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MANUfacturing eco**S**ystem of **QUA**lified **R**esources **E**xchange

D3.3
Blockchain-based supply chain platform – first version

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LIST OF ABBREVIATIONS

Table 1: List of Abbreviations

Acronym	Description
CA	Certificate Authority
DB	Database
IIoT/ Industrie 4.0	Industrial Internet of Things
IoT	Internet of Things
MANU-SQUARE	MANUfacturing ecoSystem of QUAlified Resource Exchange
REST	Representational State Transfer
RFI	Request for Information
RFP	Request for Proposals
RFQ	Request for Quotation
SDK	Software Development Kit
SME	Small and Medium Enterprises
VM	Virtual Machine
WP	Work Package

GLOSSARY

Table 2 List of Terms

Term	Meaning
Certificate Authority	An entity that issues digital certificates to be used for authentication of the communicating party holding the certificate.
Chaincode	The implementation of a smart contract within Hyperledger Fabric. A programmatic manner which governs the interaction between a blockchain client and the blockchain network itself.
Endorsing peer	A member of the blockchain network that may be called to endorse transactions for a particular chaincode. The process of endorsing a transaction includes a speculative execution of the chaincode function included in the transaction proposal responding to the caller with the read and write sets (including versions) corresponding to the chaincode execution. In addition it indicates whether it supports the transaction.
MVCC	A multi-version concurrency control employed by Hyperledger Fabric to enable speculative concurrent execution of transactions without corrupting the underlying data storage.
Ordering service	A n Hyperledger Fabric entity that provides total order among incoming transactions and their inclusion into blocks.
Peer	A central entity in the Fabric network which is in charge of validating incoming blocks (and associated transactions) and committing the blocks to its own copy of the shared ledger.
REST	A common manner of interaction among different processes. (https://en.wikipedia.org/wiki/Representational_state_transfer)

1 EXECUTIVE SUMMARY

The main goal of this document is to present the blockchain based infrastructure underlying the trust aspects of the MANU-SQUARE platform. The document starts from a short description of the technology and its specific relevance to MANU-SQUARE, diving into deeper details of two supply chain constructs that have been developed within the project, namely the Request for Quotation (RFQ) support system, and the reputation management support.

Throughout the document we mainly refer to the permissioned flavour of a blockchain which is more suitable for business scenarios. We focus on the Hyperledger Fabric implementation (https://www.hyperledger.org/projects/fabric), which is an open source project maintained by the Linux Foundation.

A blockchain based infrastructure provides many benefits for MANU-SQUARE, chief among these are the establishment of trust and clarity into shared processes, in an otherwise thrustless environment.

This document should be perceived as a continuation of D3.1 (Connecting IoT devices to blockchain services), and D3.2 (Security and privacy services). In order for this document to be self-contained, a concise summary of the project and its objectives is presented in section 2.1, while aspects of the blockchain technology and its application within the MANU-SQUARE project is presented in section 2.2.

As a report of the activities carried out during the first part of T3.3, this document emphasizes the blockchain based infrastructure and its components, concentrating on supply chain constructs built on top of the infrastructure to be used within the MANU-SQUARE platform, namely the RFQ processing and reputation management support. Note that in the remainder of this document we refer to RFQ for capacity and by-product, and for RFP for Innovation Management. The remainder of the task will concentrate on providing support to the ideas management tool. The final outcomes of T3.3 shall be summarized in D3.5, due in M30.

Following activities will further enhance and demonstrate the support for additional MANU-SQUARE capabilities, such as the ideas management, a collaborative tool to foster the join creation of innovative solutions.

The description of the work is organized in the following sections:

- Section 2 briefly introduces the main concepts behind the MANU-SQUARE platform, the blockchain essentials, and the intersection between the two within a supply chain environment.
- Section 3 dives into the uses of Blockchain within MANU-SQUARE; the architecture, capabilities, and manifestation, placing emphasis on constructs to support FRQ and reputation management.
- Section 4 details the blockchain based underlying support specifically in the project context.
- Section5 provides more details on the currently implemented and deployed blockchain based supply chain constructs.
- Finally, section 6 provides conclusions and next steps.

2 INTRODUCTION

2.1 MANU-SQUARE in a nutshell (with a blockchain angle)

The MANU-SQUARE project aims at fostering an ecosystem that acts as a virtual marketplace in which surplus of industrial resources can easily meet corresponding shortage, thus bringing the available capacity (such as production capacity), as well as other virtual and physical assets, closer to the demand to obtain the optimal match (See Figure 1). This scheme has two main advantages:

- The rapid and efficient creation of local distributed value networks for innovative providers of product services;
- The reintroduction and optimization in the loop of unused capacity and potential that would otherwise be lost.

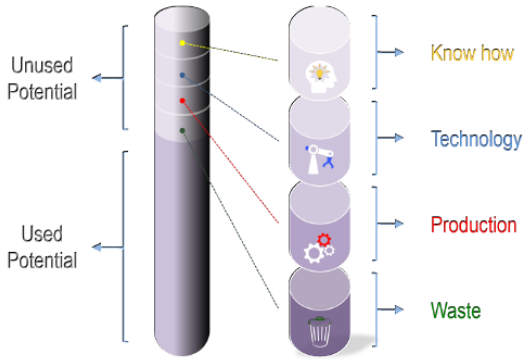

Figure 1: Composition of the unused potential

MANU-SQUARE establishes an ecosystem that is organized to match the needs of buyers with the availability of sellers in terms of know-how, technology, manufacturing capacity, and waste (or by-product). The blockchain technology introduced in this deliverable provides trust, transparency, and security to the MANU-SQUARE platform, thereby serving as a single source of truth and distributed trust in an otherwise trustless environment amongst the different stakeholders of the platform.

Throughout the documents we mainly refer to the permissioned flavour of a blockchain which is more suitable for business scenarios. We mainly focus on the Hyperledger Fabric implementation (https://www.hyperledger.org/projects/fabric). A permissioned network ensures that members agree to enter a joint network and can control the identity of participants in the network. This stands in contrast to public networks (such as bitcoin) in which anyone can join in any role, and the identities of participants is concealed. Nevertheless, not all information on the blockchain is visible to all consortium participants, but rather there is a built-in flexibility supporting differential visibility constructs.

The main objective of the project is to match shortage with surplus on a wide spectrum of areas. The main reason for integrating blockchain technology at the basis of the platform is to provide security, privacy, and trust in the process. In a multi-sided platform, such as MANU-SQUARE aspires to be, there are many entities with different kinds of relationships between them. That leads to different levels of privacy and data visibility requirements that should be supported by the platform, depending on the entities involved and the current interaction between these entities. As there are various modes of interaction between entities, there are various visibility scopes, to adhere to the required level of privacy and isolation. There is a wide spectrum of modes being made available, starting from full visibility of all information to all members of the network, through different levels of visibility separation either governed by an application, or by the creation of separate channels for specific interactions, through the establishment of private data collections which ensure that information is made available only to the intended entities even within the same channel.

The first part of T3.3, which is summarized in this deliverable, describes the architecture and capabilities provided by the blockchain platform in the context of the project. This is exemplified by the RFQ and the reputation mechanism support. In the context of the reputation management support, MANU-SQUARE aims to put forward an alternative to the currently long and costly process of establishing business relations with new companies, such as suppliers. It has been indicated that often the process of establishing working relationship with new companies entails phone calls, meetings, visits to the physical location of the company, and more. MANU-SQUARE aims to make the process digital and short. To establish trust, a reputation mechanism is put in place such that companies can know what to expect from a potential new business partner, based on the collective experience reported by additional platform members. To add trust to the reputation mechanism we establish a blockchain platform underlying the reputation engine, to maintain full traceability and non-repudiation of the reputation data.

2.2 Blockchain – in a nutshell

A blockchain revolves around the concept of a shared ledger, representing the system of record and a single source of truth for business interactions. The shared ledger is maintained by a cluster of peer processes, belonging to different organizations, providing an append only transactions log, while guaranteeing the immutability of inserted and validated transactions. It enables a network of business partners to perform transactions across organizations without resorting to a single unified trusted authority. A blockchain transaction represents a state change or asset transfer in the ledger; transactions are governed by smart contracts, which contain the rules for transactions to be invoked and the agreed upon resulting behaviour. Blockchain provides a shared, replicated, permissioned ledger ensuring trust, provenance, immutability and finality, to replace inefficient, expensive, and vulnerable processes.

These measures together provide a level of trust among partners which is difficult to achieve otherwise in an inherently trust-less and distributed environment. Most importantly, the trust is not due to a single actor within the network, but rather it is an outcome of the collective nature and properties of the underlying technology. Transactions through the platform are recorded in a final and immutable manner by the blockchain, providing all network members with an identical and trustworthy real-time view of the state. Validated transactions in a block in a ledger cannot be modified or deleted without leaving a noticeable trail.

As can be seen in Figure 2 the shared ledger provides a real-time common and replicated view of the state of the transactions among all members of a blockchain network. This reality stands in contrast to the pre-blockchain era in which each organization held its own ledger, opening the door to inconsistencies and disputes.

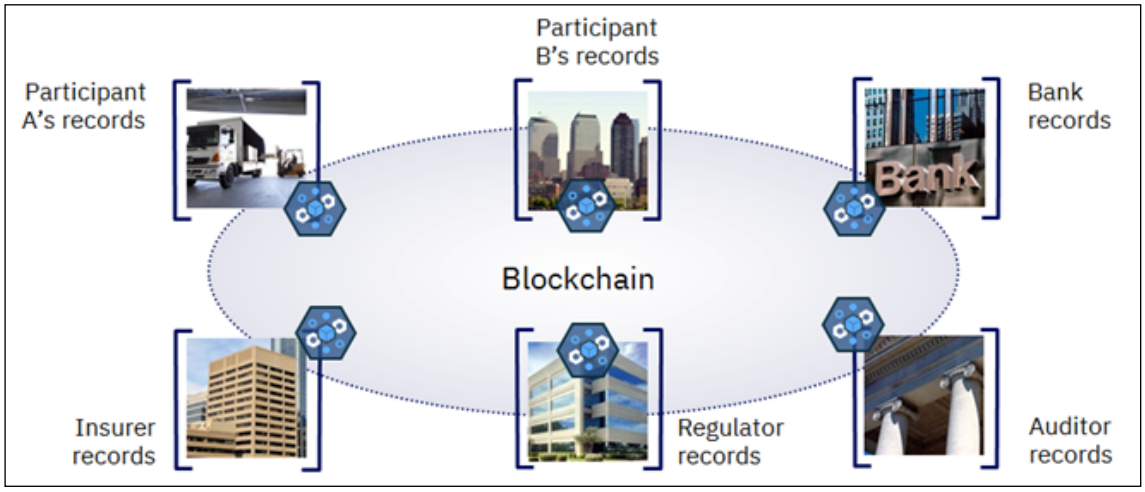

Figure 2: Blockchain's core - the shared ledger

The four cornerstones comprising the blockchain structure are a shared ledger, transaction verification by network members, smart contacts, and security & privacy measures. All these building blocks combined together provide assurance for consensus, provenance, immutability, and finality. These capabilities lay the foundation for a blockchain platform for enterprises as can be seen in Figure 3.

At a high level, the system is comprised of peers belonging to different organizations, which replicate and validate the blocks comprising the ledger; an ordering service which determines the order of the transactions and publishes the corresponding blocks; and a client that interacts with the system for invoking transactions or queries. A sub-set of the peers is involved also in endorsing transactions submitted to the system; supporting consensus for inserted transactions. All entities hold verifiable security certificates issued by a Certification Authority.

Blockchain technology usage is relatively new but interest in it is growing in many fields. The first such field is the financial services arena, but more areas are exploring the usage of this technology, supply chain being in the forefront. In various analysis reports it can be seen that Banking / Financial Services and Supply Chain remain top industries for blockchain

activity[1]. A lot of attention and funds are being devoted to exploring blockchain contribution to supply chain scenarios[2], both by industrial partners, as well as large IT providers, such as IBM, Oracle, and Microsoft.

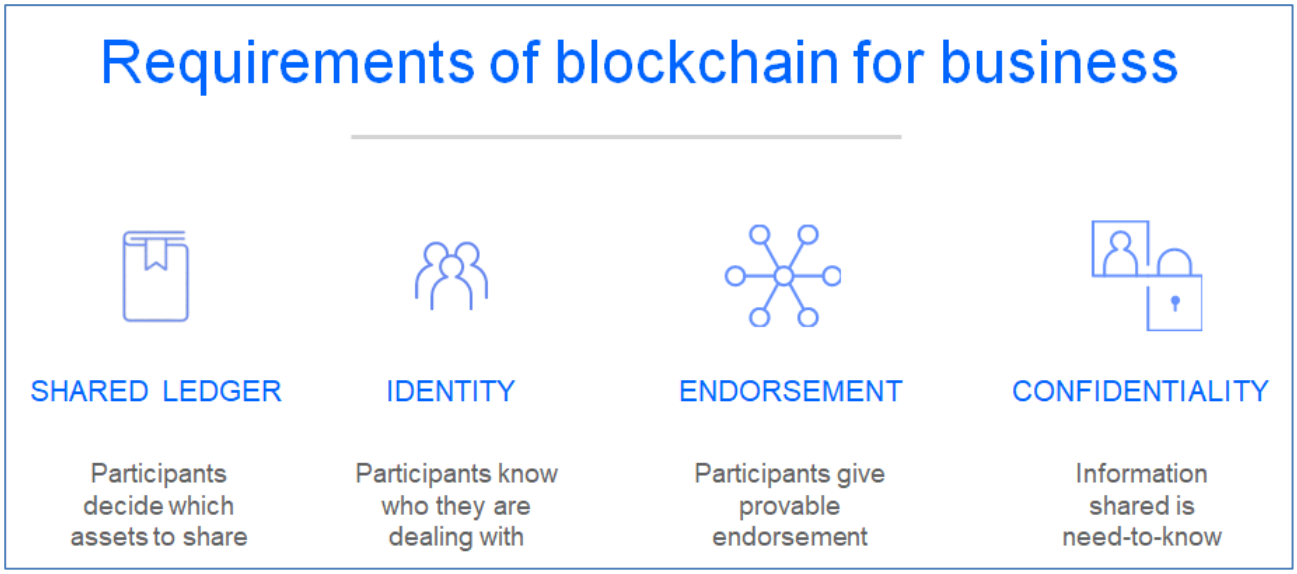

Figure 3: Blockchain essentials

2.2.1 Blockchain for supply chain

Blockchain solutions are prominent in business relationships which require data to be shared between different entities. Such data may be needed in real-time or close to it, or as a trace of past transactions to be used in the future. Companies involved do not , however, necessarily have trust in each other. Such relationships are prevalent in supply chain networks. The use of a blockchain based infrastructure enables parties which are a part of a supply chain relationship to leverage the technology to gain tangible benefits in important areas such as reduction in time, money, and risk. The blockchain serves as the single source of truth, which is shared among all participants, and is not controlled by a single entity.

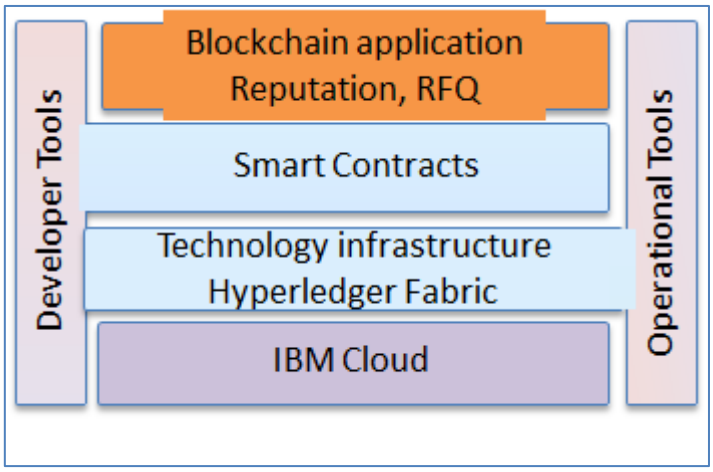

Figure 4: Technology Layers

In Figure 4, a high-level view of the technology layers involved is depicted.

[1] https://www2.deloitte.com/content/dam/Deloitte/cz/Documents/financial-services/cz-2018-deloitte-global-blockchain-survey.pdf
[2] https://newsroom.ibm.com/2018-08-09-Maersk-and-IBM-Introduce-TradeLens-Blockchain-Shipping-Solution
https://www.coindesk.com/pwc-australia-port-of-brisbane-unveil-blockchain-supply-chain-pilot
https://www.zdnet.com/article/alibaba-pilots-blockchain-supply-chain-initiative-down-under/
https://www.forbes.com/sites/bernardmarr/2018/03/23/how-blockchain-will-transform-the-supply-chain-and-logistics-industry/#748fab1e5fec

At the bottom resides the blockchain infrastructure itself, which consists for example of consensus mechanism, cryptographic validation, mechanisms for replication of blocks, and certificate authorities (CA). In our current implementation and deployment all these components are hosted and deployed on the IBM cloud. At the middle layer reside the elements which enable developers to insert specific logic which shall be tightly coupled to a specific deployment of a blockchain. This layer encompasses the specific rules governing the interactions supported for a specific network of participants. This layer is mostly associated with and implemented by Smart Contracts or chaincodes. At a higher layer resides the solution or application, which serves as a mean to connect the blockchain with the business processes of companies, be it via interaction with end-users, or digital processes and devices operating on their behalf.

As a part of the vision to incorporate a blockchain based supply chain platform, the first step is to incorporate partners data of all sort, be it machine generated data or a part of a business process involving a human in the loop. The data serves as the driving element to the agreed upon logic which resides in the blockchain level as well in the form of smart contracts. Examples as to the kind of data includes RFQ related (such as negotiations process, tenders processes), reputation management (controlling the reviews provided by participants and other transaction based KPIs) and data coming from IoT devices which enables tracing the location and state of items in real-time to drive potential notification on out-of-bounds conditions affecting agreements.

Such capabilities enable a coherent and updated view of the status of the supply chain ecosystem including availability of production resources, flow of materials and components, and the associated state as can be reported by attached IoT devices; all according to the scope, rules, and conditions agreed upon among the network partners.

The blockchain infrastructure can be used to reduce the rate of disputes and errors in logistics and to enable real-time tracking of transactions in the supply chain providing elevated accuracy, security and speed; while ensuring that data and interactions are not made visible to unauthorized partners. Moreover, full traceability and provenance of business processes execution is supported by the blockchain infrastructure.

2.2.2 Advantage of Blockchain based scenarios in the area of supply chain

In general, several benefits can be obtained by applying blockchain based scenarios in the area of supply chain.

- Enhance trust in a trustless environment – providing end-to-end provenance. Blockchain based supply chain relationships can become a validated, trusted, self-executing process, supporting non-repudiation.
- Tie in fragmented and siloed systems - A shared ledger can remedy this situation by providing a unified view to all participants at the same time, which can be accessed using the same interfaces to the same underlying system. That provides a clear picture for making decisions to all involved entities.
- Minimize disputes – Having a single source of truth, verifiable and auditable, can lead to a reduced number of disputes, and a shorter time to resolution of existing disputes.
- Data integration, including IoT, can lead to greater transparency and better, more efficient, collaboration by taking actions programmatically and automatically based on incoming data. Provide the capability to track, monitor, and report the location and status, of shipments, goods, or supplies with the integration of IoT devices. Provenance of each component part in a complex system is hard to track but is of great value, especially as items can be combined or be contained. Such information may include the manufacturer, production date, batch and even the manufacturing machine program. Moreover, producers and end users require transparency on where and how their raw materials and sub-contracted products and supplies are made. Some governments require more information about corporate supply chains, with penalties for non-compliance. In such a case blockchain enables the safe digital transfer of material and goods end to end, across the supply chain. That information includes which party had ownership to what part at what time, and what changes were performed.

- Automating contracts and processes - Terms of a contractual agreement between parties can be manifested as a smart contract running in the blockchain. For example, a buyer wants an efficient way of converting a purchase order into validated, self-executing contract updated to reflect the status of the supply.
- Differential visibility and data privacy ensure that the information is shared only among the intended partners.

3 BLOCKCHAIN USE IN THE MANU-SQUARE PROJECT

3.1 Blockchain roles in the overall platform architecture

The blockchain platform plays a role both in the underlying data layer as well as in the tools layer. As can be seen in Figure 5 and Figure 6 it is located at the lower infrastructure layer of the platform, exposing interfaces to services that the different higher-level components of the platform can use. At the data layer it does serve as a unique kind of data store in the form of a shared ledger exhibiting the capabilities detailed in sub-section 2.2.1. At the same time, it does play a role at the tools layer as well, since a part of the logic does reside in the blockchain internals in the form of a smart contract[3] which is a programmatic manner to declare and enforce the rules that govern specific interactions via the blockchain. Thus, different platform components use interfaces exposed by the blockchain component in order to take advantage of the capabilities and promises of a shared ledger. The main component that interacts with the blockchain layer on behalf of other components is the Ecosystem Data Manager. The blockchain component exposes nonetheless a REST interface to other platform components. The interfaces are grouped according to functionality provided, namely RFQ and reputation related interfaces. There are two main kinds of actions supported by the interfaces:

1. Invoke smart contact transactions – intended for MANU-SQUARE modules to be able to invoke transactions residing in smart contracts. These transactions are invoked to change the state of an entity and record that for posterity. For example, while supporting an RFQ process transactions can be invoked for publishing a new RFQ or providing a response to an RFQ.
2. Query - expose query capabilities to retrieve data stored in the blockchain. For example, while supporting an RFQ process such queries can be used for retrieving information on the complete journey so far of an RFQ (publisher, offers, negotiations, acceptance / rejection); the reputation management component can return the current state of the reputation entity corresponding to a MANU-SQUARE registered company.

[3] In Hyperledger Fabric smart contracts and implemented in the form of chaincode (https://hyperledger-fabric.readthedocs.io/en/release-1.4/chaincode.html)

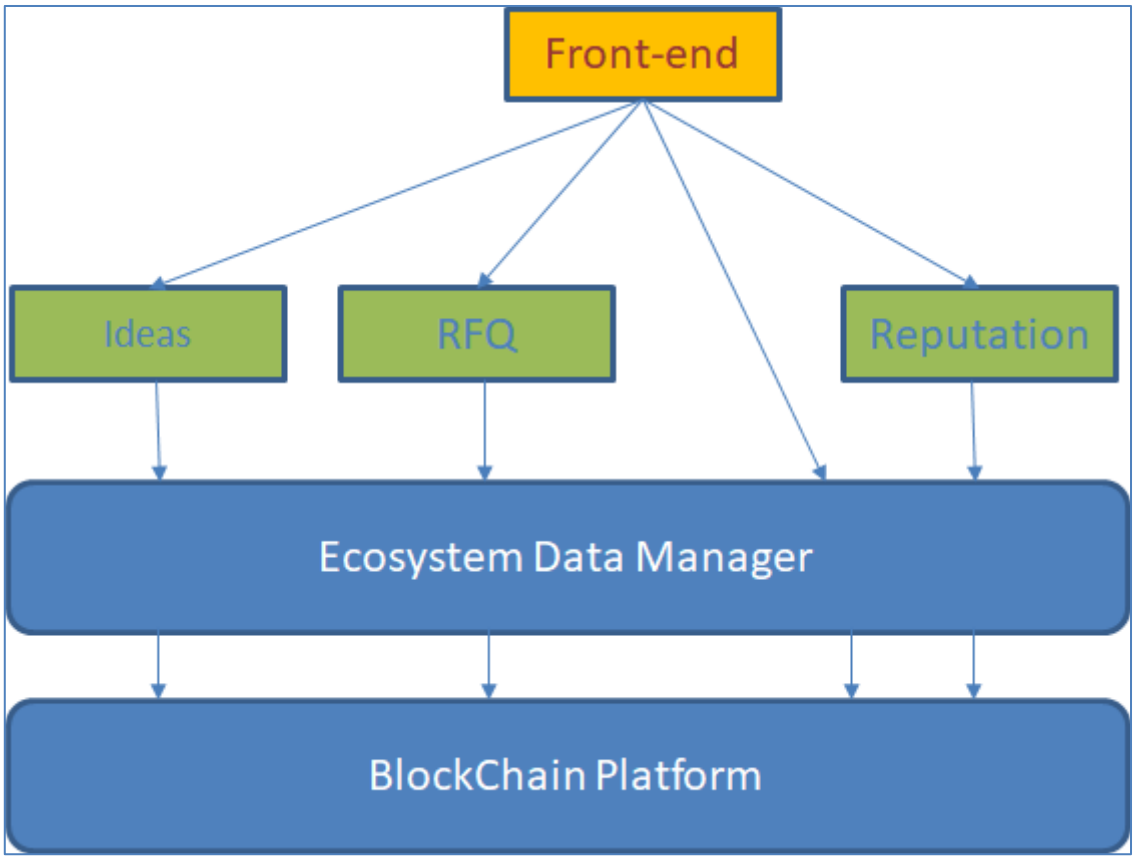

Figure 5: Components interactions

In Figure 5 a broad sketch of the integration of Blockchain within MANU-SQUARE is depicted. In the diagram we can see the blockchain network, depicted at the bottom. Within the blockchain layer we include an internal blockchain client within an application that interacts directly with the blockchain network while exposing a REST interface to the rest of the MANU-SQUARE components. The Ecosystem Data Manager acts as a mediator between the rest of the platform components and the data layer, including the blockchain.

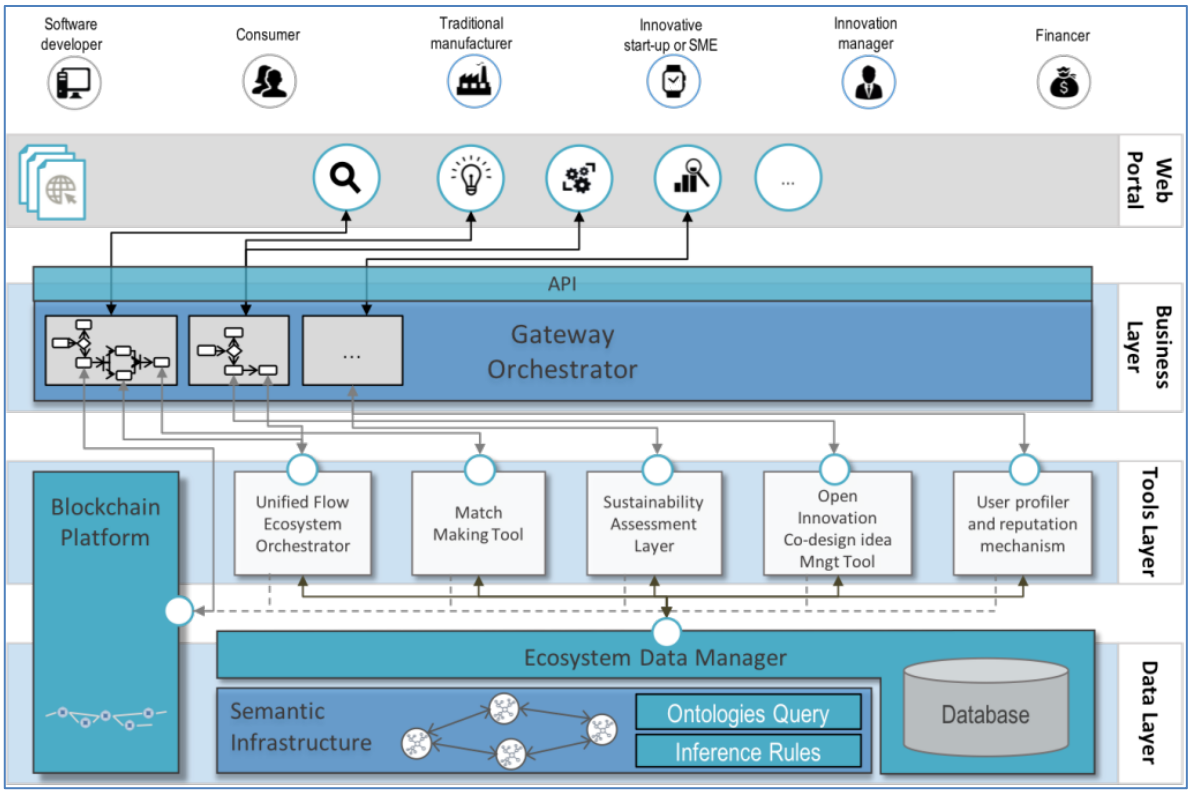

Figure 6: MANU-SQUARE high level architecture

Figure 6 provides a higher-level architecture view of the location of the Blockchain component within the platform, and the foreseen interactions with additional components and tools. The blockchain layer sits at the bottom part of the architecture, in line with additional data processing and storage components, but also has a part in the tools layer, as the smart contracts (chaincodes) that are deployed in the system hold the logic which governs the interaction with the underlying blockchain storage.

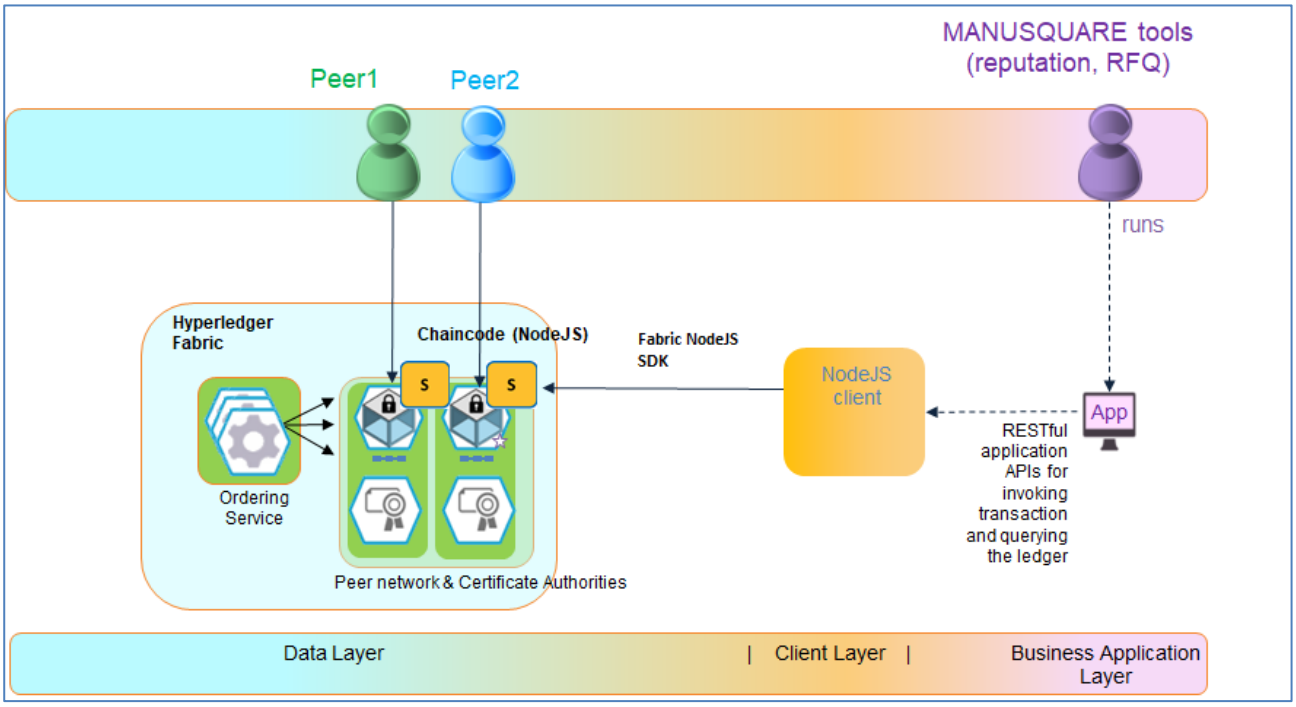

Figure 7: Embodiment within MANU-SQUARE

As can be seen in Figure 7, the blockchain support architecture for the different MANU-SQUARE tools consists of several components. First, the blockchain network itself which currently involves a single channel per service supported. That channel hosts the chaincode which drives the interaction with the component itself. The network is further comprised of peers that obtain and validate blocks of transactions and hold a replica of the shared distributed ledger. In addition, there is a chaincode implementing the blockchain smart contract, storing and updating the state of entities and allowing querying the ledger and the associated world state for information on those entities. The chaincode supporting the reputation management tool is NodeJS based, while the chaincode supporting the RFQ process is written in Golang. In addition, there exists a NodeJS client embedding internally a Hyperledger Fabric NodeJS SDK to invoke/query the appropriate chaincodes. The MANU-SQUARE tools acting as blockchain clients will invoke the blockchain client via a set of exposed RESTful APIs, passing JSON objects whose structure is agreed upon between the components, to invoke transactions that change internal state or query for stored information. An ordering service is associated with a channel (several channels can share an ordering service) with the mission to create a total order of incoming transactions, but blocks, and make the blocks available to the designated peers.

Mediating between the blockchain infrastructure, including the smart contracts layer and the rest of the components of MANU-SQUARE is an application listening for incoming requests and communicating on the other side with the blockchain infrastructure. The application exposes a REST interface to the rest of the MANU-SQUARE platform, and acts as gateway between MANU-SQUARE on the one hand and the blockchain infrastructure on the other hand. The application communicates as well with a certificate authority (CA) in order to resolve the cryptographic material and identification of entities. The application embeds an internal blockchain client which in turn can invoke transactions and queries on the blockchain itself.

3.2 Capabilities supported in the MANU-SQUARE platform

This section is intended to introduce the specific use cases and tools that will make use of the blockchain technology within the MANU-SQUARE project. As aforementioned, the Blockchain integration currently focuses on three representative scenarios, namely RFQ management, reputation management, and traceability of innovative ideas.

At a high level, the use cases in MANU-SQUARE can be divided into two broad categories. First, matching between surplus and need (for example of production capacity or by-products) to support capacity sharing. Second, innovation management for collaborative design. For both categories the MANU-SQUARE platform shall take advantage of a blockchain based infrastructure as the providers of a trusted (in a trust-less environment) single source of truth. RFQ support shall be used in the first family of scenarios, ideas management support shall be used in the second family of scenarios, and the reputation management support can support all different use cases.

The functionalities that a blockchain infrastructure can support in supply chain scenarios will be translated into plans for specific use cases to be deployed in the MANU-SQUARE platform. Hereinafter, a short description of each supported capability is provided.

3.2.1 RFQ management

RFQ is a structured and often complicated process which may involve multiple hops and interactions between the entities involved (from the initial offer through a negotiation process, culminating in a signed deal). The blockchain will help structure the process and safeguard all the interactions and advancements of the process throughout its lifecycle. This capability shall help to centralize the process and related communication, to overcome current scattered RFQ related documentation.

The process is initiated by a prospective customer and is targeted towards a potential supplier and may consist of various items to be agreed upon (such as price and delivery date). Several rounds of negotiation may be required for the positive (or negative) finalization of the process. All information exchanged digitally shall be part of a permanent record kept and made available by the blockchain.

In supporting such a process there needs to be awareness as to the data that is distributed on the blockchain platform and the visibility scope associated with that data. Different stages of the process require the visibility to a different subset of stakeholders. This requirement poses challenges to the underlying blockchain infrastructure. In a nutshell, an RFQ process with a prospective customer publishing the initial RFQ, the visibility associated with that should be wide, thus all members of a network which were identified by the match making tool as relevant and selected by the publisher shall be able to receive that information. On the contrary, when responding to an RFQ, normally the entity in question wants that information to be shared only with the RFQ publisher.

3.2.2 Reputation management

Reputation management is of crucial importance to the adoption of the platform. Thus, the trust that can be associated with this component is of great importance as well. The blockchain infrastructure shall support the traceability of the entire history related to the reputation of all involved entities at different points in time. As the platform is intended mostly to establish relationship among entities that have no prior engagement between them, the reputation management capability plays an important role. Without the MANU-SQUARE platform, companies often go through much pain over a prolonged amount of time before embarking on a business interaction with a new partner. The intention in this case is that with the added trust that can be associated to this component, companies will rely on reputation scores provided by the platform to make more informed and faster decisions for establishing new relationships. The blockchain layer exposes interfaces for company representatives to be able to enter and store reputation scores and descriptions and to query for the reputation history of an entity including the evolution of the score.

3.2.3 Traceability of innovative ideas

In this scenario, the blockchain is applied to the tracking of contributions of innovative ideas to challenges within the MANU-SQUARE ecosystem. Considering that the platform is intended to support the evolution of ideas form basic concepts to fully set-up projects in a cooperative and open manner, the blockchain is involved in keeping track of the contributions of each participant and register the ownership of every single contribution. This capability should support the ability to reward respectively the participants of ideas creation at a later stage in the product development, by a higher level ideas management that can track the evolution of the idea and participants via queries to the blockchain layer.

The blockchain layer exposes interfaces for adding information and perspective to an idea along with the possibility to query the blockchain to obtain a validated history of the idea throughout its evolution.

3.3 Contextualising blockchain use in the capacity sharing scenario

This sub-section aims to clarify the way the blockchain based infrastructure is used within the main processes supported by the MANU-SQUARE platform. Following the business process flow for a capacity sharing scenario[4], we observe the following steps:

1. Customer creates a new RFQ which behind the scene uses the match making capability of the platform to receive a ranked list of potential suppliers. The RFQ process interacts, in several points with the reputation management component which in turn queries the blockchain layer passing through the Ecosystem Data Manager taking the reputation scores of the list of potential suppliers into consideration for the calculation of the final ranking scores.
2. Embark on an RFQ process between the customer and prospective suppliers. In this stage, the customer publishes an RFQ, which is recorded on the blockchain and is made available to all prospective suppliers. Negotiation steps and counter-offers are made within a visibility constraint of the specific potential supplier and the customer, with the help of the blockchain. When a final decision is reached, each participant is made aware of the final state of his quotation, namely accepted or rejected. Once again, this information is recorded and made available via the blockchain.

[4] A comprehensive explanation can be found in D1.3 (Business processes and early validation scenarios), and D5.1 (Platform services portfolio)

3. Periodic monitoring of the project status and a corresponding update of the project status and advancements. This step may involve periodic updates of some reputation dimension in the blockchain as well, driven by the reputation management tool.
4. Project closure – Update reputation management for both the customer and the supplier. This step is executed using the reputation manager component, storing the calculated updated scores in the blockchain platform.

In the following section we can see the main corresponding interactions of the blockchain component with additional MANU-SQUARE platform components (for a visual reference please refer to **Errore. L'origine riferimento non è stata trovata.**). For all such interactions there are two broad categories of actions that are taken and supported by a RESTful interface exposed by the blockchain platform, namely invoking a transaction on the blockchain, intended to record data, and querying the blockchain platform for data previously recorded (latest state or historical data).

1. RFQ management – the blockchain component provides the underlying mechanism for keeping track and advancing the RFQ process among the customer and the suppliers. Naturally, the blockchain shall keep track of the history of the interaction from beginning to end and can serve as the reference point for the agreed upon terms and the evolution of the process. This component is further described later in section 5.
2. Reputation management – the reputation management process shall be handled by the MANU-SQUARE platform, for all involved entities, both suppliers and customers. This process is deemed an important one for attracting entities to use the platform, and for the long term sustainability of the platform. Having a blockchain based infrastructure to keep track reputation management calculated scores is essential for the trust associated with the entire platform by current and prospective customers to join and use the platform.
3. Ideas management – tracking the evolution of a challenge through related supplied ideas. A challenge is opened by an entity and recorded in the blockchain. The open process enables multiple entities to contribute ideas to a specific challenge. Each such idea is in turn registered in the blockchain. The history of the evolution of ideas leading to the fulfillment of a challenge is fully trackable by using the blockchain platform.

Similar capabilities and interactions are foreseen as well for the collaborative design and ideation management scenarios. The content and internal structure of tracked items shall differ, but at the core, similar blockchain related processes and interactions shall take place. Thus, for innovation management and ideas tracking the blockchain infrastructure shall provide a basis for the management of the entire process from a design need all the way to the agreement of a solution, tracking along the way the contribution of each party to the final products.

4 SUPPORTING BLOCKCHAIN PLATFORM ARCHITECTURE

Underlying a Hyperledger Fabric network, as most permissioned networks is the notion of a consortium, which is a group of organizations that agreed to set up a blockchain network between them, establishing the governance body and rules. As can be seen in Figure 8, most central organizations within a blockchain network will deploy (or use) a Certificate Authority (CA) on their behalf, and will contribute peer(s), which are components that endorse, validate, and hold replicas of the shared ledger. In addition an ordering service needs to be set up by the organisations, to order the transactions, cut blocks and make them available to the peers.

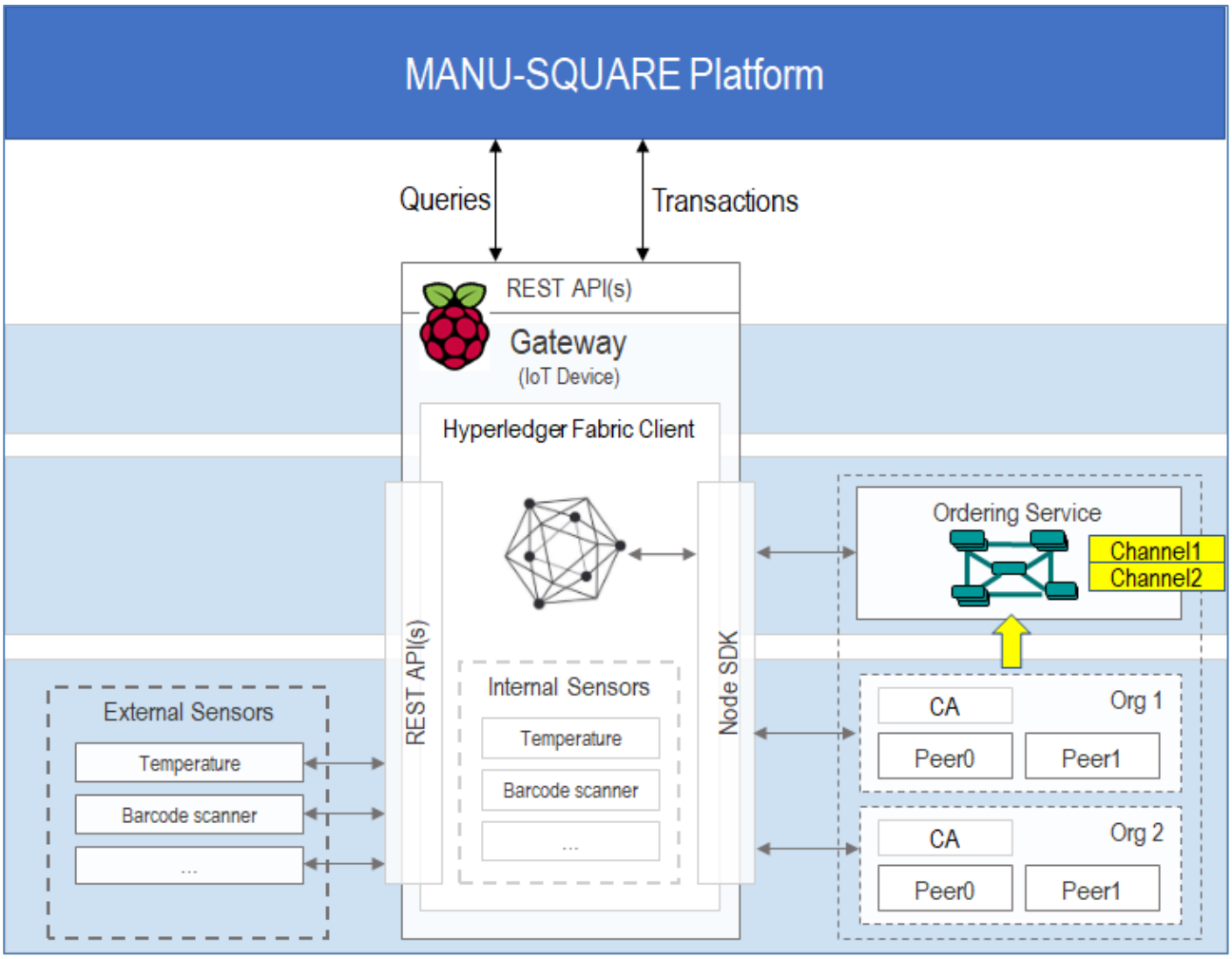

Figure 8: Blockchain network components

Transactions among members is performed in the context of a channel. A channel creates a separate ledger visible only to the organizations included in the channel.

To become a network member first each participant needs to be registered and enrolled in the network via a Certificate Authority. A user with an appropriate role (such as admin) can register additional users from his organization. Using a secret received during the registration process the new user can enroll, thus receiving the required credentials for participating in the blockchain network. Using these credentials a user may start invoking transaction on the blockchain.

To bootstrap a network we need to have an ordering service up, create peer processes on behalf of organizations, create channels, and distribute the appropriate cryptographic material, including the certificates required to participate in the network, to each entity. Once the backbone is in place we can install and instantiate chaincodes. We need to install a chaincode on each peer which may endorse transactions for that channel (endorsing peers are the only ones that actually execute the chaincode). The chaincode needs to be instantiated on one of the peers, to create the bond between the chaincode and the channel, and run the initialization method specific to that chaincode.

Once the chaincode is in place users can start invoking transactions and queries on the blockchain channel. By using a client the user assembles a transaction and sends it to the endorsing peers. In the MANU-SQUARE case the application receiving REST requests from MANU-SQUARE tools performs this operation. Endorsing peers policy is determined per chaincode and establishes the identity of potential endorsers and the conditions that have to be satisfied for a transaction to be

approved. Once the client has received responses from the endorsing peers, he can evaluate whether the transaction abides by the endorsement policy and can thus go through or needs to be dropped. Endorsing peers are the only ones that actually run the chaincode (in a simulating mode), and return the corresponding read and write sets of the transaction, namely the keys and versions of variables that were read or written by the simulated execution of the chaincode. Allowed tractions are then sent, along with the corresponding read and write set to the ordering service. The ordering service in turn orders incoming transactions, cuts blocks, and makes the blocks available to the peers. Peers in turn obtain a new block, validate the transactions in it, and applies the write set for the transactions that have been determined to be valid.

In Figure 8 we can see the components described above in play. On the right hand side we can see the main components of the blockchain network itself namely the ordering service, peers, and the certificate authorities. We can further see the channels which are declared in the system associated with an ordering service and a sub-set of the peers. In the middle we can see an application which embeds a Fabric client to communicate with the blockchain while exposing a REST interface for other MANU-SQUARE components.

The blockchain system mostly consists of three layers. First, a physical layer of deployment which includes the establishment of the network consisting of organizations, their participating servers (peers in Fabric), channels, cryptographic material, and more. A second layer includes the establishment and distribution of smart contracts (chaincode), which programmatically determine the rules and actions to be followed. These smart contracts control the state that is saved in the underlying blockchain DB. On top of these lie the business layer which connects between the external world and the underlying blockchain infrastructure. In our deployment, as in most cases, this layer consists of the programmatic core of the interactions to follow, which exposes, on the one hand, to the higher layers of external applications a RESTful interface through which the interactions with the blockchain are mediated. On the other side it includes a Blockchain client (such as the Fabric NodeSDK client),which is in charge of interacting directly with the blockchain in the form of invoking transactions, invoking queries, and establishing of call-backs. These call-backs enable an asynchronous mode of operation in which a process is notified by the blockchain network on the occurrence of events which were declared as being of interest to the application or higher layers.

5 PUTTING IT ALL TO WORK IN MANU-SQUARE

Once a generic blockchain based platform infrastructure (Figure 8) has been put in place, it's possible to develop specific blockchain constructs on top of the infrastructure to provide capabilities which are specific to the MANU-SQUARE platform hosting the blockchain network.

5.1 RFQ

One of the prime examples of supply chain constructs that is supported by a blockchain backbone is the RFQ process. We have created a simple template which demonstrates the utility of the blockchain as the underlying RFQ process back-end. In this case the blockchain serves both as the single source of trust and truth, and as the driver mechanism used to communicate between different parties. Naturally, variations of this RFQ process can be constructed, based on the foundations we detail below, supporting both structured and less structured manners of interaction between the counter-parts.

The proposed and demonstrated RFQ process consists of three main primitives, namely: Publish RFQ (offer), negotiate / communicate (counter-offer), and finish (accept or reject). The initial tender corresponds to an action that is advertised using a single channel to which the entity publishing the RFQ participates along with all relevant entities that potentially are able and willing to respond to the

proposed RFQ. Thus, the process is initiated by an entity producing a tender and submitting it to the blockchain as a transaction invoking the “publish_rfq” function of the RFQ smart contract.

In Figure 9 we can see the swagger declaration of the blockchain based RFQ support in MANU-SQUARE. The definitions are divided into three categories, namely RFQ related actions, quotation related actions, and data models. The swagger definition can be accessed and tested online at the following address: http://161.156.70.125:6891/api/, corresponding to a VM on the IBM Cloud on which the blockchain infrastructure is deployed. For the RFQ section we can observe that there are established calls available for the creation and publishing of a new RFQ, for querying the existing RFQs, for extracting information on a particular RFQ, and for declaring the selected entity for its accepted offer.

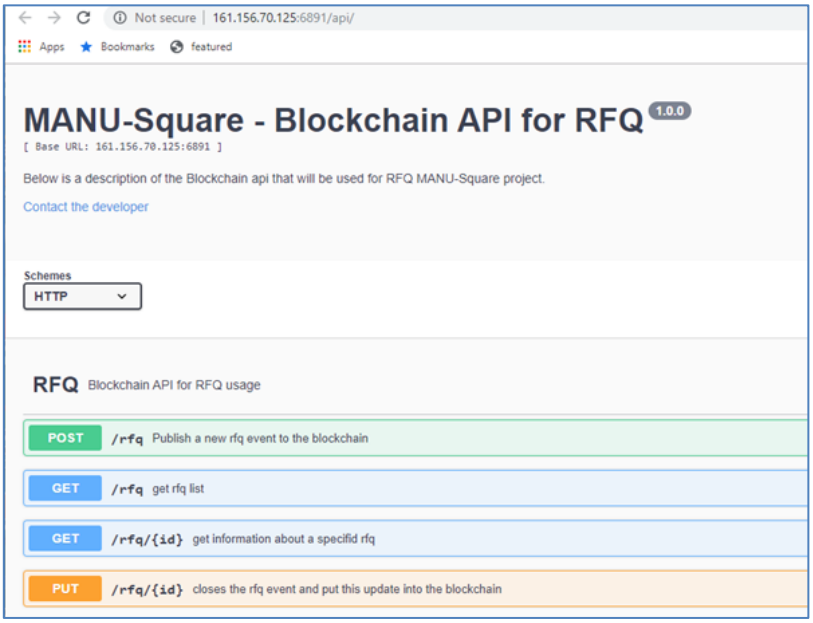

Figure 9: Swagger - RFQ calls

Figure 10 depicts the quotation related calls available for the RFQ process, which include the creation of a new quotation, querying for the latest information of a quotation, responding to a quotation, send a counter-offer, and get the historic evolution of a specific quotation.

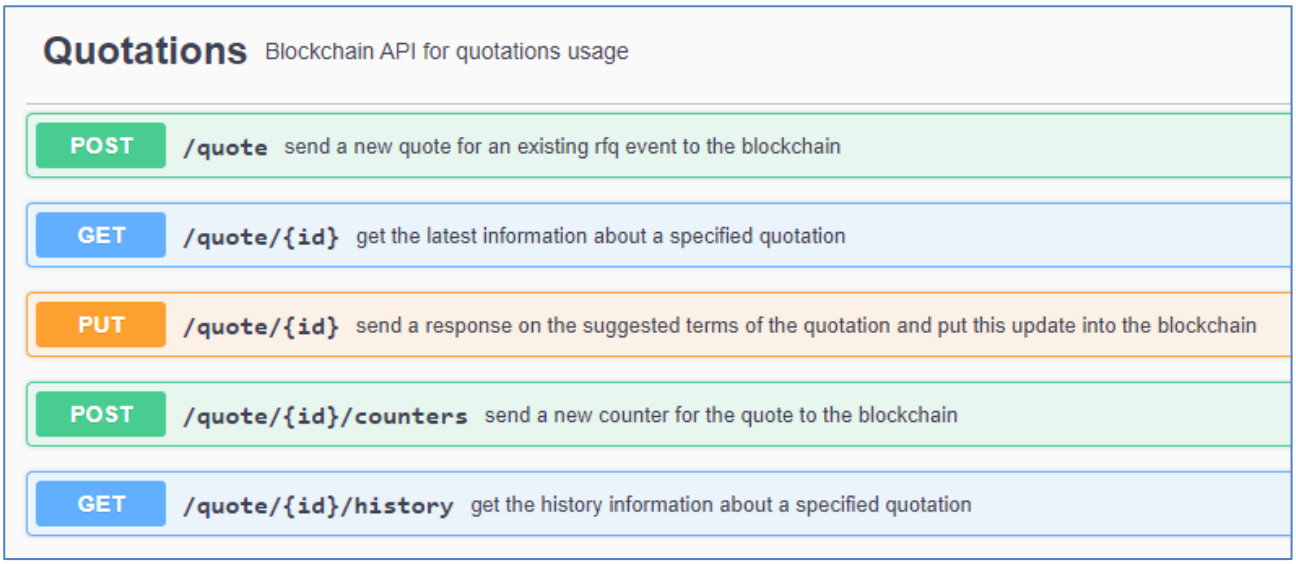

Figure 10: Swagger - quotation calls

Figure 11 depicts some of the data models that are used for the interaction between the MANU-SQUARE tools (especially the ecosystem data manager), and the blockchain infrastructure supporting the RFQ process.

```
Models

rfq {
    item                    string
    quantity                string
    conditions              > [...]
    ndaRequired             boolean
    publisher               string
}

rfqResponse {
    id                      string($uuid)
    item                    string
    quantity                string
    conditions              > [...]
    ndaRequired             boolean
    publisher               string
    status                  string
                            Enum:
                            > Array [ 2 ]
    quotationIds            > [...]
    selectedQuotation       string
    lastUpdateTimestamp     integer($int64)
}

rfqClosedResponse {
    id                      string($uuid)
    item                    string
    quantity                string
    conditions              > [...]
    ndaRequired             boolean
    publisher               string
    status                  string
                            Enum:
                            > Array [ 2 ]
    quotationIds            > [...]
    selectedQuotation       string
    lastUpdateTimestamp     integer($int64)
}
```

Figure 11: RFQ related data models

The RFQ process can work in a pull or push mode. In a push mode, in the background entities which are interested in receiving new RFQs, register themselves as interested in receiving such events on relevant RFQ related transactions

performed on the blockchain. Upon the inclusion of such a transaction in a block, the corresponding call-back is invoked. A complementary pull mode requires the deployment of smart contracts that support various kinds of queries to respond to an entity looking for open and available RFQs or looking for the history of a particular RFQ. Once again, such operations should be supported by a single channel for total visibility. For the integration of the blockchain as an infrastructure for MANU-SQUARE we make use of the pull mode in which entities query the blockchain for available relevant information.

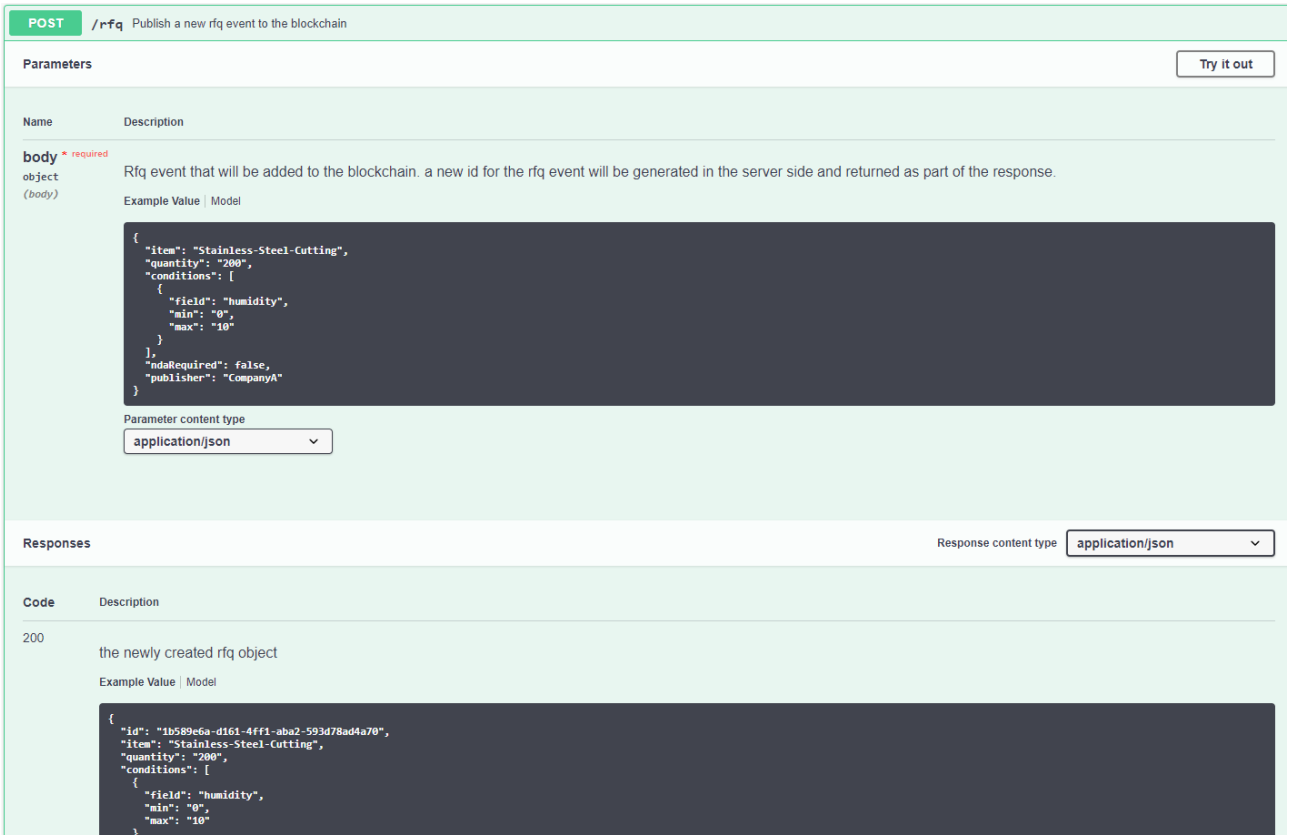

Figure 12: Publish a new RFQ

In the running example we use in this section, a company is interested to buy a capacity of a service for stainless steel cutting, and the conditions dictate the humidity in which the produced artefact should be kept throughout the process. Figure 12 depicts the API for the creation of a new such RFQ.

Figure 13 depicts the API for querying for RFQs; only ones in the state “open” are retrieved by default. All RFQs regardless of state can be retrieved as well by including a parameter in the call.

GET /rfq get rfq list

Parameters | Try it out

Name	Description
all boolean (query)	a flag whether to get only opened RFQs or all RFQs (including closed one). by default the response contains only opened RFQs unless it was mentioned otherwise. --

Responses | Response content type application/json

Code	Description
200	a list of rfq objects. Example Value | Model


```
[
  {
    "id": "1b589e6a-d161-4ff1-aba2-593d78ad4a70",
    "item": "Stainless-Steel-Cutting",
    "quantity": "200",
    "conditions": [
      {
        "field": "humidity",
        "min": "0",
        "max": "10"
      }
    ],
    "ndaRequired": false,
    "publisher": "CompanyA",
    "status": "published",
    "quotationIds": [],
    "selectedQuotation": "",
    "lastUpdateTimestamp": 1569312448
  }
]
```


500	error

Figure 13: Query for the RFQ list

Figure 14 depicts the call necessary for obtaining the current state of a specific RFQ instance.

GET /rfq/{id} get information about a specifid rfq

Parameters | Try it out

Name	Description
id * required string($uuid) (path)	rfq id id - rfq id

Responses | Response content type application/json

Code	Description
200	rfq information Example Value | Model


```
{
  "id": "1b589e6a-d161-4ff1-aba2-593d78ad4a70",
  "item": "Stainless-Steel-Cutting",
  "quantity": "200",
  "conditions": [
    {
      "field": "humidity",
      "min": "0",
      "max": "10"
    }
  ],
  "ndaRequired": false,
  "publisher": "CompanyA",
  "status": "published",
  "quotationIds": [],
  "selectedQuotation": "",
  "lastUpdateTimestamp": 1569312448
}
```


500	error

Figure 14: Obtain the current state of an FRQ

Entities receiving the notification of the publication of a new RFQ evaluate it internally and if interested can take one of two kinds of actions. First, they can ask for clarifications and negotiate, and second they can respond to the RFQ. Note that

these operations may be repeated multiple times until both sides are satisfied. This corresponds to a phase of clarifications, and potentially negotiations between the initiator of the tender and potential responders. For this stage, we assume that most of the times the correspondence for clarifications along with the actual response to the RFQ would require limited visibility of the exchanged information.

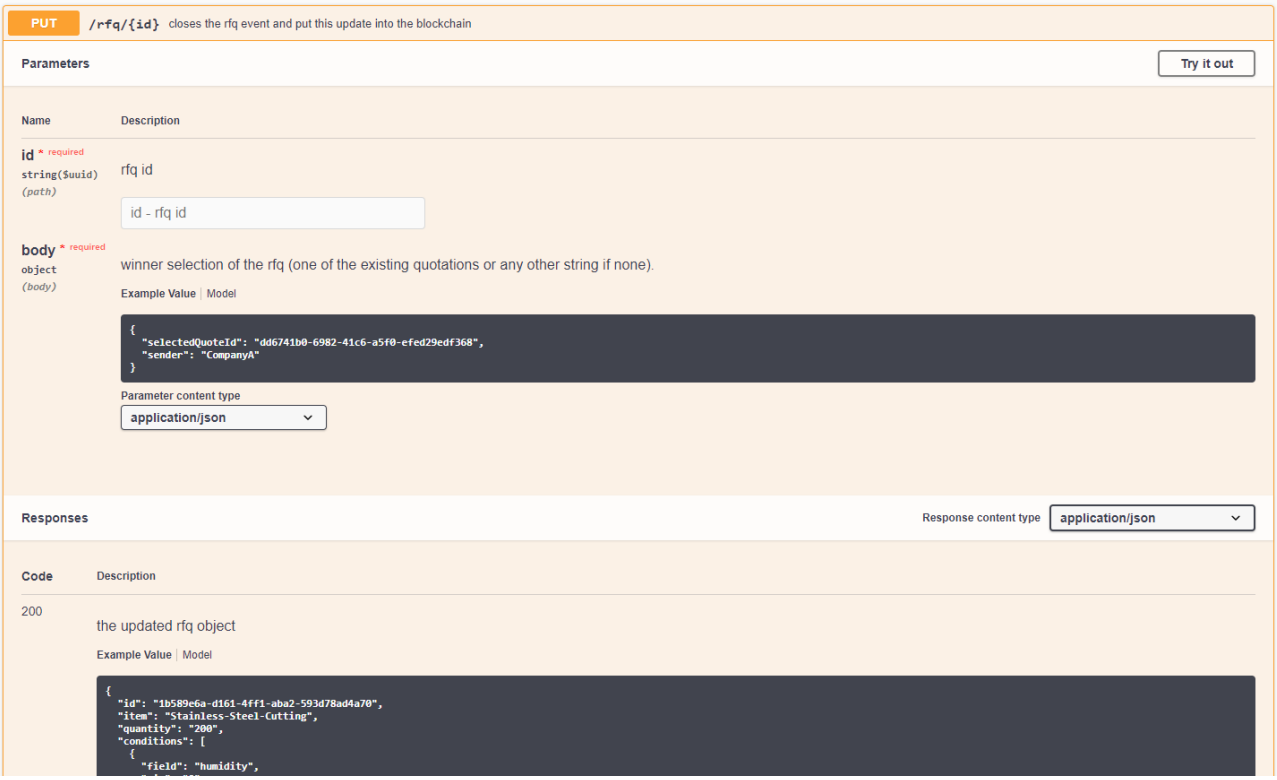

Figure 15: Accepting a quotation

All the negotiation process consists of transactions being submitted to the blockchain, which are in turn recorded and committed into the ledger. Both parties of the negotiation process can query and receive the updated new relevant information by querying the blockchain passing through the Ecosystem Data Manager. Note that all access to the blockchain is performed though MANUSQUARE tools which are served by a dedicated application embedding a blockchain client.

The content of the RFQ responses themselves should be shared only between the issuer of the RFQ and a responder. In this case, only the parties which are a part of a negotiation process have access to the information exchanged between the parties, thus the content of the RFQ response shall remain visible only to the involved parties.

Finally, the last step consists of the RFQ issuer choosing to accept an offer thus rejecting all other proposals. The API used for this operation can be seen in Figure 15. An acceptance message is sent to the selected company and all the other companies that participated in the RFQ process receive a rejecting message indicating that the RFQ is now closed, which means that they were not chosen. It is anticipated that these exchanges will take place on a single channel which is visible to all parties.

5.1.1 Quotations - Blockchain API for quotations usage

This sub-section provides some additional information on the API interface calls used to handle quotations within the RFQ framework. Figure 16 depicts the API call to be used for sending a quotation for a specific RFQ.

POST /quote send a new quote for an existing rfq event to the blockchain

Parameters

Try it out

Name	Description
body * required object (body)	Qoute that will be added to the blockchain. a new id for the quote will be generated in the server side and returned as part of the response. Example Value | Model


```
{
  "rfqId": "1b589e6a-d161-4ff1-aba2-593d78ad4a70",
  "item": "Stainless-Steel-Cutting",
  "price": "30",
  "quantity": "200",
  "currency": "USD",
  "conditions": [
    {
      "field": "humidity",
      "min": "0",
      "max": "10"
    }
  ],
  "sender": "CompanyB"
}
```


Parameter content type

application/json

Responses

Response content type application/json

Code	Description
200	the newly created quote object Example Value | Model


```
{
  "rfqId": "1b589e6a-d161-4ff1-aba2-593d78ad4a70",
  "qouteid": "dd6741b0-6982-41c6-a5f0-efed29edf368",
  "item": "Stainless-Steel-Cutting",
  "price": "30",
  "quantity": "200",
  "currency": "USD",
  "conditions": [
```


Figure 16: send a quotation for an RFQ

Figure 17 depicts the API call used to retrieve information on a specific quotation.

GET /quote/{id} get the latest information about a specified quotation

Parameters

Try it out

Name	Description
id * required string($uuid) (path)	quote id id - quote id

Responses

Response content type application/json

Code	Description
200	quote information Example Value | Model


```
{
  "rfqId": "1b589e6a-d161-4ff1-aba2-593d78ad4a70",
  "qouteid": "dd6741b0-6982-41c6-a5f0-efed29edf368",
  "item": "Stainless-Steel-Cutting",
  "price": "30",
  "quantity": "200",
  "currency": "USD",
  "conditions": [
    {
      "field": "humidity",
      "min": "0",
      "max": "10"
    }
  ],
  "sender": "CompanyB",
  "status": "opened",
  "lastUpdateTimestamp": 1569318436
}
```


500	error

Figure 17: Obtain information on a given quotation

Figure 18 depicts the API call for a responding (accepting or rejecting) to the suggested terms of the quotation

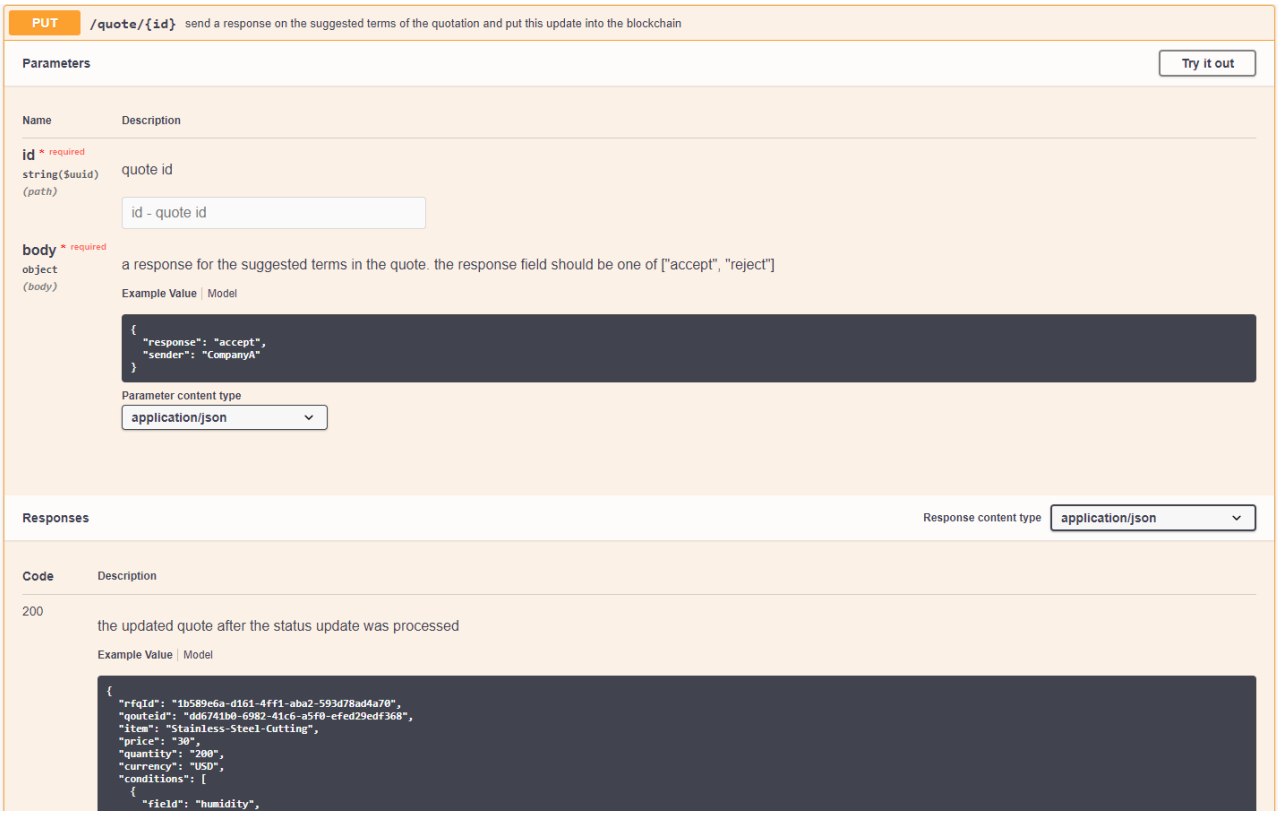

Figure 18: quotation response

Figure 19 depicts the interface exposed to enable negotiation among entities by providing counter offers in which they can negotiate both on the product, its characteristics and the environmental condition of the good while in production or in transit.

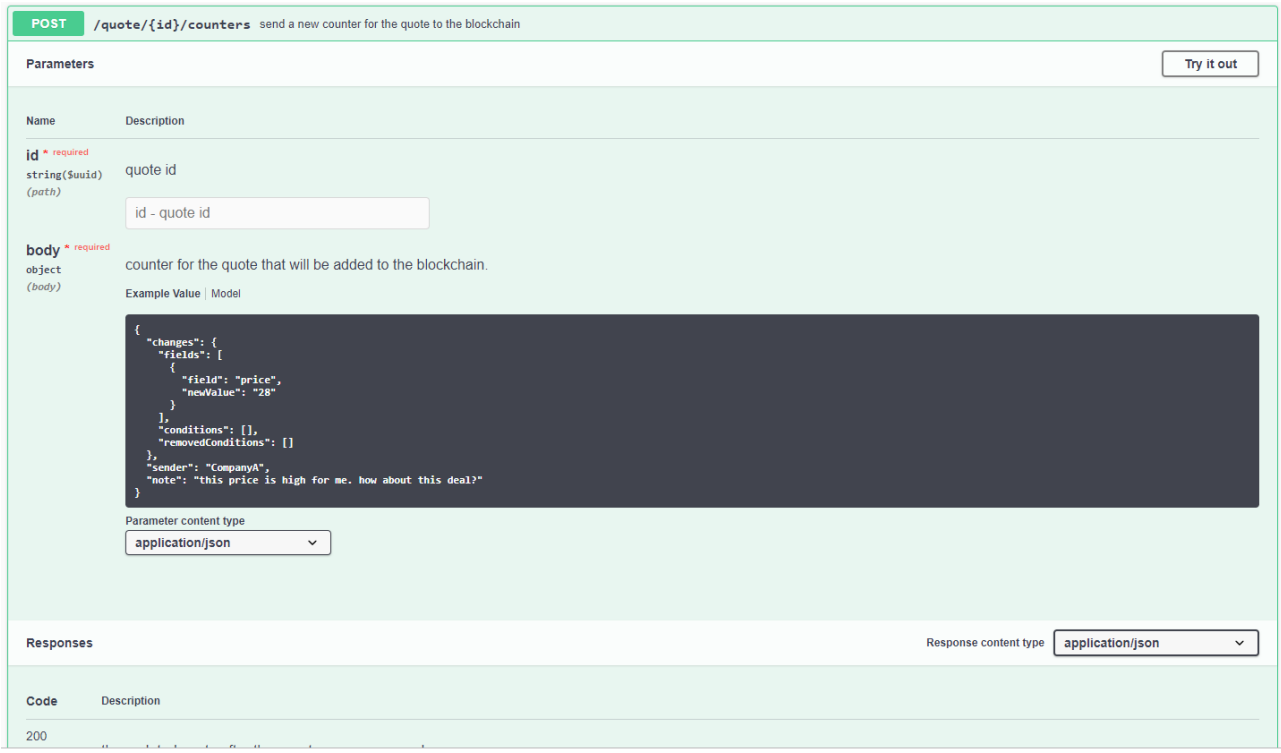

Figure 19: Counter offer

Figure 20 depicts quote history information including all the negotiation that took place between both parties. This interface provides the possibility to follow the path taken by both parties concerning a quotation and its evolution through time.

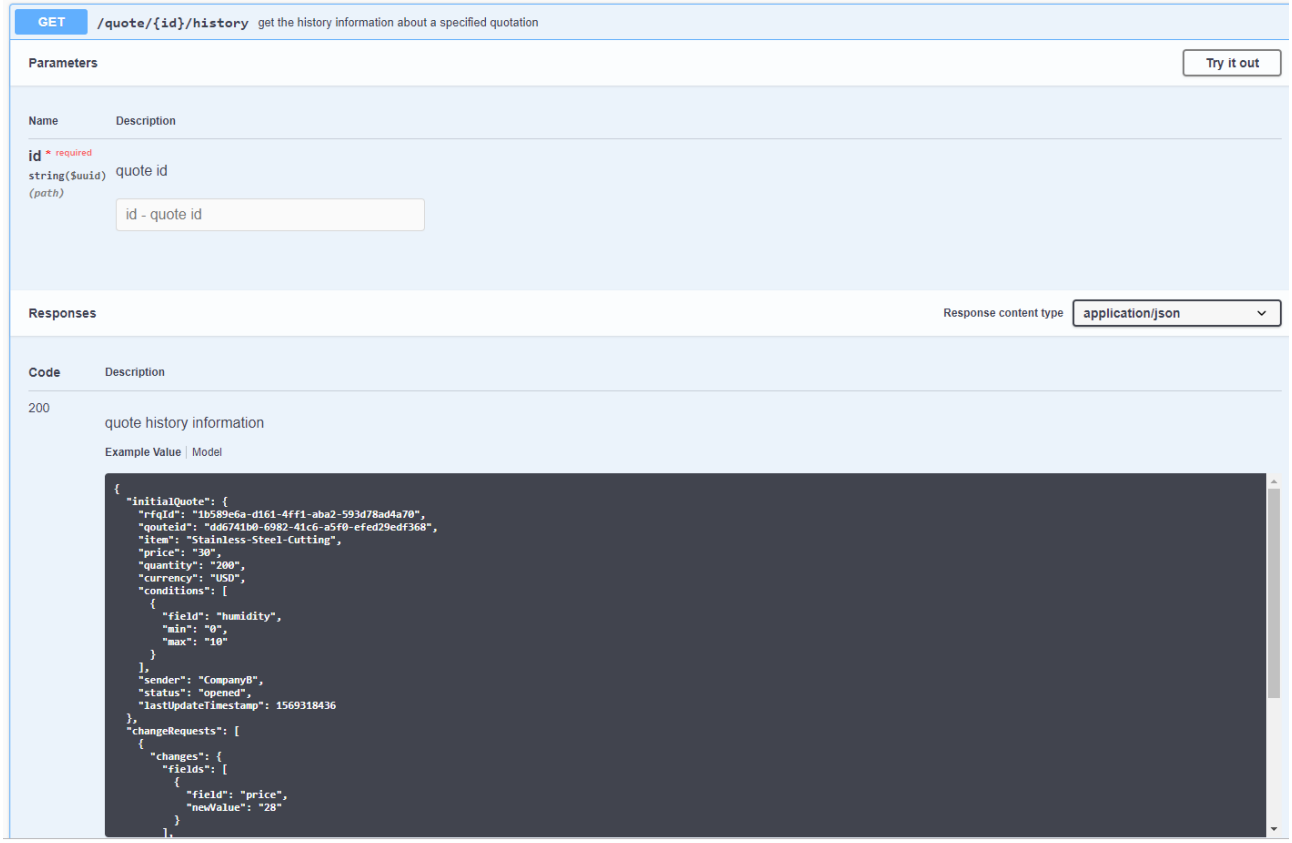

Figure 20: RFQ history

5.2 Reputation Management

Reputation management is an important service within a platform such as MANU-SQUARE, by the virtue of it being able to ease the decision of a company to conduct business processes with another company with which it had no business relations in the past. In addition, it may be interesting for companies to see what other companies are saying about an already known company. Without the use of a platform such as MANU-SQUARE companies spend a lot of time, effort, and resources to establish business relationship with another company. One of the changes required by such a digital transformation is to be able to be more agile and open to the establishment of new relationships. The reputation management component comes into play for companies to reduce the risk they take upon themselves by being exposed to the opinion of other entities which have collaborated with the company being considered as a new business partner and take that information into consideration while ranking the potential companies to collaborate with. For companies to be able to trust the information that is shown by the reputation management tool we use a blockchain back-end to ensure full provenance and traceability of the information gathered by the reputation manager. Thus, MANU-SQUARE provides an extra level of trust in an otherwise thrustless environment, by ensuring that information in the reputation manager cannot be altered or deleted in any way, without being detected.

The interfaces exposed mainly operate using a reputation entity structure depicted in Figure 21. The reputation entity is anchored by an entity id and a specific service provided by the entity in question. Thus, we can support different reputation entities for different services provided by the same entity. In addition, there is support for several reputation dimensions, divided into two main categories, namely subjective and objective dimensions (more details can be found in D4.2 Reputation tool). The entity as a whole has an overall reputation score associated to it, and each dimension type has an overall score for that dimension type. All scores are calculated by the reputation management tool and provided to

blockchain backend. Thus, the blockchain acts as trusted storage and provenance of the scores, but the "logic" determining the manner in which scores are calculated resides in the reputation management tool itself.

- entityID
- Role/service provided
- Overall reputation score
- Timestamp of overall reputation score
- Dimensions: {
  - Subjective dimensions scores {fixed list}
    - Subjective dimension update entries [..]
      - Value
      - Timestamp of update
      - Giver of update
    - Overall subjective dimension score
  - Objective dimensions scores {fixed list}
    - Objective dimension update entries [..]
      - Value
      - Timestamp of update
      - Giver of update
    - Overall objective dimension score

}

Figure 21: Reputation entity structure/model

To provide the role envisioned for the blockchain based support there are two main types of operations exposed, namely transactions and queries. The transactions supported enable the creation of a new reputation entity and to update an existing reputation entity. The latter updates an existing object with the given key with a new object provided by the caller of the interface. In addition, there are several query flavours supported. The interface supports the extraction of a reputation entity object of a given entity id, or a combination of id and service. In addition the scores for all dimension or for a particular dimension can be queried. The reputation history per entityID and service, as well as the overall score for all dimensions, and for a particular dimension. Figure 22 depicts the swagger representation of the blockchain based support for reputation management in MANU-SQUARE.

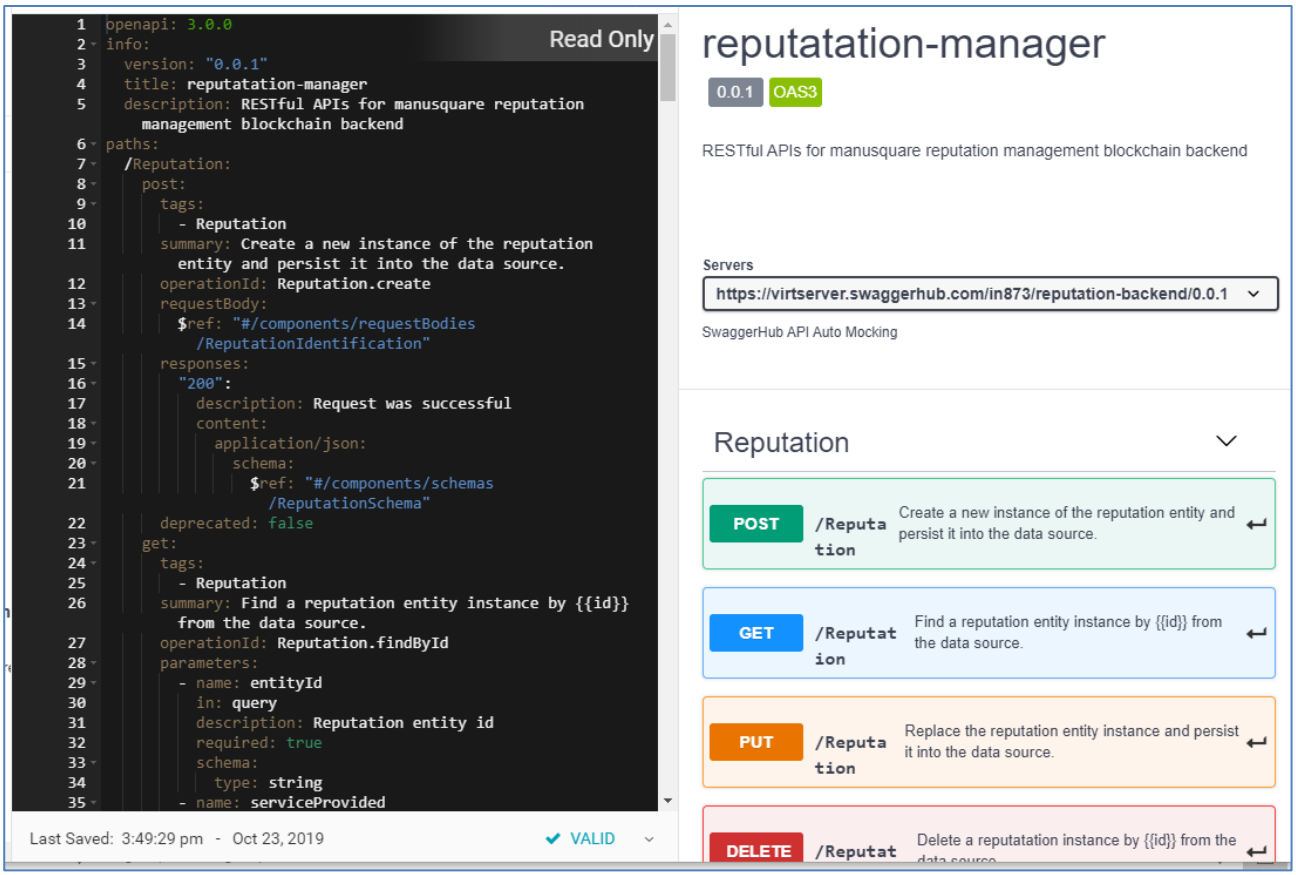

Figure 22: Reputation manager swagger

The interface provided for the addition of a new reputation entity is depicted in Figure 23. **Errore. L'origine riferimento non è stata trovata.** shows the interface for obtaining back the reputation object associated with a specific id and service provided by that entity. Figure 25 shows the interface called for updating the reputation entity of a specific entity and a service it provides. Figure 26 depicts the interface to be used to delete a reputation information of a specific instance. A note to keep in mind is that since the underlying mechanism is a blockchain, the result of the deletion is the removal of the entry from the world state, which is a DB hosting the latest version of inserted values, but past transaction information still remains stored and available in the blocks of the shared ledger. Figure 27 shows the manner in which it is possible to query the overall reputation score of a particular entity. Figure 28 shows the interface for querying to obtain the overall score of all the dimensions of a particular entity. Figure 29 shows the interface for obtaining the overall score for a given dimension of the reputation entity.

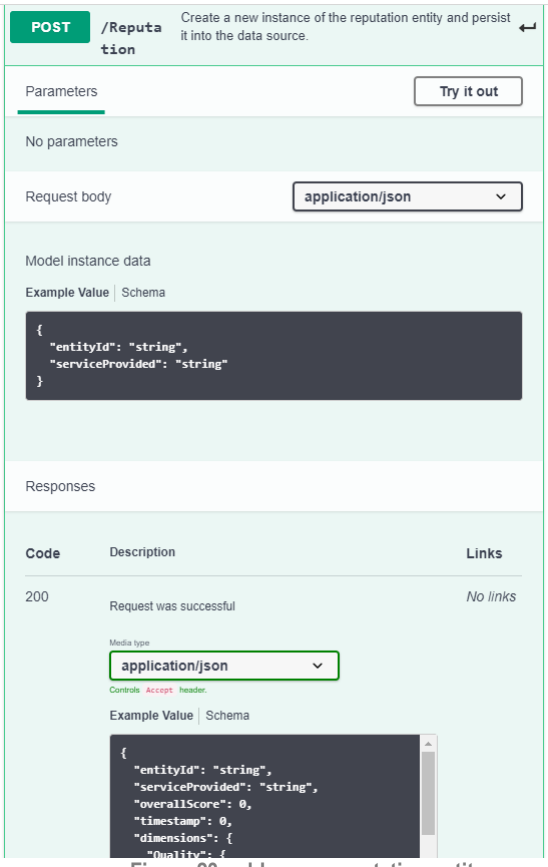

Figure 23: add a new reputation entity

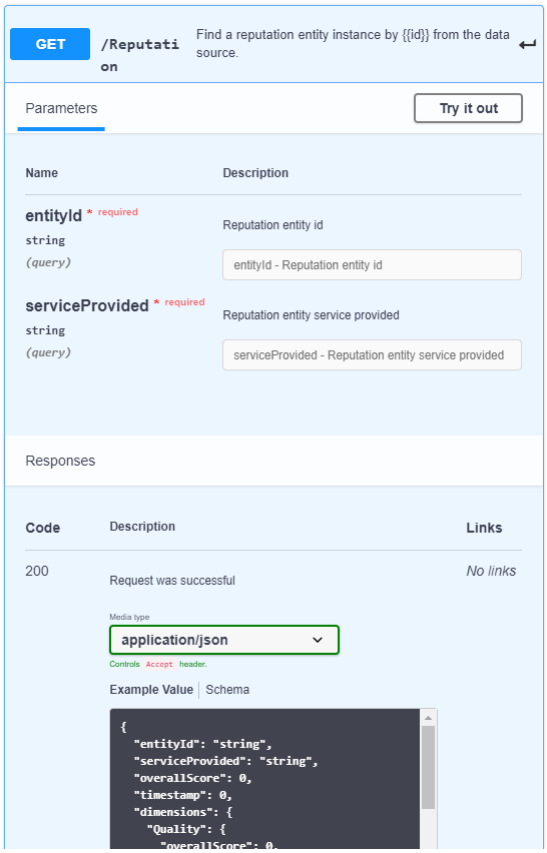

Figure 24: retrieve a reputation entity

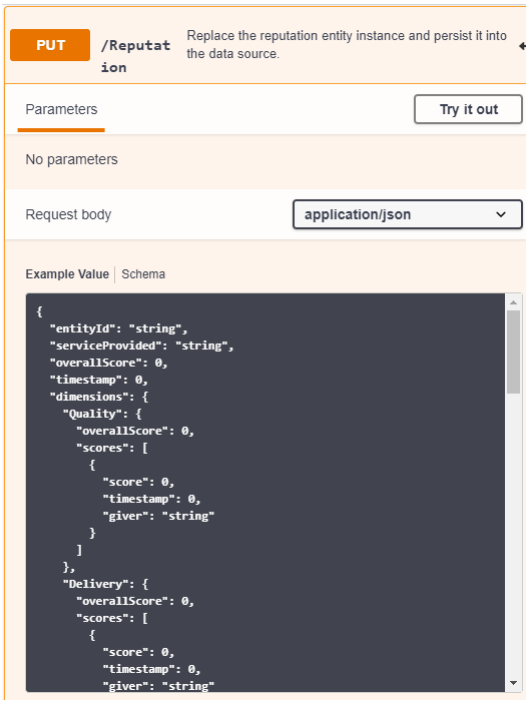

Figure 25: update a reputation entity

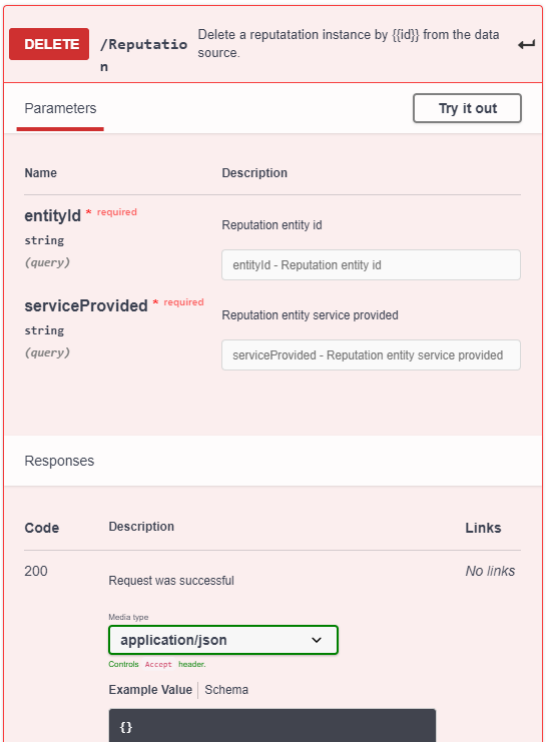

Figure 26: Delete a reputation entity

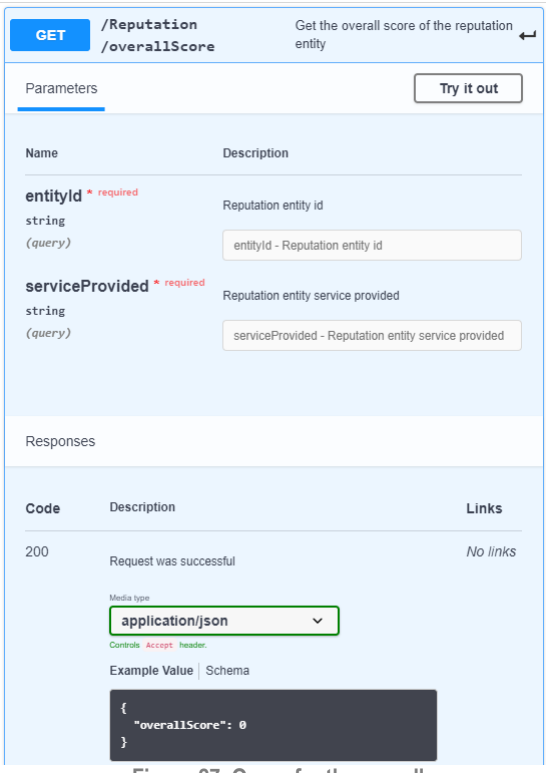

Figure 27: Query for the overall score

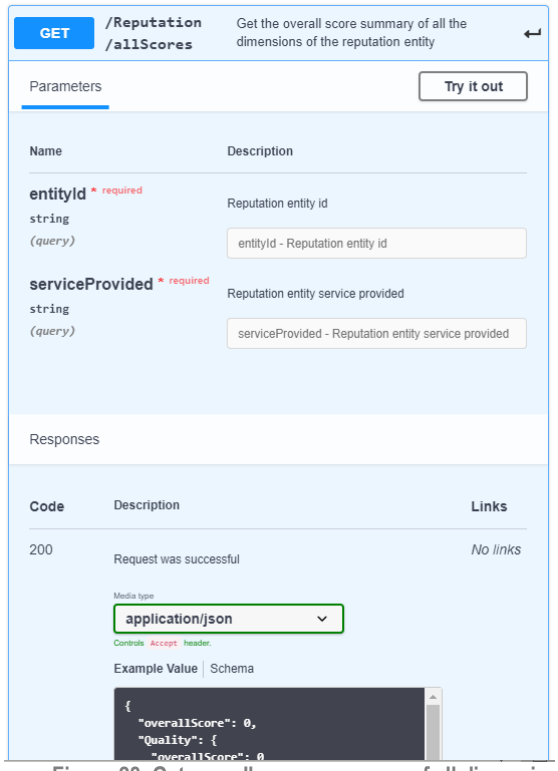

Figure 28: Get overall score summary of all dimensions

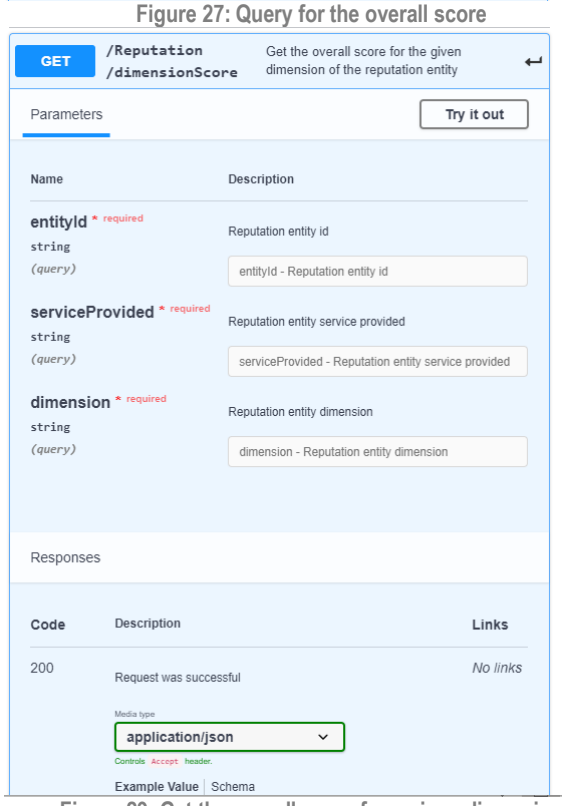

Figure 29: Get the overall score for a given dimension

6 CONCLUSIONS

This document delved into the benefits of using a blockchain network, as the back-end for supply chain scenarios, with specific emphasis on supply chain related constructs. Being a shared ledger, all the invoked transactions and data inserted

to the blockchain are clearly stored and can be made available to the parties involved, while ensuring that each entity has access only to the information that is within the scope of visibility of that entity. This document elaborated on the underlying infrastructure which ensures trust in processes in an inherently thrustless environment, by establishing a blockchain based support for supply chain related processes and constructs within a multi-sided platform. Due to the technical characteristics of the blockchain, the shared ledger can serve as the single source of truth in which all parties can access their data and act upon it, without revealing information to non-intended audience.

The main goal of this deliverable is to enhance D3.1 (Connecting IoT devices to blockchain services), which provided an overall description of the blockchain platform which shall be used as a cornerstone for the supply chain related activities within the MANU-SQUARE project, and D3.2 (Enhancing trust through blockchain-based security and privacy) which established differential visibility constructs within the extended blockchain network. The primary focus of the current deliverable was to demonstrate, based on the building blocks established in previous deliverables, the manner in which a blockchain can serve as a corner stone for supply chain related business processes and establish some of the constructs that can be used in such platforms, namely support for an RFQ process, and for a reputation management mechanism.

6.1 Next steps

The supply chain constructs described in this deliverable are currently being integrated with the rest of the platform and are currently scheduled to be a part of the second release of the MANU-SQUARE MVP.

The remainder of this task shall develop support for a collaborative ideas management system, which will enable people to share and contribute to forming ideas knowing that the underlying blockchain based infrastructure keeps track of the contributions of each individual to the forming idea and can later provide an accurate and indisputable trail of the path that led from the idea inception to its current or final state. That information enables higher layers to determine the relative contribution of each contribution to the final idea.

Finally integration with the project use cases shall be pursued.