motivated through different tokens rewards and penalties. Moreover, the Lisk Casino project is at the proof-of-concept stage and requires a concise and structured way to scale-up their operations. This is where we introduced the proposed framework to see if it can help them strategize their roadmap beyond PoC.

Solution:

Similarly to Eclesia and for several other blockchain projects, it gets immensely difficult to scale-up after achieving the Proof-of-Concept stage as majority of the projects have yet to consider the working of governance and incentives. As discussed previously, these two aspects are the most complex and critical to come up with a working model. Nevertheless, these complexities of governance and tokenization at times lead the projects to discard them from the operations. Elimination of tokenization from any DLT projects rules out the possibility to achieve a self-sustaining state and it is immensely difficult to attain network effects and retain it. The proposed framework does the job of guiding the projects in a structured format from the state of PoC to a Minimum Viable Ecosystem(MVE) while establishing token and governance policies. For the Lisk Casino project, the second step after PoC was to start brainstorming about the potential stakeholders of the system, followed by mapping out a value exchange mechanism between them which would result in significant information that could be plugged into governance modelling as an input. As a part of the case-study and possible conditions we were able to conduct a white-board exercise 6.2.

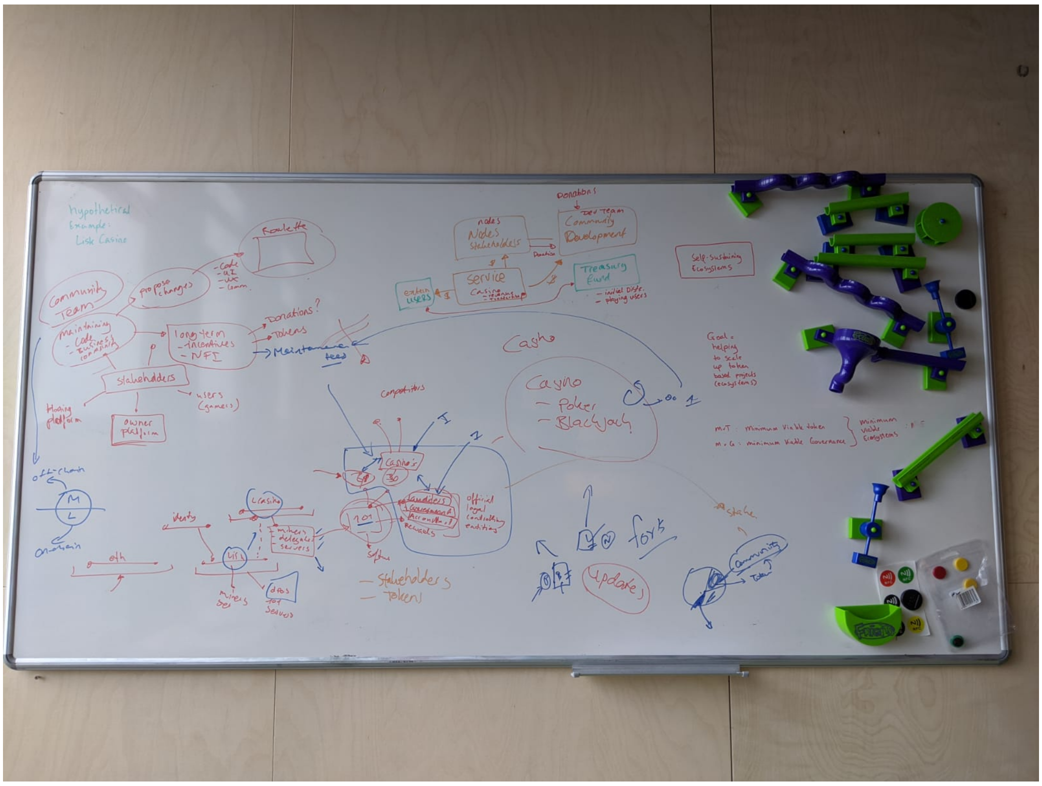

FIGURE 6.2: Whiteboard exercise for Lisk Casino Project

6.2.3 Case Study 3: SecureSECO

The SecureSECO[17] is an academic research project based out of Software Ecosystem Labs at the University of Utrecht lead by Prof. Slinger Jansen, who also happens to be supervising this research.

Nature of project:

The SecureSECO is a complex system aimed at software developers, to build a decentralized ecosystem of software components from the code repositories across different languages. It is a data-intensive domain, with a focus on source code. There are many ways to search for code in the worldwide software ecosystem, but these search methods are inefficient, at a coarse level of granularity, and only cover small parts of the software ecosystem. SecureSECO is considering DLT as the fundamental building block which can ensure privacy, enforce governance and regulations while introducing incentives or rewards to stakeholders to maintain and contribute to the ledger as they contribute to it.

Interestingly, the contents of gaming and media technologies can be extrapolated to the code-base which is the root of software dependencies. Simultaneously, there exist the problem of code-cloning which impacts the quality of media software products and further the scope of research and innovation. The plagiarism of code-base has been a major issue for the lawsuits in the digital arena (Ennam, 2017). The online platform of StackOverflow has at times been labelled as a 'code laundering platform' (An et al., 2017), as well as the copied

[17] https://secureseco.org/

code fragments, were found of low quality (Ragkhitwetsagul et al., 2019) and poorly attributed (Baltes and Treude, 2020) (Baltes and Diehl, 2019).

The source code of games and game-related software artefacts from open-source communities as well as sophisticated games produced by private gaming studios are all the results of long, persistent, collaborative, passionate ongoing work of multiple stakeholders such as designers, animators, engineers, scientists, entrepreneurs and various other contributors. Each of these artefacts is composed of hundred to millions of lines of code, with a limited number of contributors, especially in open-source arena (Pascarella et al., 2018).

Moreover, engineers from opensource communities struggle to get a fair share of recognition and incentives for their contributions and similarly, engineers from private entities lack well-defined incentives to contribute to opensource projects. SecureSECO aims to resolve these issues using DLTs and aims for a SSE.

Problem:

The primary concern of the SecureSECO is the complexity of the project and determining a concise roadmap for the development of the system. The system has multiple layers which include the scrapping of entire code-base available online, code-forensics to detect clones and low-quality code-base, decentralization of database and having DLT as the underlying protocol. The SecureSECO aims to be a public and permissionless network which can be joined by anyone without any prior authentication which adds more complexity because there needs to be a predefined strategy to deal with network congestion and managing transaction cost along with governance which nudges the stakeholders for the right behaviour with respect to network's interests while rewarding or penalising them.

Solution:

The proposed framework is meant to solve such problems by breaking down the complexity of DLTs into a structured layout. Moreover, the framework assists in asking the right questions for problem structuring and resolving the complexity of the project. The case-study was most interesting around the value exchange mapping as again it proved to be the critical deciding point for further steps. The proposed framework does the job of guiding SecureSECO in a structured format from problem structuring to a Minimum Viable Ecosystem(MVE).

The insights gathered from the case-studies and rigorous evaluations of the proposed framework are discussed in the following chapter.

Chapter 7

Framework evaluation and evolution

In this chapter, we discuss the results of the case studies, along with the insights gathered, proposed changes in the framework and the final version of the framework.

From the multiple case-studies, it became evident that initial assumptions made at the initiation of the study regarding the need for a structured approach to guide blockchain projects, especially after achieving proof-of-concept, stands true. Moreover, the framework also proved to be beneficial for helping blockchain projects to navigate through the intricacies of DLTs such as DLT architecture, governance, token engineering, classification of digital assets and security analysis.

7.1 Perception of the proposed framework

The proposed framework 5.8, was received positively by each of the case-studies. As each case-study was representing a different field of work, it was significant to see the application of the framework across them. Moreover, an important insight gathered out of data triangulation of three case-study, is the wide applicability of the framework across industries and different DLT projects.

Another, important insight was about the need for such tools which can decompose the complexity of DLT projects, and interestingly, a researched assumption at the beginning of the study for non-availability of any such artifacts that could serve the needs of DLT project was affirmed during the case-studies, as two of the case-studies had never came across such artifact, although IE-1 claimed that there is a 'blockchain assessment framework' by kryptovalley 5.1 available which attempts to align governance and token economics although it is not well structured as well as does not contain elements such as value exchange mapping and token classification. *Hence, as per the best knowledge of the authors and case-study partners, the proposed framework is the first artifact which covers all aspects of DLT project into a well structured format.*

Further, the most interesting aspect of the framework in all the case-study was *value exchange mapping*. The activity of value exchange mapping is critical to answer the dilemmas of DLT architecture, governance and token economics. Therefore, most of the time during the case-study was spent on this aspect which actually helped the partners in thinking new paradigms for their projects. Moreover, it helped in establishing new arenas for the projects to consider and work upon.

The case-study with IE-2, claimed that the artifact is, "filling the gap for the Proof of concepts with this tangible framework" whereas for IE-3 which are at the beginning of their research project claimed the need to rethink on how they perceive DLTs as a whole. This was an important realization in all of the case-studies, as it is good to know before hand, the limitations in thinking while working on a DLT project, such that it saves significant time for the project in the future from reiterating over all the assumptions and decisions made. Now, as a result of the case-study, they have better and precise questions to figure out along with the structured artifact while starting out the project. It has been observed several times, in DLT arena, that it demands a new ideological approach to build such ecosystems as they are fundamentally different from traditional and hierarchical systems. Here, it tends to attain positive-sum game (Buchanan, 2001) and establish economies of scale (Catalini and Gans, 2016) whereas, for traditional ecosystems are aimed at zero-sum games.

7.2 Framework Evaluation

The framework evaluation was as per the guidelines by Prat, Comyn-Wattiau, and Akoka (2015). The framework was evaluated in two rounds of the case-study, where in the second round, the partners were asked to rate the framework on a likert scale of 5 (Joshi et al., 2015) for each of these parameters Operation Feasibility, Ease of Use, Completeness, Usefulness, and Effectiveness.

7.2.1 Operational Feasibility

Operational feasibility is the degree up to which the partners see the framework being used by other DLT projects in practice. In terms of operational feasibility, there was 100% positive response from the case-study partners. The partners significantly perceived the value of the framework for DLT projects and leaders. The framework proved to be applicable to different fields of work as well as different project maturity level. IE-1, claimed that the framework is aligned to the LeanStack[18] startup innovation framework which makes it widely feasible as it can easily be integrated into the existing process model. Moreover, all partners stated to use the framework while working on any other DLT project down the line. The IE-2, expressed that the framework helps in thinking every aspect of DLTs in a precise and structured manner.

7.2.2 Ease of Use

The Ease of Use is the degree up to which it is easy to use the framework and answer the dilemmas of concerned DLT project. As DLTs are complex systems, the framework was intended to make the process simple and easy to go along. According to IE-1, the framework helps in clear thinking of critical steps. Moreover, IE-1 stated it was easy to follow steps and could be used by anyone having a brief knowledge about the intricacies of DLTs. As per IE-2, the DLT projects are complex and framework assist in making it easy to understand. Although,

[18]https://leanstack.com/

Evaluation characteristics	Case Evidences (Likert Scale of 5)	Prominent Comments
Operational Feasibility	IE-1 : 5/5 IE-2 : 5/5 IE-3 : 5/5	IE-1 : "This framework could be used by every other DLT projects and relevant to LeanStack Startup Innovation Framework" IE-2 : "It makes of you think of every other feasibility aspects" IE-3 : "Would be willing to come back to this framework for future DLT projects"
Ease of Use	IE-1 : 4/5 IE-2 : 5/5 IE-3 : 2/5	IE-1 : "Well structured framework which assist in clear thinking of critical steps" IE-2 : "DLT ecosystems are complex and this framework helps in breaking down those complexities" IE-3 : "Framework is helpful but DLTs are complex and therefore, it gets overwhelming to consider each aspects"
Usefulness	IE-1 : 5/5 IE-2 : 4/5 IE-3 : 5/5	IE-1 : "It helps in thinking about DLT elements that are essential for scaling-up" IE-2 : "It is a tangible artifact for blockchain projects" IE-3 : "It helps in rethinking how blockchain projects operate"
Completeness	IE-1 : 4/5 IE-2 : 5/5 IE-3 : 5/5	IE-1 : "The discover and design phases are complete and accurate although deploy could still be improved" IE-2, IE - 3 : "The framework is complete and covers all major aspects of DLT project"
Effectiveness	IE-1 : 4/5 IE-2 : 4/5 IE-3 : 5/5	IE-1 : "The framework is relevant to needs of DLT projects but there is always room for the improvement" IE-2 : "The aspects discussed in the case-study are effective and helps in thinking beyond Proof of Concept" IE-3 : "It helps in asking right questions which are crucial for the project"

TABLE 7.1: Evaluation through multiple case-studies

while going into depth of each step, it was an overwhelming experience for IE-2, as there was a lot to consider at the same time. Nevertheless, for IE-2 the framework made it easy to think about steps to push forward their proof of concept to achieve MVE. The IE-3, downrated the ease of use, due to overwhelming aspects of DLT. Here, the framework was not criticized as it was just being perceived complex due to the nature of DLTs.

7.2.3 Completeness

The completeness attained high confidence of the partners while claiming it is an efficient and thorough framework with all critical aspects of DLTs. IE-1, praised the interactions between different stages and subsequent steps although the deploy phase was missing a step between 'optimizing and validating' and 'Minimum Viable Ecosystem'. The amendments were made for the revised framework. Moreover, IE-1 claimed, having a design and deploy as an iterative process, concretes the assumptions while getting the feedback from the deploy phase to make alterations in order to achieve self-sustaining ecosystems. Also, it offers room to adjust the DLT architecture following the feedback from the deploy phase. IE-2 and IE-3, also found the framework covering all major required elements.

7.2.4 Usefulness

Usefulness is the degree up to which the framework assists in asking relevant questions in order to resolve the dilemmas while designing SSE. The usefulness received high confidence from the partners. IE-1 stated this framework is indeed useful for them as it helps in the structuring of thoughts for scaling up their startup. The IE-2, mentioned the framework as a tangible artefact which adds value as it enables strategizing beyond the Proof of Concept. Lastly, IE-3, claimed the framework helps in rethinking the elements of DLTs and to reconsider their strategy and start fresh from the first step of problem structuring.

7.2.5 Effectiveness

Effectiveness is the degree up to which the gathered insights from the framework are directly applicable to the requirements of the project. Even the effectiveness was met with high confidence from the case-study partners. As per the IE-1, the framework is accurate and precise although there is always room for improvement. Again for IE-2, it was helping them think beyond Proof of Concept and strategize for MVE which was their current need. IE-3, rated full for the effectiveness as it helped them to ask the right questions at the beginning of the project. Moreover, IE-3 stated to follow the framework throughout the project timeline.

7.3 Adjustments to the proposed framework

The framework overall received high confidence from all of the case-study partners. Meanwhile, the framework was rigorously evaluated in all three case-studies. All the three phases of the framework were improved to increase the applicability of the framework and making it more relevant to industrial usability.

The first amendment was, suggested by the IE-2, for the entry point for a proof of concept DLT project. The best way to go beyond the PoC is to start with stakeholder mapping while having the goal for MVE. Therefore, the changes were made to the first step, where 'Problem Structuring' (figure 7.1) was amended with 'Problem Structuring / Proof of Concept'(figure 7.2).

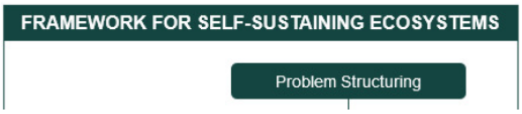

FIGURE 7.1: Discover : Problem Structuring

FIGURE 7.2: (Revised) Discover : Problem Structuring / Proof of Concept

The second amendment was about changing the label of 'Determining Blockchain Architecture' to 'Determining Evolutionary DLT Architecture'. These changes were suggested by IE-1 and IE-3. The 'evolutionary' was added as the architecture might change over time as per the feedback received from the deploy phase. The architecture might also evolve with change in governance or token economics model. Moreover, the next change was to make, DLT architecture, governance and token economics modelling, a cyclic process, as all three are interdependent. The figure 7.3 was amended to figure 7.4. Further, a note was added in the footnotes for 'Determining Evolutionary DLT Architecture' to make it explicit that DLT architecture refers to public, private, permissioned or permissionless along with consensus mechanisms 7.5.

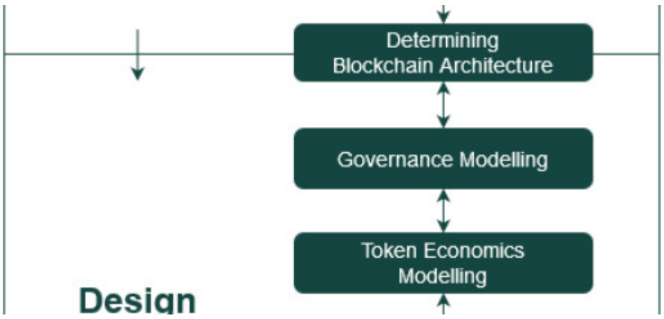

FIGURE 7.3: Determining Blockchain Architecture with linear process

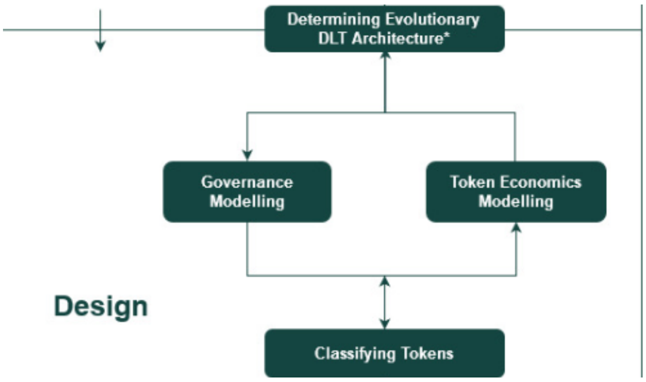

FIGURE 7.4: (Revised) Determining Evolutionary DLT Architecture with cyclic process

FIGURE 7.5: (Revised) Note

The next major change was in the deploy phase, suggested by IE-1 regarding adding a step between optimizing and MVE. The amendments were the existing step was renamed to 'Testing and Optimizing' followed by 'Incubation and Validation'. The Deploy phase entails, testing of the assumptions made in the first two phases and optimizing them as per the requirements. The 'Incubation and Validation' are about deploying the project on mainnet and getting real-time feedback on optimizing the network for accomplishing MVE. The figure 7.6 was amended to figure 7.7.

FIGURE 7.6: Deploy phase

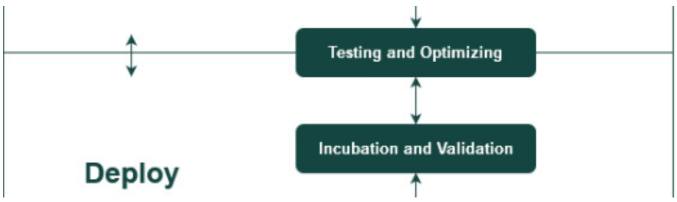

FIGURE 7.7: (Revised) Deploy phase

7.4 Revised framework

The figure 7.8 is the final version of the framework after all amendments.

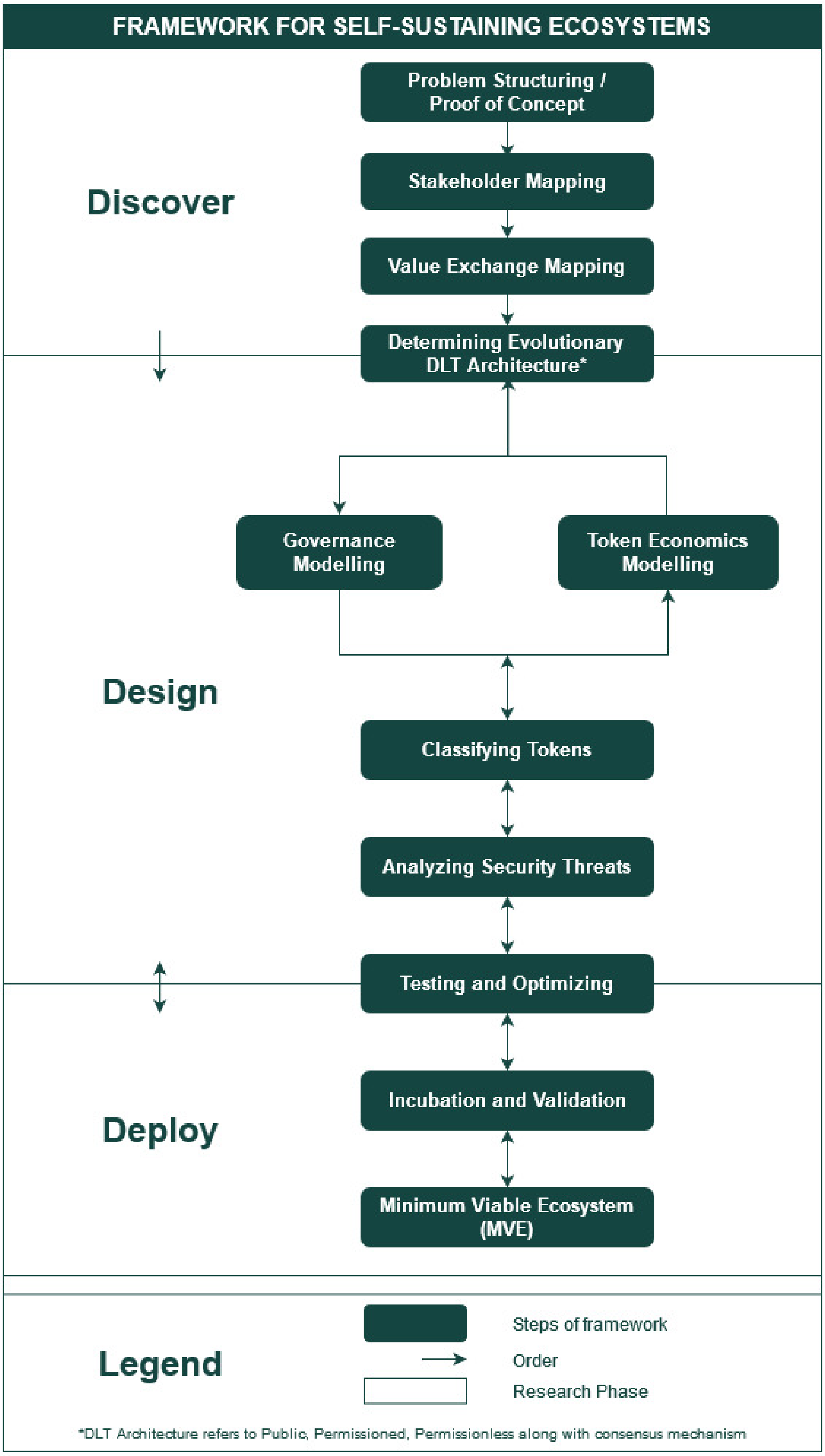

FIGURE 7.8: Revised framework for self-sustaining ecosystems - Final Version

Chapter 8

Discussion

This chapter is divided into two parts. We start with a formal evaluation of the design process according to the DSR guidelines by Hevner and Chatterjee (2010). Next, the chapter continues with a general discussion about the implications of the framework in terms of strengths, limitations and impact. Throughout both sections, we also discuss of identified limitations.

8.1 Alignment with DSR guidelines

As discussed in Chapter 2, the strategies for evaluation of the design product and process using the guidelines by Taxonomy of Evaluation Methods by Prat, Comyn-Wattiau, and Akoka (2015) and DSR by Hevner and Chatterjee (2010), respectively. We use them in ex-post, natural setting to evaluate the design product(artefact) for its effectiveness for real-life assessment. Further, we also use DSR in an ex-post, artificial setting to evaluate the design process with a focus on design science methodology and MLR method. For the evaluation of MLR we use guidelines suggested by Garousi, Felderer, and Mäntylä (2019). Wherever applicable, we discuss threats to the validity of this research according to an overview by Wohlin (2014) and Runeson and Höst (2009).

Design as an artefact: This research has resulted in the development of a framework which supports blockchain leaders with the understanding and analysing the critical aspects of DLT projects such as the purpose, tools required, technical considerations, governance model and token engineering. The framework is a conceptual framework describing three phases and eleven steps into intricacies of blockchain infrastructure.

Problem relevance: The framework is a response to the challenges and new opportunities for research work on topics such as token engineering, sociotechnical ecosystems, mechanism design and shared governance (Risius and Spohrer, 2017; Treiblmaier, 2020). Despite their importance, these elements are still poorly understood and insufficiently researched (Hsieh, Vergne, and Wang, 2017; Finck, 2018; Zavolokina et al., 2020). Moreover, we identified a lack of structured artefacts or tools that can be used by blockchain ecosystem to understand blockchain more concisely in a structured approach that assists in brainstorming critical factors and strategizing for the ecosystem design. The governance and token economics of a blockchain have a significant influence on the ongoing blockchain projects for strategic development and sustainability. Therefore, these domains are of paramount importance for stakeholders relying on them (Lyons, Courcelas, and Timsit, 2019). *The framework is, therefore, addressing a relevant* *business problem and research gap.*

Design evaluation: To evaluate the proposed framework, we created an evaluation strategy based on the work by (Prat, Comyn-Wattiau, and Akoka, 2015). The evaluation of the artefact consisted of an ex-post evaluation with blockchain projects active within the gaming ecosystem through demonstration of the framework as a part of multiple case-studies. During the evaluations, we focused on several quality attributes of the framework such as completeness, ease of use, understandability, operational feasibility, usefulness and effectiveness. In line with the objectives of the framework, these criteria were selected from the holistic view of artefact evaluation criteria proposed by Prat, Comyn-Wattiau, and Akoka (2015).

Various validity threats were identified for the design evaluation. Interaction of selection and results are a possible threat to the case-studies as the subject volume is not representative of the volume that we would like to generalise to. The framework was evaluated by blockchain leaders who have enough knowledge and expertise about blockchain technology.

The threats of evaluation apprehension and selection could also have influenced the results. Due to the blockchain projects participating voluntarily, and knowing that their answers be used as input for analysis, it could be possible that they generally responded more positively due to politeness or because they were more motivated by the subject. We tried to mitigate the threat of experimenter expectancy by having multiple people validate the evaluation protocol beforehand.

Research Contributions: The outcomes of this research have both scientific as well as societal contributions.

The **scientific contributions** include:

(i) Curation of the conceptual framework providing an overview of three phases and eleven steps for DLT projects

(ii) The ability for researchers to categorise and identify areas of research related to token engineering and mechanism design while using the framework

(iii) Detailed categorization of classification of crypto-assets which are based upon multivocal literature study 5.6.

(iv) Documentation of the design process for creating the conceptual framework which can be useful for other researchers interested in the design of conceptual frameworks and artefacts.

(v) A number of tools mentioned as a part of the framework are independent research artefacts, which were brought together as a result of this study to design a structured approach while dealing the DLT projects.

Furthermore, **societal contributions** include:

(i) Result of the case-studies indicates, the need for such tools that adds significant value for blockchain leaders and makes their life relatively easy due to operational feasibility, usefulness, completeness and effectiveness of the framework.

(ii) Framework assists in defining strategic roadmaps for blockchain projects to scale-up.

(iii) Unlocking the possibilities for designing self-sustaining ecosystems.

(iv) This study serves as a direct response to the challenges listed by Treiblmaier (2020) for research on various topics of blockchain.

Research rigour: The input for the designed framework is based on prior literature about cryptogames, blockchain consensus models, types of tokens, blockchain governance, digital assets and incentive models. Furthermore, most of the research process has been structured around established research framework such as DSR and evaluation method as multiple case-studies. The execution of the literature studies suffered from mono-operation bias because only the search engine Google and Google Scholar were used to identify relevant multivocal literature. However, we reviewed the impact to be limited as additional searches on other databases did not retrieve many new results. To increase the reliability of this study, we have aimed to provide extensive documentation where possible, for example by giving thorough documentation of the research approach in Chapter 2 and additional reporting in appendices. All case-studies were recorded and transcribed for later analysis.

Design as a search process: The design of the framework followed an iterative approach of constant evaluation with fellow researchers and colleagues. The framework was compared to the current developments in the blockchain ecosystem on a daily basis. Moreover, by attending external events and discussions with people active in the blockchain ecosystem served as valuable insights and input for the design and evaluation of the framework. As being the ambassador for Hedera Hashgraph community and member of Lisk Community Utrecht, it gave us more opportunity to discuss the framework with people from these blockchain communities which added multiple perspectives and critical thoughts which are eminent for applicability, feasibility and usability of the framework.

Communication of research: The findings of our study are communicated extensively through this thesis. The framework was designed with the goal in mind to be of added value for different stakeholders preoccupied with blockchain projects like businesses, governments, lawyers, economists and not just limited to technical audiences such as engineers. An introduction to blockchain technology is included in Chapter 4 along with blockchain glossary in Appendix C, to provide an overview of the concepts involved in the study and to extend the accessibility as well as the understandability of this thesis to a broader audience. Finally, the DSR evaluation reporting structure (Shrestha, Cater-Steel, and Toleman, 2014) was used as a template to communicate the evaluation results.

8.2 Further Discussion

8.2.1 Strengths of framework

Prior to starting this research, the researcher's knowledge and experience on the elements DLTs was extensive but topics such as token engineering and mechanism design were only studied briefly previously. There was a researched assumption that the DLT community lacks a structured approach while working on a DLT project. Moreover, the aspects such as governance and token economics modelling are rarely considered at the early stage of any DLT project due to their complexity although these elements determine key design decisions in order to build a dApp which is scalable. At the beginning of this research, token engineering was the sole topic to focus on but while progressing and getting a better idea of the range of the topics it was decided to further scope our research and propose a framework which is complete in itself while aiming for self-sustenance where it is not just limited to token engineering aspect. This increased the operational feasibility of the framework. The goal of the framework is helping, DLT projects to efficiently strategize and implement their solutions which includes governance and token engineering as default. The case-studies made it evident that the framework is a required tool and important for projects to scale-up. The results of the case-study received high confidence on the framework in terms of operational feasibility, completeness, effectiveness and usefulness. The framework provides scope for experimentation or exploration throughout the process while aiming for Minimum Viable Ecosystem which is self-sustaining. Moreover, it fills in the gap for the projects that have already achieved Proof of Concept and are struggling to further scale it up. Here, the framework could be leveraged to extend the DLT project's audience and offerings.

8.2.2 Limitations of framework

During the case-studies, the framework was sometimes perceived as a bit complex but that was also because of the nature of DLT projects. The case-study reference material included all sub-category frameworks which can guide the projects but it did add complexity to the main framework. Moreover, the case-studies were conducted with only three partners and results were promising. Although, the data gathered is insufficient to derive a thorough conclusion from just three case-studies. To reach, a precise conclusion there needs to be more case-studies. Also, it is expected that the framework will evolve along with the results from case-studies as well as with progress in the DLT space. Further, there could be more efforts in making the framework more easy to perceive. The element such as value exchange mapping which was the most discussed element of the case-study, could benefit from a defined framework which can make value mapping efficient. On the other hand, the evaluation of the deploy phase was limited as none of the projects were at that stage and also, it requires state-of-the-art agent simulations to get precise results but that in itself is a technical challenge. Lastly, the framework works as a guiding principle which extensively helps in answering 'why', 'who', 'what', 'when' for the project but have limitations while answering 'how' as the help from the framework is in the form of new questions.

8.2.3 Impacts of framework

One of the most evident impacts of the framework, during the course of case-studies was that each partner experienced some new territories within the DLTs which were critical for their projects. It enabled rethinking and reconsideration of elements crucial for DLT projects. Moreover, the framework was received as a complete artefact covering all the required DLT elements for the project. The effectiveness of the framework for each of the project was impeccable as it enabled them to think about every dimension in the DLT. Each of the partners stated, to use the framework for their existing work and would be willing to come back to it, in future DLT endeavours. Lastly, the framework is critical for the DLT projects which are struggling to scale-up.

Chapter 9

Future work and Conclusion

9.1 Future work

In this study, multiple case-studies were limited to three participating partners due to time constraints. The case-studies resulted in positive feedback claiming for the need for such a framework while working on blockchain projects. Although, there were few comments during the case-study which claimed it to be a complex artefact due to the nature of DLTs, therefore, future work could be for improving and simplifying the framework and making it more concise and intuitive wherever possible.

The modelling of token economics through *agent based modelling* would allow designers to bypass any theoretical limitations and model the agents as per the assumptions directly while taking into account every possible constraint. Agent model simulations can be coupled with probabilistic models and deep learning models to extract valuable insights. This can enable self-sustaining economic operations.

Going in-depth of *mechanism design* concepts such as voting protocol, auction mechanisms, token curated registries, bargaining protocols etc. Such that we form a knowledge base which could be reduced to simple concepts to serve a wide range of audience through tools such as framework. These simple concepts could be used as options listed next to the Token Utility Canvas B.2 and Javelin Board B.3, such that it could easily be filled up. Moreover, the academic work regarding token engineering is limited which makes it important to conduct more research into token engineering and its subsets.

Moreover, analyzing of security aspects of self-sustaining ecosystems is critical and therefore, it should be studied in details along with DLT architecture, governance and token economics. Specifically, analysis of quantum-resistant cryptography and quantum enabled security threats should be evaluated carefully.

Moreover, each step of the framework can further be studied into details, for example, the value exchange mapping which was one of the most discussed elements in the case-study. The value exchange mapping is a reflection of a set of premature assumptions of the ecosystem design and requires a thorough framework which might boost the overall usability of the framework.

9.2 Conclusion

As DLTs being a new and emerging technology, it is hard to pinpoint the impact it will have down the line. The digital collectables and gaming have been around long enough for communities and markets to materialize around their infrastructure. DLTs are paving a path to become a driving force into a safer, secure and transparent ecosystem for dealing with digital assets (Yaga et al., 2019).

The objectives that were set out for this study were to improve the lack of understanding and tools available to ease deployment of scalable blockchain projects aiming self-sustenance. The preceding chapters reported on the design of a conceptual framework that aimed to capture the main dimensions and layers of blockchain project in a comprehensible manner to guide blockchain leaders in a structured manner. The study was organised around the following research question:

RQ Main: ***How can a framework be created for designing self-sustaining ecosystems?***

The main research question has been studied on the basis of three sub-questions. This chapter concludes the study by answering the research questions in the following sections.

Sub-questions:

SQ1: ***What are the core aspects of DLTs for designing self-sustaining ecosystems?***

The chapters 3, 4 and 5 were the result of multivocal literature study, which narrowed down the core elements of DLTs to network topology, types of nodes, consensus mechanisms and security which are critical to establish a self-sustaining ecosystems. The consensus mechanism along with the DLT architecture helps in determining the governance, token engineering, and type of digital assets. These findings served as an input for designing the framework.

SQ2: ***What steps does SSE designer need in order to design a self-sustaining ecosystem?***

Chapter 5, defines the precise steps needed while working on a blockchain project. The steps are the result of multivocal literature study, performed in the previous chapters. The framework is divided into three phases: Discover, Design and Deploy. The 'Discover' phase is all about problem structuring which might be in the form of a proof of concept, followed by stakeholder and value exchange mapping. The next step is to determine an evolutionary DLT architecture which is about determining public, private, permissioned, or permissionless ledger along with the consensus mechanisms. This step is overlapped with the 'Design' phase as it is critical to solidify some of the assumptions regarding DLT architecture as they are important to establish governance and token economics.

Nevertheless, there is freedom, to alter the architecture as the project gains more knowledge about the core requirements. The analysis of security in the design phase is the critical step to build self-sustaining ecosystems. The last phase is 'Deploy', which primarily deals with testing and optimizing of previously made assumptions using techniques such as agent model simulations or probabilistic models to enhance the economic and governance system. The next step in deploy is to incubate and validate the project on the mainnet. The ultimate goal of the framework is to achieve a ***Minimum Viable Ecosystem*** which is self-sustaining in itself while having a default market and mechanism design to establish positive-sum game.

SQ3: ***How can the proposed framework be evaluated?***

The proposed framework was evaluated through multiple case-studies from the gaming ecosystem as it is at the forefront for the adoption of DLTs [18]. Moreover, gaming ecosystems are the flag-bearer for the digital assets (collectables) on DLTs which was presented with the case study of CryptoKitties in chapter 3. This narrowed down the subjects for the case studies.

Further, the case studies were conducted with three blockchain projects from different fields of work which included a startup, community driven ecosystem and an academic research project. The startup represented a digital collectable marketplace, the community driven project is a Casino(gambling) application and the academic project was for building a self-sustaining ecosystem for software engineers which could easily be specialized to game developers.

Nonetheless, the framework was rigorously evaluated in the two rounds conducted for each project. The criteria for evaluation of framework were operational feasibility, ease of use, usefulness, effectiveness and completeness. The results of the framework were positive and affirmative to the need of such artefacts for breaking down the complexities of DLT projects while envisioning a strategic roadmap for scaling-up the project to attain the required network effects.

To answer the main research question, **how can the framework be created for designing self-sustaining ecosystems?**

Hence, the framework was curated while studying the intricacies of DLTs and identifying the key elements of DLTs which dictates the design decisions to achieve self-sustenance. These key elements were further structured into three phases of Discover, Design and Deploy where Design and Deploy are the iterative phases. Further, the framework was rigorously evaluated with ongoing DLT projects as a part of multiple case-studies. The results affirmed the need for such artefacts which helps in strategizing the engineering decisions of next-generation sociotechnical ecosystems.

[18] https://dappradar.com/rankings

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Appendix A

Extra sources for knowledge base

A.1 Online courses followed for constructing knowledge base for drafting Decentralization Framework

Course	Offered by	Completion Date	Topics	Score
Blockchain Revolution Specialization 4 Courses - Introduction to Blockchain Technologies - Transacting on the Blockchain - Blockchain and Business: Applications and Implications - Blockchain Opportunity Analysis	INSEAD, Coursera	26th February 2020	Blockchain Fundamentals, Intricacies of transactions, Blockchain Business Models, Blockchain value design, Threats of Blockchain, Real-world case-study building	-
IBM Blockchain Essentials V2	IBM	3rd April 2020	Blockchain Fundamentals, Consensus Mechanism, Cryptography	-
SAP Leonardo and Blockchain	SAP	15th April 2020	SAP Leonardo, Blockchain for entreprises	27.3/30
Practical Blockchain Fundamentals	Beyondskills	29th April 2020	Smart contracts, tokens, DeFi et al	-
Introduction to Digital Currencies (20 weeks course)	University of Nicosia	30th April 2020	Blockchain, DLTs, Byzantine Fault Tolerance, Consensus Mechanisms, Crypto Wallets, Bitcoin, Ethereum, Types of Tokens, Smart contracts, Applications of Blockchain et. al	99.33/100

Appendix B

Elements of Framework

Discover: Stakeholder and Value Exchange Mapping: DAOCanvas

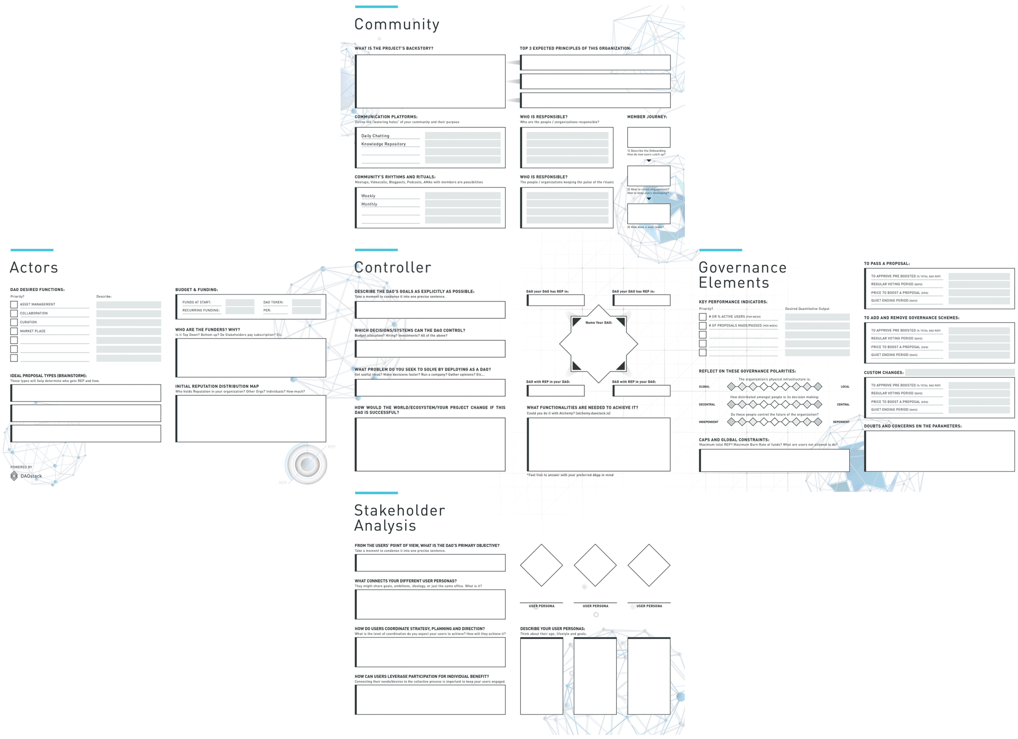

FIGURE B.1: DAOCanvas

Deploy: Token Utility Canvas

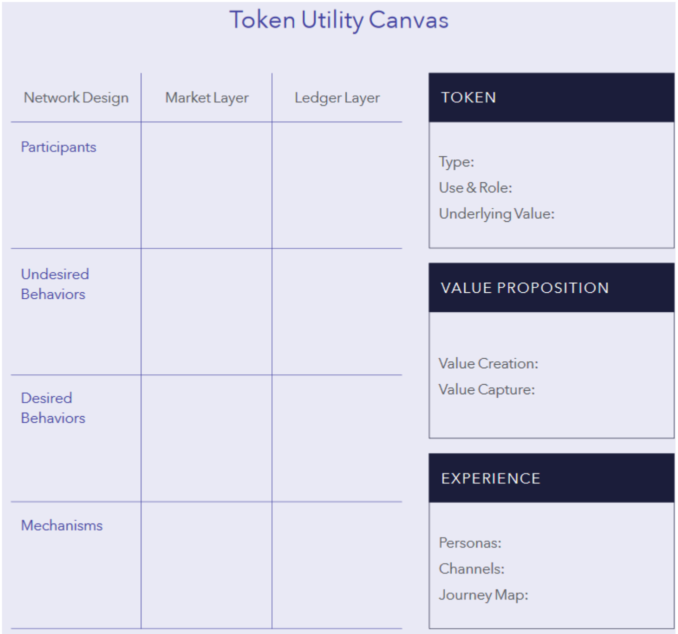

FIGURE B.2: Token Utility Canvas (Dhaliwal et al., 2018)

Deploy: Javelin Board

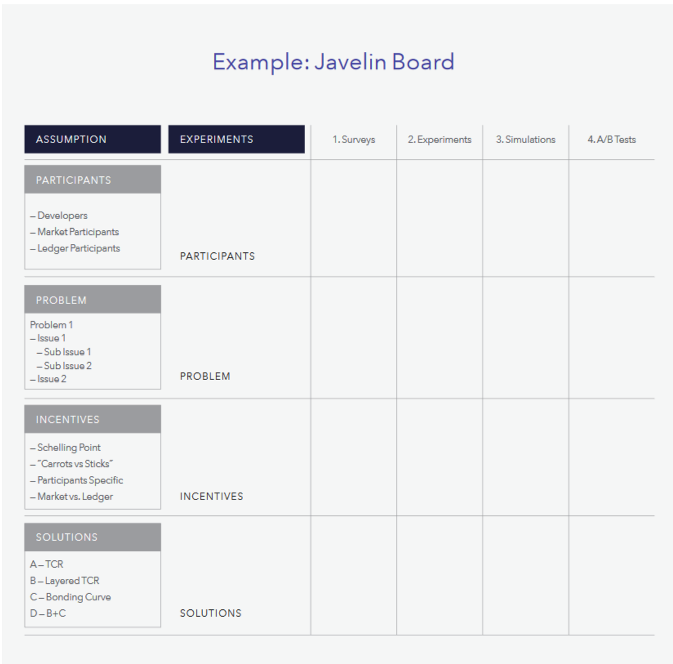

FIGURE B.3: Javelin Board (Dhaliwal et al., 2018)

Appendix C

Case-Study Protocol

C.1 Informed consent

- Taking part in the study
  - ☐ The research information sheet dated 03/07/2020 has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.
  - ☐ I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without any justification.
  - ☐ I understand that taking part in the study involves an audio-recorded interview, or if I don't agree with the interviewer recording the interview, an interview in which information is captured by written notes.
- Use of the information in the study
  - ☐ I understand that information I provide will be used in the master's thesis of Swayam Shah, more specifically in the chapter that deals with the evaluation of the proposed framework.
  - ☐ I understand that personal information collected about me that can identify me, such as my name or function, will not be shared beyond the study team.
  - ☐ I agree that my information can be anonymously quoted in research output.
- Signatures

Name of Participant:
Signature:
Date:

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Researcher name:
Signature:
Date:

C.2 Research information sheet

Version 1.0, Date: 21/06/2020

Context and purpose of the research

You have been asked to participate in a case-study as part of a research project about the framework which helps blockchain leaders envision a strategic project development goals to achieve self-sustenance. This research is executed as a master thesis project in the program of Game and Media Technology at the Utrecht University, under the supervision of Dr. Slinger Jansen and Dr. Zerrin Yumak.

In this research, we have proposed a framework. It is aimed at capturing the main dimensions and layers of blockchain governance and tokenomics in a comprehensible manner. The goal of the framework is to guide businesses, regulators, developers, and other stakeholders with the understanding of each precise elements which act as a fundamental concepts for initial considerations of primary elements required for a blockchain project, aiming for self-sustenance.

For example, by helping them with the identification of those questions that are relevant to ask when looking forward to start or scale-up a blockchain project.

This case-study consists of two rounds. In the first part, we want to explore your relationship with blockchain and nature of your blockchain project. Furthermore, we are interested in your own understanding of self-sustenance and process to attain it, and which aspects related to it are in particular, interest to you. Furthermore, we together, apply the proposed framework for your use-case and observe where it is providing assistance and where it can be improved to make it more effective and usable. If the project wants to maintain confidentiality, you choose to work on the framework yourself without any interference from researcher, although the participant would have to answer a set of questions, to help the research work. We are interested in your initial opinion of the framework, especially in regards to perceive its Operational feasibility, Ease of use, Usefulness, Completeness, and Effectiveness.

In the second round of the case-study, which is meant to be scheduled after a week of first round. Here, the purpose would be to gain more insights on your experience with the framework and if possible, to get more perspectives on it from other team members of your project who might have been involved while applying the framework to your project.

Usage of data and personal information

You can withdraw from the case-study at any time by simply letting me know. If you wish to withdrawal from the study at a later moment in time, you can let us know via e-mail. Any of the information provided during the will then be deleted and not included within the research output. The latter request should occur within 10 days after the first-round took place. The master thesis is expected to be publicly available in the thesis archive of Utrecht University. During the case-study, I will take notes. If you agree, the interview will also be audio/video recorded. Relevant parts of the audio-recording will be transcribed for further analyses. You also have the right to request access to, and rectification or erasure of the interview recordings and note takings. The information captured, either by note-taking or transcribing of the interview recording, will be anonymized before serving as input for the master thesis. Personal information regarding the interviewees will not be shared beyond the study team. The study team consists of me (Swayam Shah) and my internal supervisors (Dr. Slinger Jansen and Dr. Zerrin Yumak).

Additional questions

Do you have any unanswered questions about the case study protocol?

Contact details of the researchers:
Researcher Name: Swayam Shah, email: s.r.shah@students.uu.nl
Supervisor: Slinger Jansen, email: slinger@slingerjansen.nl

C.3 Brief overview of Case-Study protocol with questions

- ☐ Case-study Protocol
  - ■ Kick-off discussion for pitching the idea of framework to relevant case-study partners
  - ■ If the concerned partner is interested in going further, we schedule 2 mandatory rounds for evaluation. The case-study partners are free to schedule more calls/meetings if required.
    - ∗ First round is at the very beginning of case-study
    - ∗ Last round is at the end of case-study
  - ■ The First round is focused as to discuss the proposed framework and solve for their use-case.
  - ■ The Last round is aimed to gauge their overall experience and get feedback with the framework.
  - ■ The time between 2 rounds can be utilized by the partner to work on the framework with their team members which helps the study, as the framework gets rigorously evaluated and scope for getting more perspectives on framework.

- ☐ First Round
  - ■ Present the framework and key points explaining the aim, vision behind the framework and overall thesis.
  - ■ Questions (Understand nature of project)
    - ∗ What is the aim/vision of the project?
    - ∗ Who are the stakeholders?
    - ∗ Is project aimed to attain self-sustenance?
    - ∗ How important is tokenomics?
    - ∗ How important is consortium modelling?
    - ∗ What are primary concerns for the project?
  - ■ Evaluation of the Framework:
    - ∗ Introduce the draft version of Framework
      - · Do you find this framework easy to understand?
      - · On a first impression, do you think it could be beneficial for stakeholders that are looking into the governance, digital assets and tokenomics of a particular blockchain?
      - · Why (not)?
      - · If yes, how exactly it can bring in benefits for you?
    - ∗ Does this framework expand your views on the topic of blockchain governance and tokenization? [Point out feedback indicators]
- ☐ Last Round
  - ■ Discussion on interesting findings and answering, questions that may come up during the time frame of case-study.
    - ∗ Would you see yourself coming back to it in the future when you are dealing with other blockchain projects?
    - ∗ Would the working incentive model drive up network effects of the ecosystem?
    - ∗ Are there any final things you would like to add this case-study?
    - ∗ Rating on 5-point Likert scale for Operational Feasibility, Ease of use, Completeness, Usefulness, Effectiveness as per (Prat, Comyn-Wattiau, and Akoka, 2015)
    - ∗ Are there any aspects of the framework, that you would like to change or improve?
      - · Additions
      - · Improvements
      - · Removals

[End of Case-study]

Appendix D

Blockchain Glossary

Blockchain Terminology	Meaning
Altcoin	An Altcoin (umbrella term encompassing "alt" for "alternative" and "coin") is a labelling for a cryptocurrency that is alternative to Bitcoin.
Anonymization (data anonymization)	Anonymization is the process changing data in such a way that identifiers are being encrypted, removed, substituted, distorted, generalised or aggregated so that data privacy is ensured.
Bitcoin	Bitcoin is a blockchain based cryptocurrency and a digital paymentsystem invented by an unknown with the alias Satoshi Nakamotoin 2008.
Blockchain	The blockchainis a publicly accessible distributed ledger that was initially designed and implemented to enable Bitcoin transactions. It is a piece of IT infrastructure that serves as a database which is used to keep a continuously growing list of records, so called blocks.
Byzantine fault(error avalanche)	The Byzantine fault is a condition of a distributed computing system where components may fail, yet imperfect information exists on whether a component has failed and if so which one(s).
Byzantine fault tolerance	Byzantine fault tolerance is the ability of a computing system to cope with the questionable reliability of data caused by the Byzantine fault.
Consensus mechanism	A consensus mechanism describes the actions necessary to achieve agreement on data in distributed systems.
Crypto protocol	A crypto protocol is the underlying set of rules upon which Dapps are built; prominent crypto protocols are Ethereum, NEO, Stellar, Lisk, QTUM etc.
Cryptocurrency (programmable currency)	A cryptocurrency is a digital currency in which encryption techniques are used to control the generation of units of currency and verify the transfer of funds, operating independently of one single central unit.
DAG (directed acyclic graph)	A DAG is a directed graph such that staring at any node and following the vertices along their direction, there is no way to return to the original starting node; DAGs are being used as an alternative DLT to blockchain technology.
Decentralized Autonomous Organization (DAO)	The DAO is an organization setup to pool funds to develop technologies supporting new decentralized business models.
Decentralized application (DApps)	A dappis an application that runs on a decentralized P2P network, such as Ethereum.

Digital asset	A digital asset is an asset securitized in a digital manner, e.g. by a token.
Digital wallet (mobile wallet, mWallet)	A digital wallet is an electronic device that stores payment and authentication information and thus permits an individual to make electronic payments and/or mobile payments. By using digital wallets users can purchase items online with a computer or use smartphones to purchase something at a store. Some digital wallets also permit money transfers among users.
Distributed Ledger Technology(DLT)	The DLT is a digital system recording and storing data and which is consensually shared and synchronized across a geographically spread network across multiple sites, institutions and/or geographies.
Ecosystem (business ecosystem)	An ecosystem is a network of interacting individuals and organizations such as suppliers, producers, competitors, and other stakeholders that produces goods and services of value to customers, who are themselves members of the ecosystem.
Fungible	Fungible is a quality of an asset denoting that the asset can be exchanged for another asset of a similar or identical type without any significant loss occurring to the holder; to be fungible tokens must not bear any unique information.
Gas	Gas is a measurement of how much processing is required by the Ethereum network to process a transaction; transactions with higher Gas prices are prioritized by the network.
Gwei	Gwei is a denomination of Ether and a popular measurement unit of Gas. 1Ether=1000000000 Gwei.
Hard fork	A hard fork is a specific form of a fork which occurs when the developers of a blockchain decide that changes must be made to the code so that it will create lasting incompatibilities between the older and newer version; contrary to a soft fork a hard fork requires that all nodes upgrade to the new version of the code; as all nodes will only recognize the new blocks as valid, a soft fork is backward-compatible.
Hashgraph	Hashgraph is a DLT and alternative to blockchain which achieves superior performance by using a consensus mechanism based on a virtual voting algorithm combined with the gossip protocol.
Hyperledger Fabric	Hyperledger Fabric is an open-source modular platform based on blockchain technology designed for enterprise contexts.
Immutability	Immutabilityis a feature of data stored on the blockchain. Hence, the blockchain contains a history of transactions which is typically permanent and unalterable history of transactions.
Multisig (multisignature)	Multisig is a process that requires more than one signature to approve a transaction before it can be transmitted to the blockchain and thus increases security for cryptocurrency transactions.

Non-fungible token (NFT)	An NFT is a non-fungible token, i.e. a token that bears some unique information; NFTs are therefore oftentimes considered collectable tokens.
off chain	Off chain is a property of a transaction denoting that it does not occurs on a > distributed ledger such as the blockchain. An off chain transaction does not have to validated it is typically faster than an on-chain transaction.
on chain	On chain is a property of a transaction denoting that it occurs on a > distributed ledger such as the > blockchain, and thus that it is reflected there as soon as its state has been validated. An on-chain transaction is therefore regularly slower than an > off-chain transaction.
Open-Source	Open source is a principle according to which the source code of software is made available to anyone and for any purpose, such as inspection, modifying, and distribution by the copyright holder.
P2P (peer to peer)	P2P is a quality of decentralised system describing the fact that all participants (peers) are equally privileged and equipotent participants; in the context of the blockchain, P2P describes a network of equally privileged and equally potent nodes.
PoW (proof of work)	Proof of work is a consensus process that requires a datum that is very costly to produce in terms of time and/or resources, yet which can be very simply verified by another party.
PoS (Proof of Stake)	Proof-of-stake is a consensus process that requires network participants to 'lock up', resp. 'stake', specific quantities of tokens used in the network for a short amount of time in order to 'vote' and generate network consensus; the participant can mine or validate block transactions corresponding to the quantity of coins or tokens one holds: the more coins or tokens are held by the miner, the more mining power one has.
Signature	A signature is the mathematical operation for verifying the authenticity of a transaction or a document and can for instance be used to prove someone's ownership over his/her digital wallet or data.
Smart Contract	A smart contract is an online contractual agreement based on the Ethereum blockchain that runs exactly as programmed without any possibility of downtime, censorship, fraud or third-party interference.
Timestamp	A timestamp is a set of information identifying the time at which an event is recorded by a computer; on the blockchain timestamps show the chronological order of the blocks and marks the exact time of each transaction; timestamps prove what has happened when on the blockchain.
Token	Tokens are cryptocurrencies that are created and accounted for in DLT systems and represent an asset, a usage right or a unit of value issued by a organization.

Tokenization	Tokenization is a method of protecting sensitive information by substituting a critical data element with a non-sensitive unique alphanumeric identifier, referred to as a token, that has no exploitable meaning or value to third parties. E.g. tokenization can be used to create a representation of a real-world asset by adigital token.
Tokenomics	Tokenomics (umbrella term that encompasses, token and economics) is the economics for the underlying token. It sets forth when, which quantity of tokens are issued and burned and for which purposes they can be used and when; it thus determines the framework for supply and demand.
Cryptoeconomics	It is the use of incentives and cryptography to design new kinds of systems, applications, and networks. Cryptoeconomics is specifically about building things, and has most in common with mechanism design — an area of mathematics and economic theory.
Turing complete	Turing complete is a term given to a system that is able to recognize or decide specific other data-manipulation rule sets (the ones used by Turing Machines); Turing complete is a label used to express the power of such a data-manipulation rule set; the large majority of modern programming languages are Turing complete.