Towards A Data Marketplace Ecosystem

Blueprint For A Community-Driven Data Marketplace

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***Abstract*— The amount of data generation has been increasing exponentially over the last decades. The reasons for this amount of data are pretty similar: The evolution of technology, as well as new technologies, such as the Internet of things or artificial intelligence, as well as data-driven business models. However, the profiteers of the data boom are few players, like big tech companies. Small- and medium-size companies do not have access to the same amount of data and thus cannot benefit from the data boom and adapt their business models. This paper presents the concept of a data marketplace ecosystem to overcome the inbalance between big tech companies and these smaller companies. In comparison to other data marketplaces, our proposal is entirely community-driven. Instead of a single authority or player, it is developed and controlled by a community. The concept is closely related to software ecosystems and adaptive and open systems. The paper presents a blueprint of such an ecosystem based on blockchain technology and smart contracts, discusses the related state of the art, and reflects critically on the results.**

Keywords- Blockchain; Data; Data marketplaces; Community; Data ecosystem; Open platforms, Data Trading.

I. INTRODUCTION

Over the last decades, the amount of data generation has been exponentially increasing, driven by new technologies like the Internet of Things (IoT) and Artificial Intelligence (AI) [1]. In 2020, people created 1.7 MB of data every second, and by the end of 2020, 44 zettabytes made up the entire digital universe. This amount of data means there are 40 times more bytes than stars in the observable universe!

Data is generated and collected in such a massive amount is pretty simple: Data has become the oil of the 21st Century [3]. Data is the fuel for new business models that are common for the most valuable companies in 2021, like Amazon, Apple, Meta Inc., and Google [4].

However, most of the available data is related to a very limited number of companies and organizations that form almost an oligopoly – the so-called Big tech companies: Alphabet, Meta, Apple, Amazon, Microsoft, and Tesla [5], [6], [7]. For Small and Medium Enterprises (SMEs), it is much harder to extract the same value from their data compared to these large enterprises due to three main challenges: (a) they have no access to such an amount of data, (b) they have not access to the technology to process the data, and (c) they have not the knowledge to transform their traditional business towards data-driven business models [8]. To cope with these challenges, we *introduce the concept of data marketplace ecosystems* in this paper.

A data marketplace ecosystem is a specific concept marketplace. Various data marketplaces already exist in different shapes and can be categorized along multiple dimensions, making a general classification of the multiple forms of business models difficult. In [9], a comprehensive model incorporating various dimensions for categorizing electronic marketplaces is proposed. For the categorization of electronic marketplaces in our work, we consider this model (see Figure 1).

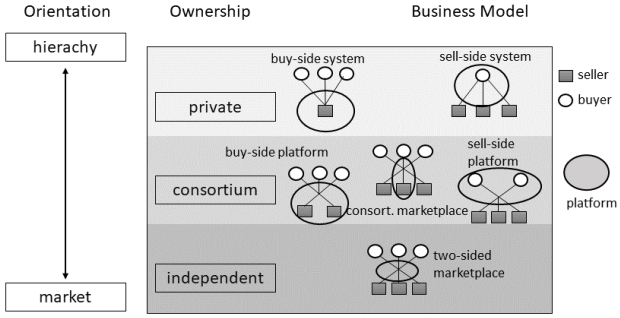

Figure 1: A taxonomy for data marketplaces from [9]

In this model, first, providers are placed on a scale of orientation between hierarchy and market, as shown in figure 1. Economies have two basic mechanisms for coordinating the flow of material or services through adjacent steps in the chain: markets and hierarchies. Markets coordinate the flow through supply and demand forces and external transactions between individuals and companies. Market forces determine the design, price, quantity, and target delivery schedule for a given product that will serve as an input into another process. On the other hand, hierarchy coordinates the flow of materials through adjacent steps by controlling and directing it at a higher level in the executive order rather than letting market transactions conform to it. Managerial decisions determine the design, price, quantity, and delivery schedules at which products from one step on the chain. Thus, all transactions between suppliers and buyers can be classified as either hierarchical or market-based.

Furthermore, data marketplaces are categorized based on their ownership (see figure1), which can be (a) private, i.e., owned by a single company (seller or buyer); (b) consortia-based, i.e., owned by a small number of companies (seller or

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buyer); and (c) independent, i.e., the marketplace is run as a platform without any connection to sellers or buyers.

The last dimension in the model of [9] differentiates between six business models. As shown in figure 1. at the hierarchy level are the privately-owned platforms. These types of business models typically facilitate the selling and buying of its owner, i.e., a company, and only allow one-to-many and many-to-one relations. The consortia-based platforms are between; these models typically collaborate with various companies and facilitate their buying and selling methods. Many-to-many marketplaces are usually operated by independent parties and have minimal entry restrictions at the market level.

According to [9], most of the currently existing data marketplaces, like knoema.com or mdm-portal.de, have a hierarchy private or hierarchy consortium-based business model, see figure 1. Consequently, a single company, organization, or a small consortium of companies and organizations have control over the data marketplace – that is what we define as an *ownership data marketplace.*

As a result, the buyer and the seller have to trust the owner of the marketplace, which is a major problem, as it cannot be ensured that the data will not be misused. One example of this is the Facebook-Cambridge Analytica data scandal in early 2018, where they used personal data for political advertising without the consent of the users [10].

To avoid this, in contrast to an ownership-controlled data marketplace, we *propose our concept of a Community-driven data marketplace, i.e., a data marketplace ecosystem***.** A data marketplace ecosystem does not belong to a single authority and is instead owned and controlled by a *community system*, part of the marketplace. The community system itself is open such as new participants may join the different communities and thereby contribute to and supervise the data marketplace and its evolution. Therefore, the data marketplace ecosystem comes with an *open business architecture platform* that provides the technical foundation for transparency and trust by enabling peer-to-peer transactions for the whole data marketplace ecosystem. The community system has various responsibilities that help define, develop, and evolve the open business architecture platform. These responsibilities are the *relationship between the community system and the open business architecture platform.*

The rest of the paper is structured as follows: Section II gives a brief overview of the state of the art of data marketplaces, software ecosystems, and technologies for transparent and trustable peer-to-peer business transactions. Section III presents our concept for a data marketplace ecosystem that is driven by a community. Section IV summarizes and gives insights into future work.

II. STATE OF THE ART

This Section aims to present an overview of the current state of the art in data marketplaces on the one hand and software ecosystems on the other hand. Finally, blockchain technology and smart contracts are introduced since our blueprint is based on these technologies.

A. Data marketplaces

A data marketplace ecosystem is a specific concept for a data marketplace. Like any data marketplace, a data marketplace ecosystem is an electronic marketplace to trade data. An electronic marketplace is commonplace for interaction between *sellers* and *buyers*, where interactions determine the price and quantity of goods. Moreover, the marketplace provides infrastructure for trading. Marketplaces are concrete locations that facilitate the market. A marketplace is an infrastructure that enables the abstract concept of a market. A market serves three primary functions: First, it serves as an institution, i.e., it assigns roles such as buyers and sellers. Provides trading protocols and governs the behavior of the participants. And finally, a market defines the process of transactions [1]. Thus, an electronic marketplace, also known as e-commerce, is an infrastructure or concrete agency that allows participants to carry market transactions via an electronic medium. As in a data marketplace, transactions and other market processes such as buying and selling data are carried out through an electronic medium. In general, a *data marketplace* is a platform for trading data [11]:

- It provides an infrastructure for trading.
- It allows sellers to sell data.
- It allows buyers to buy data in exchange for money.
- It defines the trading protocols and the transaction process.

Moreover, the existing data marketplaces can be classified into two categories [12]:

1. Marketplaces are more motivated by the Internet of things devices, which allow subscribing data, such as *data.iota.org* or *streamr.com.* Here the Stakeholders deal with *Real-Time Data (RTD)*, where the buyers need real-time data or a subscription to real-time data, e.g., traffic data for a navigation application.
2. There are platforms and marketplaces like *kaggle.com*, *knoema.com, redliondata.com,* or *dataandsons.com,* and even more, where users can find *Non-real Time Data (NRT)* which we define as datasets. For example, this data can be used to train an Artificial intelligence model or make a forecast based on historical data.

Real-time data will increasingly turn into a commodity in the coming years. Intending to provide real-time data, Streamr is an RTD marketplace. Anyone can publish events to data streams, subscribe to streams, and use the data in decentralized apps. Much of the data is free, but the terms of use are stored in Ethereum smart contracts [13].

The IOTA Marketplace is a decentralized data marketplace that aims to make IoT data available to any compensating party. The main goal is to solve the following 3 challenges [14]:

1. Producing an initial, open-source Proof of Concept
2. Exploring new IoT/M2M solutions and business models for the "Economy of Things"

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3. Growing a co-creation ecosystem to foster permissionless innovation

The Mobility Data Marketplace (MDM) enables different parties to offer mobility data, such as petrol prices or motorway construction sites [15]. Compared to Streamr, Datum and the IOTA Marketplace, MDM is not based on any cryptocurrency or blockchain technology behind and is a closed system.

In recent years, many ideas have been proposed to give back the power to the consumers to decide whether they want to share their data. One such project is Datum; the Datum Client empowers users to take control of all their data and optionally share or sell their data through the Datum network [16].

Another NRT Data Marketplace is Synapse AI, which comes up with the idea that users can sell their personal data to train AI Applications. It is built like many other solutions on blockchain technology [17], [18].

Current research focuses on NRT data marketplaces, designed decentral and usually based on blockchain technology. The main field of application is the exchange of IoT data, and the research objectives are generally ruled by reference architectures [19], [20], [21].

Most of the actual NRTD Data marketplaces are quite closed systems, where the sellers especially have to trust the organization behind it because they have to upload their datasets there. In addition, as already mentioned, this trust has been tarnished, at least since the *Facebook-Cambridge Analytica data scandal*.

The RTD marketplaces are mostly still a work in progress and used mainly for pushing some cryptocurrencies behind them, even though there is now no data marketplace known where a Buyer can find RTD and NRT in one marketplace. Another disadvantage of the work in progress RTD marketplaces is that they are designed for cryptocurrencies, and Users can only pay with these currencies. Still, most actual cryptocurrencies are volatile, which has a powerful impact on the market. Moreover, the introduced data marketplaces are private or consortium-owned. The RTD marketplaces, based on blockchain technology, are also owned by the consortium behind their cryptocurrency. The blue area shows where most of the, I.e., ownership data marketplace exists, and the red site offers our approach towards a community-driven, I.e., a data marketplace ecosystem.

B. Software Ecosystems

An ecosystem in nature is the relation and the balance between organisms and their environment, and the environment directly influences the life and the development of the organisms [22]. This concept can easily be transferred to software systems that consist of several independent components, so-called software ecosystems.

The interest in software ecosystems in research increased rapidly from 2010 until today, as shown in a literature Study by Konstantinos Manikos 2015, who has analyzed 231 papers about software ecosystems. The research papers mainly focus on "architecture" (which means software architecture), and another focus was variability, integration, quality, and requirement engineering [23].

One of the main reasons for a software ecosystem is the large variety of configuration options, which give the user a high degree of freedom. Some examples for software ecosystems are the Linux kernel, Debian, Eclipse and Android [24].

Even though most ecosystems have the same goal of being as open as possible, they differ greatly in the organizational structure behind them. To tackle the question of how to provide an open and independent system on the one side, but also provide a fixed and secure framework as well as rules on the other side, there different kinds of organizational structures [23], [24]:

- Monarchy: The ecosystem is orchestrated by one actor.
- Federal: The ecosystem is orchestrated by a set of representative actors.
- Collective: The ecosystem is orchestrated through processes involving all the actors, e.g. voting Anarchy: the ecosystem is characterized by the lack of a general orchestration and each actor acts on their own, based on local needs.

Other research work speaks not only of the software ecosystems but also of IT ecosystems in which machines, IoT devices and humans are considered more part of the overall system. So, IT ecosystems are complex adaptive Systems of Autonomous Systems [25]. I(o)T ecosystems extend software ecosystems' challenges with hardware interoperability and more robust semantical gaps [26].
The term Software ecosystem was first described by David G. Messerschmitt and Clemens Szyperski in the book of the same name and defines software ecosystems as a set of businesses functioning as a unit and interacting with a shared market for software and services, together with relationships among them [27]. In this, the challenge is to bring ecosystems together with business models.

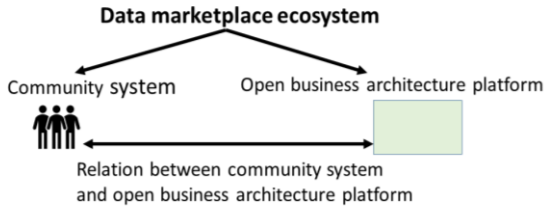

Figure *2*: Overview of a data marketplace ecosystem

The actual research and the challenges in the software ecosystem are like our problem. Moreover, delegating control to a community follows the same approach as our concept. Therefore, we introduce a data marketplace ecosystem, as shown in figure 2. based on the already done and ongoing research in the field of the software ecosystem. The data marketplace ecosystem has a community system and an open business architecture platform. The responsibility of the community system with regards to the open business architecture platform is the relationship between them.

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C. *Technologies for transparent and trustable peer-to-peer business transactions*

1) Blockchain: In recent years, a new technology called blockchain evolved, which has the potential to provide a trustworthy, secure platform for peer-to-peer transactions. Blockchain enables distributed, transparent way of communication. On an abstract level, a blockchain is a distributed ledger that allows users to send data and verify it without a central entity [28]. Blockchain, at its core, is a distributed and decentralized open ledger that is cryptographically managed and updated by various consensus protocols and agreements among its peers [29].

2*) Smart Contracts*: Researcher Nick Szabo was the mid-1990s, first conceived the concept of smart contracts. Nick Szabo describes smart contracts as a set of promises specified in a digital form, including protocols within which parties will perform what promises. Thus, the essential components of a smart contract are [30]:

- A set of rules or promises
- It is in a digital form
- The Protocols for communication and performance are defined
- Performance of actions is triggered automatically.

Blockchain provides a platform to run smart contracts. Thus, enabling automatic execution of contracts on behalf of the users. But it is important to note that smart contracts and blockchain are different ideas. A blockchain can exist without smart contracts, too e.g. bitcoin is a blockchain application that exits without smart contracts. However, smart contracts and blockchain enable many new possibilities, which were not achieved until now. Blockchain provides two out of the four important components for smart contracts i.e. a protocol for communication and performance of actions between various parties and a digital form. Further, the first concept of smart contracts related to blockchain technology is exposed on the blockchain, which is quite a problem regarding privacy. But now, there are also ways for smart private contracts, as an example, hawk a decentralized smart contract system that does not store financial transactions in the clear on the blockchain [31].

III. DATA MARKETPLACE ECOSYSTEM

In this Section, we present our overall concept of the data marketplace ecosystem, see figure 3. The main components of the ecosystem are on the *community system*, the *open business architecture platform,* and the *relation between* them which builds together the *data marketplace ecosystem.*

A *data marketplace ecosystem* is a decentralized, open and large software system owned, controlled, and used by a community system. It consists of the following components:

1. A *community system* is a group of people who share a common interest but still form a heterogeneous system. The community system can be subdivided into different homogeneous subgroups.
2. The *open business architecture platform* is the platform i.e., the data marketplace itself, which the community systems develop, operate, and use. IT describes the technical realization of a whole system for a data marketplace ecosystem. A blueprint for this will be presented in Section 3.3, but first, we introduce the community system.
3. The responsibility of the community system for the open business architecture platform is the *relation* between the community system and the open business architecture platform.

Along with having an open architecture and community-driven, the data marketplace ecosystem is also open for integration. It provides not just the buyers and sellers a platform to exchange data but also an open architecture for developers to integrate various services according to user requirements. Because of these various services, the marketplace users are not restricted to using just one predefined service but can rather use a variety of options. E.g., to sell the data is not to be converted in a format that the platform supports. Still, the developers can offer various services for selling and storing data in many different formats and types. The same applies to payment, and the developers have the opportunity to integrate various payment options and offer them as services.

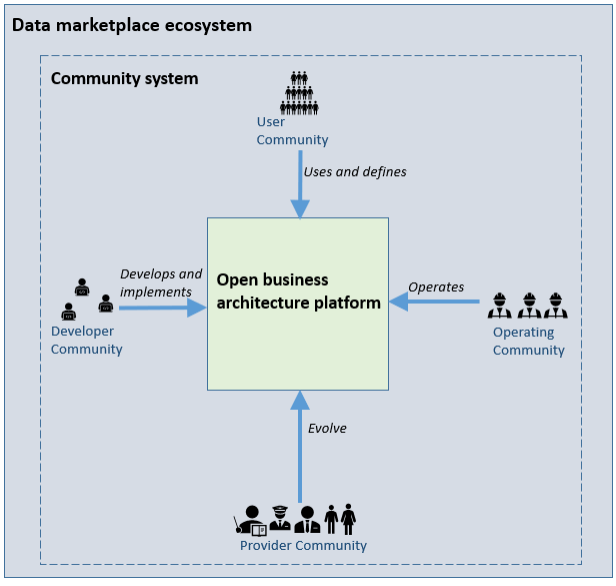

Figure 3: Overview of a data marketplace ecosystem

A. *Community system*

To avoid an *ownership data marketplace*, controlled by a single authority or small consortium, our concept of a data marketplace ecosystem is Community-driven. In order to achieve this objective, it is also necessary to ensure that the

organizational structure behind the ecosystem is not monarchial. For this, we propose a *community system*.

As mentioned earlier, the community system consists of various communities performing different tasks and having various responsibilities. All these communities together build the data marketplace ecosystem. We define the community system of a data marketplace ecosystem into the following four communities:

1. *Provider community:* A not anarchical ecosystem requires some authority of control. As it is a goal of this system is to be as open as possible. We propose the provider community, which gives them control of the system to the users and benefits many other services or developers who want to integrate the services in the data marketplace. However, not everything can be combined. The services various services one hand, do not restrict the buyers and sellers, but not every service cannot be integrated because it might imbalance the ecosystem or introduce a threat to the ecosystem. Thus, the data marketplace needs some rules and standards. The provider community defines rules for the data marketplace ecosystem, e.g., a service to be offered on the marketplace should meet some standards. The provider community defines these standards and validates if the services meet them whenever it wants to be integrated into the platform.
2. *Developer community:* The developers create different services that can be integrated into the data marketplace to fulfill user requirements. Their task is to build new services that are in line with the data marketplace ecosystem.
3. *User community:* The users of the data marketplace use the platform for buying and selling data. They also define new requirements for the marketplace.
4. *Operator community:* The operator community operates the data marketplace ecosystem. The operating Community provides the computation for the data marketplace to function. This is motivated to avoid single ownerships, even if they just provide the technical infrastructure (e.g., a server).

B. Open business architecture platform

Besides the *community system*, the second part of the data marketplace ecosystem is the *open business architecture platform*, which is the core concept for technical realization. An architectural blueprint for this is shown in figure 4. The individual aspects are explained more in detail below.

The central concept of this blueprint is to provide a completely *decentralized* data marketplace ecosystem, which is open and flexible as far as possible. Still, it provides nonfunctional requirements like safety, security, privacy, and dependability. In order to avoid single ownership to give control of the marketplace to the users, the system architecture is decentralized using blockchain technology at its core. This means not even one single service runs on a central server. Everything is provided by the distributed nodes and running inside them (as shown in the background of figure 4). The operator community provides the computing power and the verification from these nodes**.**

These concepts ensure that the whole system is entirely *distributed* and *decentralized.* Every open system needs ways to communicate with the outside and interact with its users. For this, the communication from the *open business architecture platform* to the outside is provided via interfaces, and we propose different interfaces..

The *data interface* enables the possibility to connect external data sources to the marketplace. It is motivated by two facts. First, many companies already have their own data storage system or use one from a provider they trust, and second, it increases the degree of openness. For example, this can be a simple database hosted on any random server, a cloud provider, IPFS, etc., for NRTD, and services to exchange RTD from IoT Devices or different kinds of data sources. Furthermore, an interface to other already existing marketplaces is not excluded. In addition, services can be located here. For example, check the quality of a data set or convert it to another format.

The *money interface* is based on the same idea and aims to integrate as many payment options as possible. These could be traditional payment services, like interfaces to different bank systems and online payment systems like PayPal, Alipay, or cryptocurrencies.

Both interfaces are divided into two kinds of different ports for the services. One-half of the services can access external services, and the other half not what increases the *security* of the overall system.

The core foundation interface contains services only executed within the nodes in Smart contracts. They are strictly not allowed to communicate with external services, which increases *security* and *privacy*. The developer community inside can also develop smart contracts. The *basic smart contracts* provide at least a minimum of functions that are required for a platform to build a useable system. The *developer community can develop advanced smart contracts* and become part of the ecosystem after approval by the provider community.

The mentioned services and smart contracts are divided into two different types: *The essential services* (shown in red in figure 4)-developed by the developer community- provide the minimum of functions and build the backbone of the platform and the *advanced services* (shown purple in figure 4). The idea behind this essential service is that the marketplace always has some basic minimum services which are required for it to always at least function. The advanced services in addition-developed by the developer community must meet the ecosystem standards and must be accepted by the provider community. This ensures the flexibility and expandability of the platform. The aim of the detour via the provider community is to avoid jeopardizing the overall system's stability and security and avoid illegal activities.

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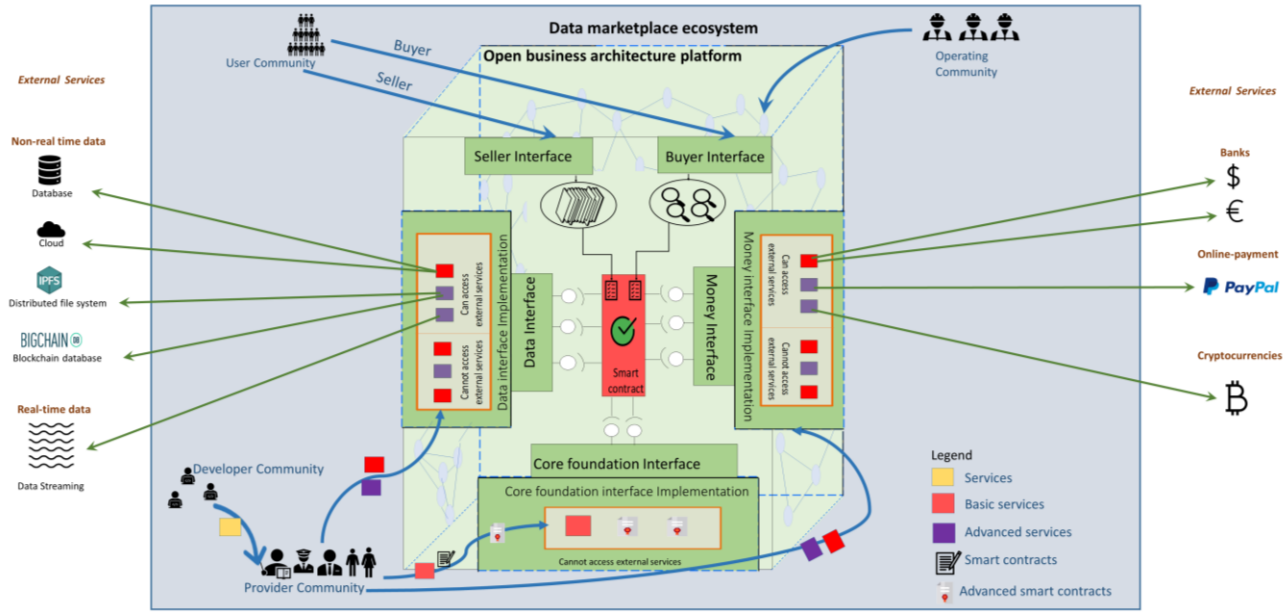

Figure 4: Blueprint for a data marketplace ecosystem

The actual users/the user community (buyers and sellers) of the marketplace access the marketplace via the *buyer* and *seller interface*, which is not a technical interface, but a user interface to get an overview of the offers, buy, or sell data. It supports the users in something of sale via the platform and configures the services according to their requirements.

C. *Relation between the community system and the open business architecture platform.*

As outlined above, the community system and the open business architecture platform build the whole data marketplace ecosystem.

This interaction and the different community system roles are essential building blocks for the platform architecture design. In fact, the developer community, for example, can implement new services, and the provider community checks them if they meet the ecosystem standards. Thus, they have different access levels to the open business architecture platform.

Figure 5 shows an overview of the relation between the community system and the open business architecture platform. As mentioned in Section 3.1 the community system has various roles and responsibilities. The user community uses the platform and creates new requirements. The developer community gets these requirements, and they develop new services based on these requirements. The services are then sent to the provider community, who can check whether these services meet the ecosystem standards. The provider community adds the services in the open business architecture platform if the services fulfill these standards. Figure 6 shows how a new service is added to the open business architecture platform and the roles the community system plays in adding them.

The *provider community* introduced as the overall control instance (comparable with the judiciary in a constitutional state) has the highest access permissions. They are also the only Community that can change the basic services, new services, and smart contracts

The *developer's Community* is comparable with the government in a constitutional state. They need permissions to build services that must interact with the interfaces and communicate with external or internal services. But to ensure the overall system's security, they do not have access to the platform core.

The *user community* (comparable with the nation in a constitutional state) cannot directly interact with the platform core and cannot implement or change services inside. They only use the application layer to interact with the open business architecture platform.

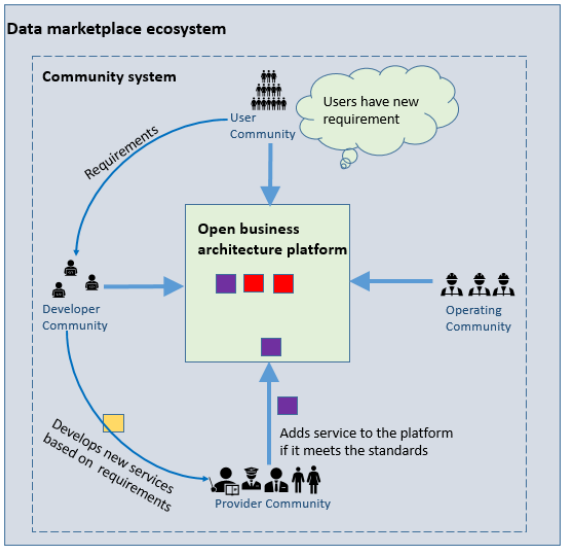

Figure 5: Overview about the relation between the community system and the open business architecture plattform

For all the introduced roles, the different community members need access permissions, which means that they must register, and a user administration service is required in the core foundation interface implementation. The only exception here is the *operating Community*. They do not have to register since they will not interact with the platform but only provide the computing power. Since it is an open system, anyone can simply participate.

IV. Summary and Conclusion

This non-trivial concept for an ecosystem data marketplace is based on the following basic principles in summary:

1. There is no central entity which controls the marketplace. Instead, it is governed by the community system**,** and the whole ecosystem is *Community-driven*.
2. The complete system is *decentralized* and *distributed*, based on underlying blockchain technology. The main reason for this is to avoid, that the services, or data inside the marketplaces are owned or hosted by a single entity. Nevertheless, other technologies can also provide these functions besides blockchain.
3. The architecture is designed to be as *open* as possible but ensures *security* and *privacy*. New services can be added via the developer community and will be controlled by the provider community.
4. The main goal of the different communities inside the community system is to avoid anarchy on the one side and monarchy on the other side. The subcommunities have the task of controlling and balancing each other.

This paper presented a blueprint for a data marketplace ecosystem based on underlying blockchain technology. The paper aimed to present a concept for a data marketplace that does not belong to a single authority.

Our concept is Community driven and proposes on the one side an initial concept for the community structure and, on the other side, an architecture that is aligned to this Community. In order to keep the marketplace as open and flexible as possible but to guarantee a solid security standard, clear interfaces are defined.

Nevertheless, this project is still a work in progress and will be continuously expanded in the near future. Our future work will include proposals about how our proposed ecosystem can be implemented and its challenges. There are already some open challenges that we identified in our earlier work. These are, for example, the final concrete organization form between the communities in the community system, the selection of the basic services, and a lot of open questions about how to increase the stability and the security of the whole system. Further, we identified in our previous work some main challenges related to data marketplaces, which we still want to provide solutions for in the data marketplace ecosystem. Some of these challenges are, e.g., how to check and guarantee data quality or automatically generate metadata for the product offer [32]. Especially for dealing with data quality, we proposed a core concept where buyers can define requirements and an intelligent contract, which holds this requirement and the dataset and verifies the compliance.

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