POC4COMMERCE
D2. 'PROPOSED DESIGN SPECIFICATION AND APPROACH'

23/04/2021

Grant Agreement No.: 957338
Call: H2020-ICT-2020-1

Topic: ICT-54-2020
Type of action: RIA

POC4COMMERCEE

D2. 'PROPOSED DESIGN SPECIFICATION AND APPROACH'

DUE DATE	24/05/2021
SUBMISSION DATE	24/05/2021
TEAM	POC4COMMERCE
VERSION	1.0
AUTHORS	Giampaolo Bella, Domenico Cantone, Cristiano Longo, Marianna Nicolosi Asmundo, Daniele Francesco Santamaria

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

Executive Summary

The Semantic Web is conceived to provide appropriate representation languages that describe the objects of the observed world through a formally defined semantics. The yearned digital commerce demands an ontological approach leveraging a hierarchical semantic modelling towards the effective and efficient interoperability of blockchain technology with the eCommerce domain, from commercial actors to supply chains, including distribution, pricing, and selling mechanisms. The relevant literature is rich in representation models that can be combined and appropriately extended to meaningfully describe digital marketplaces. POC4COMMERCE addresses the stated challenge of developing a consistent, unambiguous, and shared model supporting the semantic interoperability of the ONTOCHAIN heterogeneous stakeholders, by delivering a stack of the most appropriate ontologies for the building blocks of the ONTOCHAIN ecosystem in general and of eCommerce in particular.

POC4COMMERCE identifies three main ontological layers. The first exploits the ontology OASIS to depict the stakeholders of the ONTOCHAIN ecosystem, vertically focused on the commercial environment. The second layer is responsible for describing commercial offers and products by extending the ontology GoodRelations. The third layer absorbs OASIS and the BLONDiE ontology to provide a clear description of blockchains and, in particular, of the Ethereum public ledger, including smart contracts used to generate, destroy, and exchange (digital) tokens. Finally, POC4COMMERCE delivers a search engine that profitably finds goods, products, information, and services, meeting the end-user requirements and published by the wide array of ONTOCHAIN commercial participants. On one hand, POC4COMMERCE, also thanks to the vision of a blockchain integrated with a semantic web application, impacts on how digital commerce is carried out in the Web 3.0 and beyond by realizing an affordable marketplace where sellers and buyers may freely choose the services associated with their business activities, making the ONTOCHAIN ecosystem readily functioning and building a sustainable environment for people and software to interoperate. On the other hand, POC4COMMERCE contributes to a shift towards a novel micro-economic model where individuals and companies cooperate and coordinate, deciding the allocation and utilization of resources, without third-parties intermediaries, instantiating the equilibrium between demand and supply, which determines the competitive capability of any organization.

POC4COMMERCE's key exploitable results and revenue streams give rise, through the dynamics of the ecosystem that the project practically establishes, to virtually innumerable business opportunities also for the ONTOCHAIN Consortium or its individual partners, for example in the roles of providers of data, data storage, data search and data publishing that POC4COMMERCE brings to a focus. SME partner SWB is already running a blockchain-enabled marketplace, devel-

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

oped under the supervision of UNICT, offering essential functionalities for trading Sicilian wheat; therefore, SWB will practically act as a deployment site for the ONTOCHAIN ecosystem. The impact on academic partner UNICT will be correspondingly large, sparking off a new strand of publications and a new breed of research projects and development activities, at least covering Call 2 and Call 3 of ONTOCHAIN.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

List of Figures

List of Tables

Abbreviations

DL - Description Logic [3].
IPFS - Interplanetary File System [27].
IRI - Internationalized Resource Identifier [11].
NFT - Non-fungible token.
OWL - Web Ontology Language [19].
RDF - Resource Description Framework [23].
RDFS - RDF Schema [36].
SPARQL - SPARQL Protocol and RDF Query Language [34].
SWRL - Semantic Web Rule Language [32].
W3C - World Wide Web Consortium.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

1 MAIN FOUNDATIONS

This Section summarises the relevant state of the art by introducing the main building blocks on which POC4COMMERCE stands and develops.

1.1 Preliminaries on Semantic Web

Semantic Web tools and languages pursue the goal of achieving full interoperability of computer systems, promoting common data formats, exchanging protocols on the web, sharing and reusing data across applications and across enterprise and community boundaries. In the Semantic Web vision of the internet, software agents are enabled to query and manipulate information on behalf of human agents by means of machine-readable data carrying explicit meaning, hence they are able to automatically process information thanks to appropriate representation languages that express meaning with formally defined semantics. To reach this objective, the *Word Wide Web Consortium* (W3C) conceived the *Web Ontology Language* (**OWL**) [19], a family of knowledge representation languages relying on *Description Logics* (DLs) [3], as the standard language for representing Semantic Web ontologies.

An *ontology* is a formal description of a domain of interest carried out by combining three basic syntactic categories: *entities*, *expressions*, and *axioms*. These form the logical part of ontologies, namely what ontologies can express and the type of inferences that can be drawn [24, 20]. Ontologies can also be combined together in order to describe more complex domains. A specific type of ontologies, namely *upper-level* or *foundational ontologies* [24], is designed to model higher level and independent categories concerning the real world. Foundational ontologies provide general terms that are used to connect domain-specific ontologies (also called lower-level ontologies), allowing one to reach a broader semantic interoperability. For instance, the *Descriptive Ontology for Linguistic and Cognitive Engineering* (DOLCE) [13] is designed to capture the ontological categories underlying natural language and human common sense, whereas the *CIDOC Conceptual Reference Model* (CIDOC-CRM) [9] is conceived to model concepts and information in the ambit of cultural heritage and museum documentation.

OWL, currently in version 2.1, provides users with constructs useful for designing ontologies for real world domains that are available neither in the basic Semantic Web model *Resource Description Framework* (RDF) [23], nor in the basic Semantic Web language *RDF Schema* (RDFS) [36] — the latter being an extension of RDF admitting taxonomies and primitives to define range and domain of relations and subsumption axioms. As RDF, OWL exploits the notion of RDF triples [8], which are ways of connecting entities or *resources*. The term resource is used to indicate any

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

physical or digital entity described via Semantic Web technologies. Resources are identified by an *Internationalized Resource Identifier* (IRI) [11], an extension of the *Uniform Resource Identifiers* (URIs) [4] with internalization features. Resources should be also *deferenceable* [37] via the *HTTP* protocol [12] using content negotiation and, in the case of digital resources, they must be accessible via their IRI.

Facts and relations involving resources are stated by means of triples consisting of

- the *subject* resource
- a property, labelled by an IRI, and
- an object which may be either a resource or a *concrete* datum (data type value such as strings and numbers).

Resources are *individuals* (actors), *properties* (actions), and *classes* (sets of actors with common features). Properties are of two types: object-properties and datatype-properties. Object-properties relate pairs of individuals, whereas datatype-properties relate individuals with some data type values. Triples can be combined to build knowledge. Specifically, RDF triples are embedded in sets called *RDF graphs* [22], which may be either *named graphs*, i.e., RDF graphs with associated *names* defined as IRIs, or *unnamed graphs*; in their turn RDF graphs can be collected in RDF datasets [8], containing exactly one unnamed graph, called *default* graph, and zero or more named graphs. More details on these notions can be found in [35].

The expressivity of the OWL language is extendable by the introduction of rules of the *Semantic Web Rule Language* (SWRL) [32]: SWRL rules are Horn-like rules consisting of an implication between an antecedent (body) and a consequent (head), intending that whenever the conditions specified in the antecedent hold, the conditions specified in the consequent must hold too. The reader is referred to [1] for details on the SWRL language.

Semantic Web knowledge is modifiable and retrievable by means of the *SPARQL Protocol and RDF Query Language* (SPARQL) [34], promoted by the W3C as the standard query protocol for RDF datasets. Mostly like SQL, the SPARQL language is a declarative language conceived to query and perform modifications on RDF graphs by executing SPARQL queries. SPARQL queries are constituted by a *head* and a *body*: the *head* comprises a modifier identifying the corresponding type of query (i.e., *ASK*, *SELECT*, and *CONSTRUCT*), whereas the *body* consists of an RDF graph pattern. Most notably, SPARQL *CONSTRUCT* queries allow one to retrieve information from a queried dataset and express it as new RDF triples. A detailed overview of SPARQL can be found in [10].

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

In what follows, we summarize the main ontologies adopted, extended, or comprised in the POC4COMMERCE project according to the digital commerce vision in the ONTOCHAIN philosophy fashion.

1.2 OASIS, an ontology for representing agents

OASIS (*Ontology for Agents, Systems, and Integration of Services*) [7, 6] is a very recent foundational OWL 2 ontology modelling multi-agent systems by representing agents trough their behaviors, namely, purposes, goals, responsibilities, services provided, information about the world they observe and maintain, and their interactions with other collaborating agents. Additionally, OASIS models information concerning executions and assignment of tasks, restrictions on them, and constraints used to establish responsibilities and authorizations among agents.

In [7] the ontology has been exploited to define an ontology-based protocol for the Internet of Agents (IoA) and to realize a transparent communication and information exchange system among agents via Semantic Web technologies. The resulting protocol is founded on the exchange of OASIS fragments, each consisting of a RDF description of a request that is checked, by means of suitably constructed queries, against the corresponding RDF description of the agent behavior selected to satisfy it. Moreover, to show the advantages of the proposed approach, notably its interoperability, scalability, and modularity, the authors also presented the case study of a TRL3 prototype version of a domotic assistant exploiting many features of the ontological protocol to activate and manage applications, devices, and users interacting with each other within a home environment.

OASIS models agents by representing their behaviors which are publicly exposed. By exposing behaviors, agents report to the communication pairs the set of operations that they are able to perform and, eventually, the type of data required to execute them and the expected output. Representing agent behaviors has many advantages since it permits to abstract from implementation details thus to make the task of discovering agents extremely transparent and automatic. Agents may join a collaborative environment in a *plug-and-play* way, since there is no need for third-party interventions. As a consequence, users can freely choose products and services according to their needs since provision methods and supply chains are clearly described and represented. Moreover, by means of Semantic Web technologies and of automated reasoners, data provides machine-understandable information which can be processed, integrated, and exchanged by any type of agent at a higher level. Data consistency can be easily verified, and information can be inferred and retrieved by exploiting what is already provided by the knowledge base.

Representation of agents and their interactions in OASIS is carried out along three main steps.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

The first step consists in defining the agent behavior *template*: templates are high level descriptions of behaviors of abstract agents that can be implemented to define more specific and concrete behaviors of real agents. For example, a template may be designed for agents whose behavior consists in selling and shipping products to buyers, and it may be implemented by an *apple* seller that ships its products using the Fedex courier. Templates are useful to guide developers to define the most suitable representation of their agents.

The second step consists in representing the agent behavior either by implementing a template or by defining it from scratch. As depicted in Figure 1, agent behaviors are represented by the goals to achieve, in their turn goals are related with their constitutional elements, namely tasks. Tasks represent atomic operations that agents execute and are described by actions to perform. Actions are drawn from shared and common vocabulary and can be simple or composed, eventually associated with requested input parameters and expected outputs.

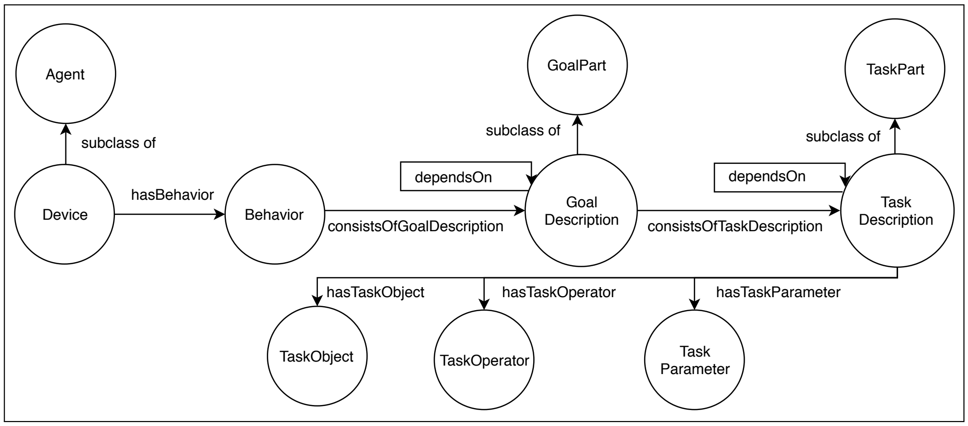

Figure 1: Ontological schema of agent behaviors.

In the third step, in OASIS actions performed by agents are associated with the behavior are associated with the behaviors that generate them. To describe such association, OASIS introduces *plans*, which represent the will of agents to activate some agent behaviors or to get some activities performed. Plans in their turn are associated with their executions that also provide information about the obtained output.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

1.3 GoodRelations, an ontology for commercial offers

Semantic description of goods and commercial offerings has been recognized as a crucial task for eCommerce [15, 28, 21] as it enables the implementation of *semantic search engines* [17] to find out items in a very specific range.

GoodRelations [18] is an OWL vocabulary describing offerings on products or services, legal entities involved in them, prices, offering terms and conditions. Well-known content management tools as Joomla,[1] osCommerce,[2] and Drupal[3] support publishing data with the GoodRelations ontology (see [2] for a report of the adoption and usage of Good Relations). GoodRelations has been integrated in *schema.org* [26],[4], a general purpose vocabulary largely used for tagging web page contents by means of *Resource Description Framework in Attributes* (RDFa)[33]. Thus, offerings described using GoodRelations in conjunction with schema.org and published via RDFa are recognized by major search engines such as Google,[5] Yahoo,[6] and Bing,[7] which use RDFa to enhance the appearance of individual search results with a structured description [5].

The core class of the GoodRelation vocabulary allows one to represent an `Offering`. An offering is an announcement of an agent providing a certain *business function*, which is one of "sell", "lease out", "maintain", "repair", "provide service", "dispose", and "buy", for a certain *product or service instance* to a particular target *audience* and under particular commercial conditions.

A *business entity*, i.e., a legal agent, can create such an offering or *seek* for someone else providing goods and terms under particular conditions.
An offering can either refer to

- a clearly specified instance (class `Individual`) or
- a set of anonymous instances of a given type (class `SomeItems`) or
- a product model specification (class `ProductOrServiceModel`).

An offering may be linked to multiple *Price Specifications* that specify alternative prices for non-overlapping sets of conditions which can be characterized by:

[1] `https://www.joomla.org/`
[2] `http://www.oscommerce.com/`
[3] `https://www.drupal.org/`
[4] `http://blog.schema.org/2012/11/good-relations-and-schemaorg.html`, `https://schema.org/`
[5] `http://www.google.com`
[6] `www.yahoo.com`
[7] `www.bing.com`

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

- the lower and upper limits of the eligible quantity,
- the monetary amount per unit (in combination with a currency), and
- whether this price includes local sales taxes, namely, VAT.

The time scope of an offering can be eventually specified and different accepted *payment methods* (eventually combined with additional *payment charge specifications*) may be available for an offering: in advance or after delivery, by credit card, cash or bank transfer, and so on.

Delivery methods indicated for an offering are standardized procedures available to provide the product or service with the destination of fulfillment chosen by the customer. They can be eventually coupled with *delivery charge specifications*. Also, the product or service may be available at some physical *location* (a shop, an office, ...) characterized by a geographical position and a set of opening hour specifications for various days of the week.

Finally, offerings may be provided with information about *warranty* on goods.

1.4 BLONDiE, a semantic representation of blockchain basic elements

In the POC4COMMERCE vision, smart contracts are completely represented and modelled as agents operating on the blockchain. In addition to smart contract functionalities, modelled by OASIS, it is also convenient to represent the native structure of the blockchain and the related information. The BLONDiE ontology [31] aims to achieve such a goal by modelling information concerning the two currently most relevant cryptocurrencies, namely Bitcoin and Ethereum, potentially covering and easily extendable to every blockchain available. The ontology tries to answer (not only to) the following main competency questions:

- Who mined a specific block?
- What is the height of a specific block?
- How many transactions are written in a block?
- Is a transaction confirmed?
- How many total coins were transferred on a block?

BLONDiE, currently at version 0.4, is an OWL ontology comprehending 21 classes, 11 object-properties and 50 data-properties, whose general structure is summarized in Figure 2.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

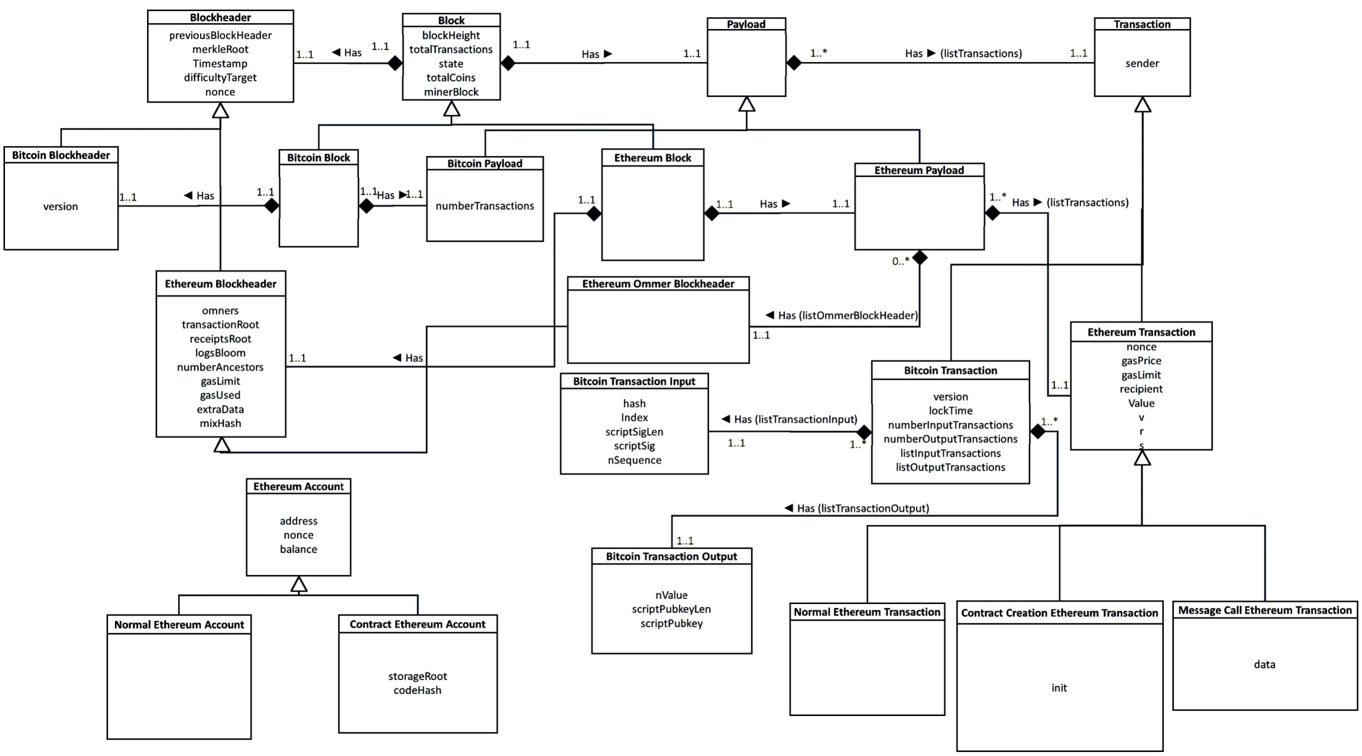

Figure 2: The BLONDiE ontology E-R Diagram.

The domain covered by the ontology includes the structural information of Bitcoin and Ethereum blockchains as expressed in the official documentations including the following elements:

- The *block-header* of a block. The block-header is the section summarizing the block itself. It includes several metadata such as the difficulty of the block and the time when the block was mined, the Merkle root of the included transactions, nonce, and so on.
- The *block*. Blocks are containers for all the transactions. In BLONDiE a block is represented by means of all the information concerning the block itself, such as the node miner and the block height, and it is associated with the transactions contained by means of its *payload*. Blocks are specialized according to the type of blockchain (Ethereum or Bitcoin) they belong to.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

- The *payload*. It represents the data of the block and is specialized for each type of blockchain. Payloads in BLONDiE are associated with the related transactions.
- The *transaction*. Transactions consolidate state passages and are specialized depending on the type of the transaction. In Ethereum, there are three types of transactions, *normal transactions* associated with Ether transfers, *contract creation*, associated with smart contract instantiation, and *message calls*, i.e., passages of messages from one account to another, eventually including data.
- *Account*. Accounts are referred to the wallets used to store cryptocurrencies, to pay for, and to authorize transactions.

2 DESIGN SPECIFICATION AND APPROACH

A blockchain-oriented commerce aimed to bring affordable, interoperable, and trustworthy digital marketplaces to human societies demands an accurate semantic representation of participants and of the provided supply chains, including product delivery and payment systems.

Ontologies and Semantic Web tools provide the best technology nowadays available for modelling real world scenarios arising from digital contexts. However, the task of providing practical, efficient, and effective ontologies, in particular for complex and intrinsically intertwined domains such as commerce, science, government, and healthcare, requires an epistemological effort to deliver a sufficiently general model describing the observed world. The model ought to be both vertically and horizontally extendable to capture the possible evolutions and changes in the domain. For these reasons, POC4COMMERCE delivers a family of foundational and domain-specific ontologies constituted by the most suitable representation systems for modelling complex and evolutionary scenarios in modern, affordable, and interoperable blockchain-oriented marketplaces.

2.1 REFERENCE SCENARIO

POC4COMMERCE provides an ecosystem of modular ontologies describing each semantic compartment of eCommerce, in particular, eCommerce carried out through and by means of blockchains. The advantage of ontological approaches relies on a high versatility and technological independence allowing one to deliver the ontologies by exploiting a wealth of different suitable implementation infrastructures. For instance, the family of ontologies developed by POC4COMMERCE remains adequate and flawlessly continues to provide the desired semantic representation whether the

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

corresponding knowledge base management system is centralized on a single data provider or is distributed over a peer-to-peer network.

POC4COMMERCE revolves around two reference scenarios, the *publishing* of product or services and their *discovery* but these are identified for the mere sake of convenience, in such a way that any development can be readily reconducted to the real world.

In the first scenario depicted in Figure 3, **service and product providers** publish their assets through the POC4COMMERCE knowledge base. Providers and users may request a digital identity to one of the ONTOCHAIN **authority release services** in order to certify the legal entity represented by the provider itself and to declare the **supply chain** of the product or of the service, or their capabilities to contribute to the environment, through the ontological stack of POC4COMMERCE.

Providers are subsequently enabled to generate the ontological fragments representing and describing their physical or digital assets and the corresponding offering, and to publish them in the POC4COMMERCE knowledge base by exploiting one of the facility managers provided by ONTOCHAIN, which simplify the access mechanisms to the ecosystem. Facility managers may have different natures: for example, they may be realized either by means of web servers, or by suitable blockchains, or more simply through smart contracts.

Simultaneously, blockchain tokens corresponding to the provided assets are published on the selected blockchain. Tokens are public, secure, uncensorable, and transferable digital certificates emitted on the blockchain to grant predetermined rights, such as ownership, to the corresponding assets. In POC4COMMERCE tokens are semantically represented together with their corresponding assets in order to guarantee a semantic indexing that makes them easily and accurately searchable inside the ecosystem. Asset transfer is carried out by publishing offerings that establish price, quantity, and purchase modality. Any operations concerning tokens such as minting, transferring, and destroying is semantically represented in POC4COMMERCE, thus providing a full and complete ontological description of the evolution of the ecosystem.

Indeed, once assets are semantically represented and the related offerings are made available through the ontological approach of POC4COMMERCE, end users are enabled to search for products and services by setting the general features of the desired product and/or by describing the desired supply chain releasing it. This scenario is summarized in Figure 4.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

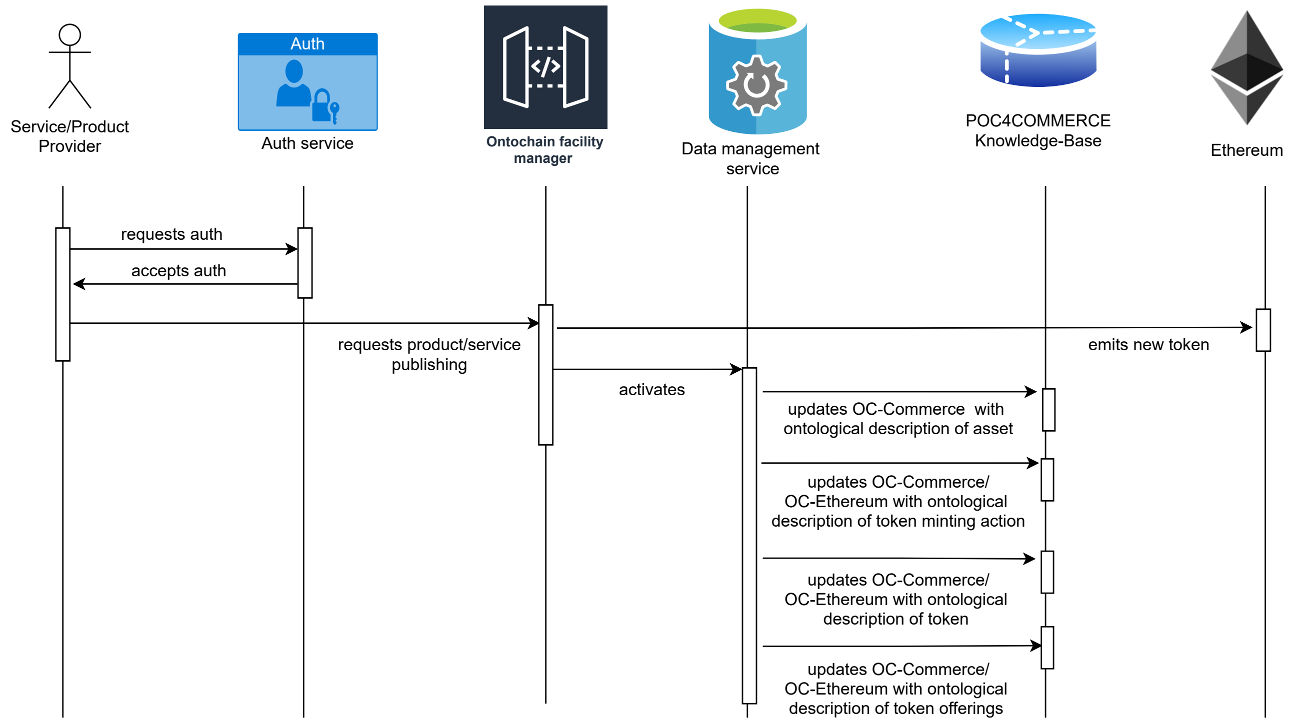

Figure 3: Product and service publishing scenario

Finally, users may exploit the ONTOCHAIN facility manager to access the POC4COMMERCE search engine and use the specification of the product or service they aim to find over the knowledge base storing the ontological representation of published assets. The search engine packs the results provided by the data management service performing the query, delivering them to the calling users by means of the ONTOCHAIN facility system. Eventually, users may summon one of the quality of service and product valuers in order to obtain an evaluation of the discovered assets or service. From now on, users are enabled to access the service, buy the desired asset, request a new search or a new evaluation.

The two reference scenarios are flexible and suitable for many implementations and configurations. It is clear that they are chosen here because they are paradigmatic but can be extended with additional ones.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

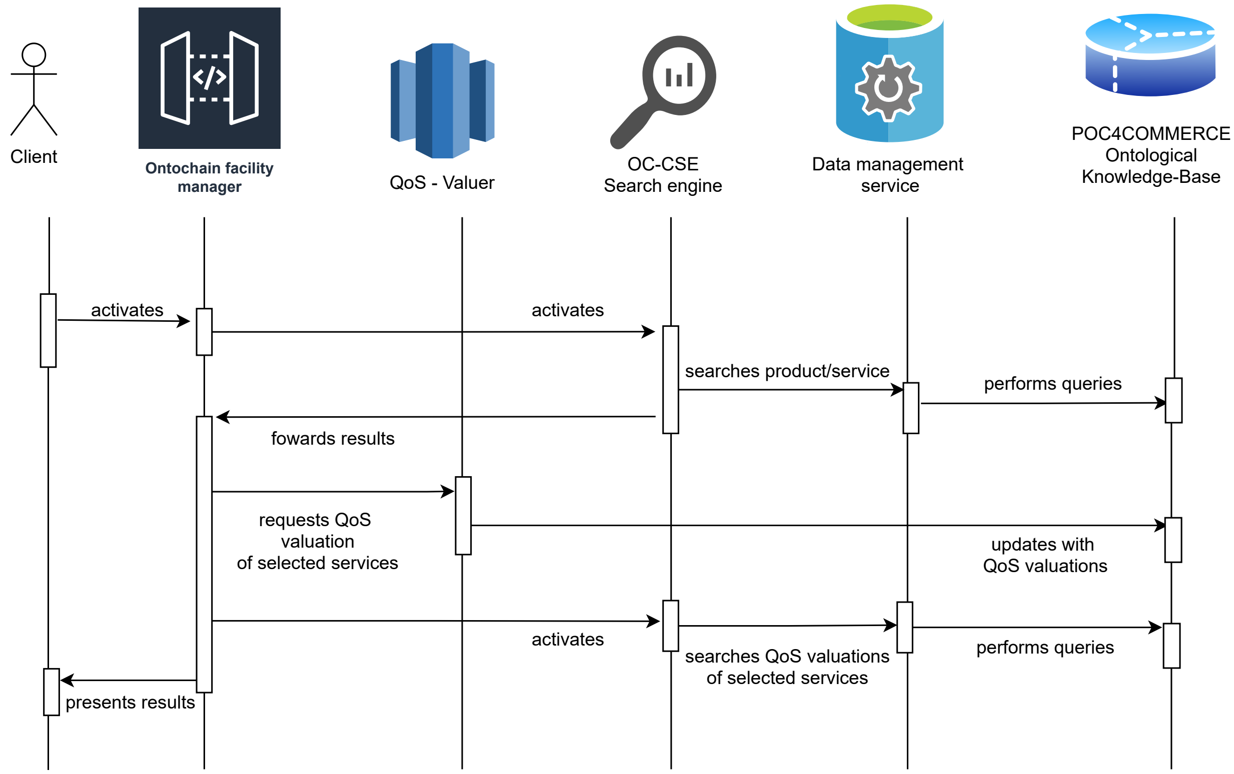

Figure 4: Product and service discovery scenario

2.2 USE CASE

The scenario illustrated in Section 2.1 is instantiated to the practical and effective use case depicted in Figure 5, showing an Italian green apples vendor called *AppleBay* that wants to sell his assets through an Ethereum ERC721 compliant smart contract on the blockchain. The smart contract is used to generate the non-fungible token (NFT) assigning ownership rights of a specific and predetermined batch of apples that can be shipped to buyers. User *Bob* would purchase apples using, for example, fiat currency through a digital payment platform such as PayPal. To complete the purchase, the token corresponding to the apples batch that Bob buys is transferred to the buyer as a proof of the quality and quantity of product purchased and of the payment received by the seller. Then, the product shipment process can be performed.

As first step, both participants AppleBay and Bob access the ONTOCHAIN facility manager

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

to obtain their digital identities. We can conceive such facility manager either as a) a simple entry point to the repository of the (distributed) ontological knowledge base built exploiting a combination of Ethereum and the *Interplanetary File System* (IPFS) [27], as in the case illustrated in [6], and maintained by the participants or b) a RDF triple-store such as Neo4J or OpenLink Virtuoso maintained by a centralized and certified authority.

Next (step 2), AppleBay has to publish the ontological representation of the service he desires to deploy by generating a fragment of OC-Found representing the green apple selling service located in Italy and a fragment of OC-Ethereum describing the smart contract releasing NFTs of green apple batches. The facility manager can be used to make publicly available the generated fragments. In this phase, the facility manager may also assist AppleBay by providing a set of predetermined templates of agent behaviors that AppleBay implements. AppleBay may exploit the provided templates to deploy the ontological representation of the effective service realized. AppleBay can also deploy the smart contract managing the tokens either autonomously or by relying on the facility manager.

From now on, the supply chain of AppleBay is semantically described and publicly available through the ecosystem, and offerings concerning the marketable assets may be generated. Each time a token is generated by the AppleBay smart contract, the seller generates an ontological representation of the offering concerning the asset as a fragment of OC-Commerce (step 3), in addition to the ontological representation of the token and the related minting action as a fragment of OC-Ethereum. Offerings modelled by OC-Commerce are connected to the corresponding supply chain by means of the semantic representation provided by AppleBay and exploiting the ontologies OC-Found and OC-Ethereum. Such a representation depicts the distribution mechanisms provided by AppleBay, which are finally searchable by potential clients such as Bob.

Bob can rely on the facility manager to access the OC-CSE search engine exploited to find the desired product (step 4). For instance, Bob would search for a service realising NFTs corresponding to green apples batches produced in Europe and accepting PayPal as a payment system. The search engine generates the SPARQL query describing Bob's requirements by submitting it to one of the triple stores available so as to probe the repository for the desired results. Since AppleBay is a vendor corresponding to Bob's requirements, the available offerings produced by AppleBay are then returned to Bob in the shape of one of the standard RDF serializations. Bob now has the required information to complete the purchase or, additionally, he may invoke, by taking a step similar to 4, a quality valuer to estimate the reputation of AppleBay, the number of NFTs already sold or the age of the service.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

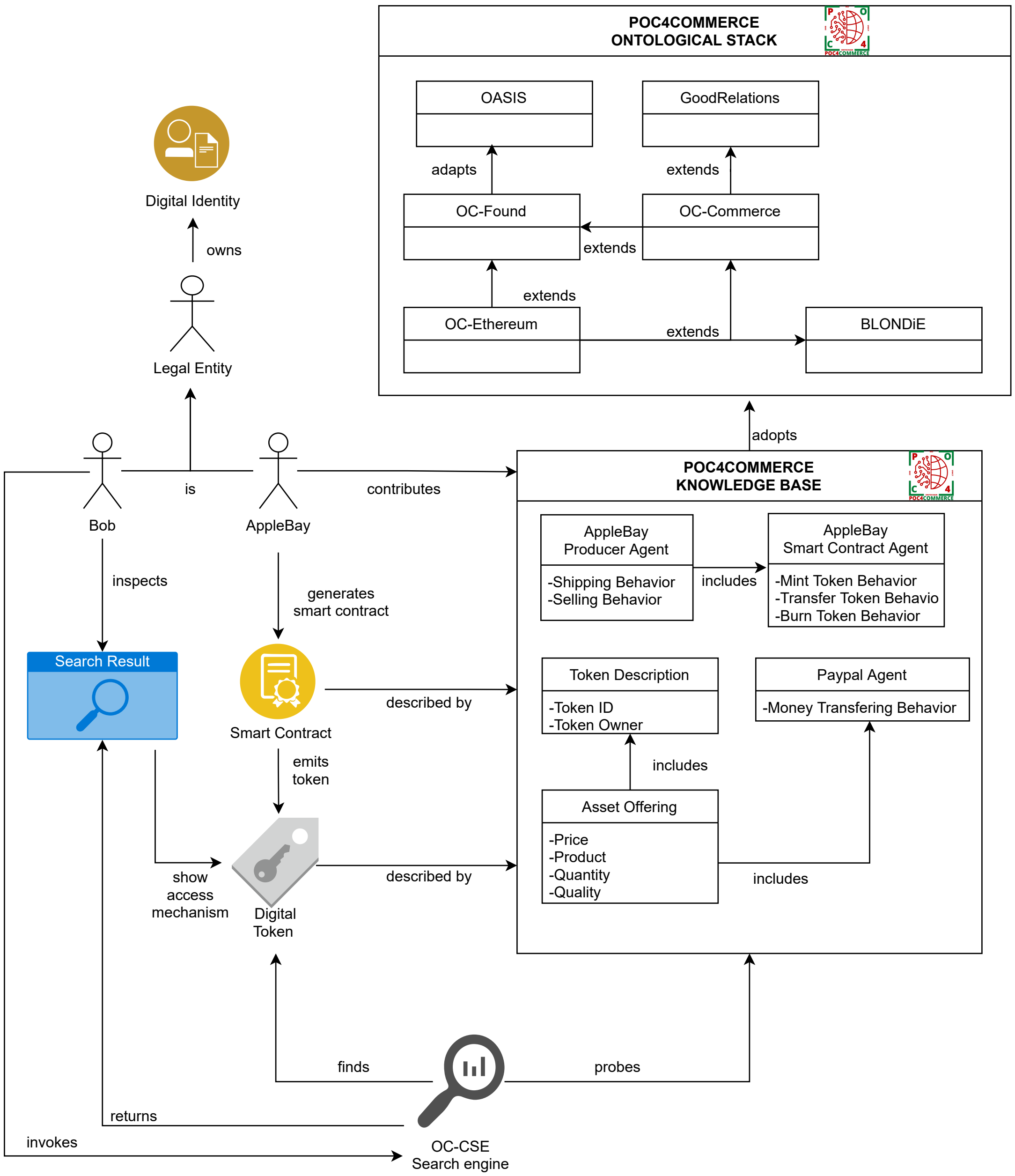

Figure 5: Use case of the vendor AppleBay and the buyer Bob

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

2.3 SOLUTION DESCRIPTION

The semantic representation of the ONTOCHAIN ecosystem, with a focus on the commercial vertical domain, is pursued by POC4COMMERCE through an ontological stack constituted by three principal layers extendable to cover more knowledge domains or to characterize more precisely the available ones.

The first layer in the stack is the TRL4 ontology **OC-Found**, which models the **stakeholders** of the ONTOCHAIN ecosystem, vertically focusing on the commercial domain. An ontology for the ONTOCHAIN stakeholders, and in particular for the main commercial actors, must be able to describe how participants contribute to the ecosystem, what they are capable of doing, and how they perform the proposed operations. This is crucial in terms of commercial transactions, since the entire supply chain of exchanged assets, i.e., products and services provided, asset release mechanisms and payment methods are fully semantically described, hence unambiguously published and shared. The TRL4 ontology **OASIS - An Ontology for Agent, Systems, and Integration of Services** potentially satisfies the objectives set by the first layer by providing a general description of agents, conceived as entities performing various actions in terms of the goals and tasks they accomplish: as summarized in Section 1.2, OASIS is adopted by OC-Found a) to provide the effective descriptions of the participant behaviors in the shape of behavioral templates exploited to build the semantic representation of the services joining the ecosystem, and b) to model the actions that agents perform, thus entirely describing changes and evolution of the environment.

The second layer is represented by the TRL4 ontology **OC-Commerce**, which is responsible for describing commercial offerings and products. The ontology **GoodRelations** could be used for such objective since it is applied in many industrial applications and can be easily integrated with the first layer. However, GoodRelations is not able to describe participants and how they provide supply chains: such a gap is filled by extending the ontology OC-Found with GoodRelations, thus merging product and supply chain descriptions with offerings published by participants.

The third layer is constituted by a clear description of blockchains and, in particular, of the Ethereum public ledger, used to produce and exchange (digital) tokens by means of smart contracts. Even though blockchain blocks and transactions may be described by adopting the **BLONDiE** ontology, in order to describe both tokens and smart contracts, including their release and exchange mechanisms, a vertical extension of the OC-Found ontology to blockchains smart contracts and tokens is considered: the resulting TRL4 ontology, called **OC-Ethereum** describes a) the smart-contracts as agents joining the ONTOCHAIN ecosystem and b) the exchanged tokens as actions performed by smart contract agents.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

The competencies of POC4COMMERCE ontologies are summarized in Table 1.

Competency	OC-Found	OC-Commerce	OC-Ethereum
Agent	X		
Agent interaction	X		
Asset		X	
Offering		X	
Auction and bargaining operation		X	
Ethereum block and transaction			X
Smart contract agent			X
Smart contract interaction			X
Token			X
Token operation (minting, transferring, destroying)			X

Table 1: Competencies of POC4COMMERCE's ontologies

Finally, on top of the ontological stack, POC4COMMERCE provides a TRL2 semantic search engine called **OC-Commerce Search Engine**, implemented by exploiting the modern programming language and Semantic Web APIs, together with SPARQL engines, to profitably find goods, products, information, and services, meeting the final user requirements and published by the wide array of ONTOCHAIN commercial participants. OC-CSE builds suitably constructed queries representing final user requirements and search desiderata that are injected to the provided data-management systems: the search engine enables the interoperability of commercial parties, whose businesses would have been disconnected otherwise, favouring the spread of products and services through the ONTOCHAIN ecosystem and reducing economic inefficiencies.

2.4 SOLUTION FUNCTIONALITIES

Overarching functionality *Provision of ontological stack for formal representation of, as well as reasoning over, the semantic core of ONTOCHAIN tailored but not limited to an interconnected and interoperable eCommerce domain.* POC4COMMERCE exposes its overarching functionality through a set of detailed functionalities.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

Detailed functionalities

1. *Semantic formalisation of agents independently from their implementation details and configurations representing ONTOCHAIN actors and participants, in particular those relevant for the digital commerce domain, focusing on products and services supply chain.* POC4COMMERCE takes an epistemological approach to conceive active web resources as agents that are in turn modelled through their respective behavior, i.e., their ability to contribute to the environment.

2. *Facilitation and support for users and applications to access semantically discernible, data-oriented web content.* POC4COMMERCE supports each stakeholder's publication of its semantic "manifesto", expressing, e.g., what types of data or services the stakeholder treats or exposes and how anyone can seamlessly interact with those.

3. *Enablement of users and applications to locate, select, employ, compose, and monitor web-based services automatically and autonomously.* POC4COMMERCE demonstrates this, in particular, over a digital marketplace, which requires a complete description not only of key elements such as providers, buyers and goods, but also of eCommerce logics such as price determination mechanisms including auctions, payment systems, transportation means and all other activities aimed at facilitating the match of demand and offer.

4. *Wide semantic formalisation of Ethereum blockchain and related smart contracts.* POC4COMMERCE may cover a virtually infinite plethora of agent types and, notably, will cover blockchains such as Ethereum, including fungible, non-fungible, and semi-fungible tokens, in particular those related to (physical) products or services involved in commercial exchanges, along with the smart contracts for minting, destroying, and managing exchanges of tokens.

5. *Provision of knowledge base necessary for automated web service discovery, invocation, composition and interoperation.* POC4COMMERCE also delivers a foundational tool to profitably probe a semantic blockchain, the OC-CSE search engine. OC-CSE embeds Semantic Web API, reasoning service interfaces to generate ad-hoc and parametric SPARQL queries required by users and applications to probe the ONTOCHAIN ecosystem and in particular the digital marketplaces realized leveraging the POC4COMMERCE ontological stack.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

2.5 ARCHITECTURE DIAGRAM

The family of ontologies and the related semantic applications conceived by POC4COMMERCE are depicted in the architecture diagram in Figure 6.

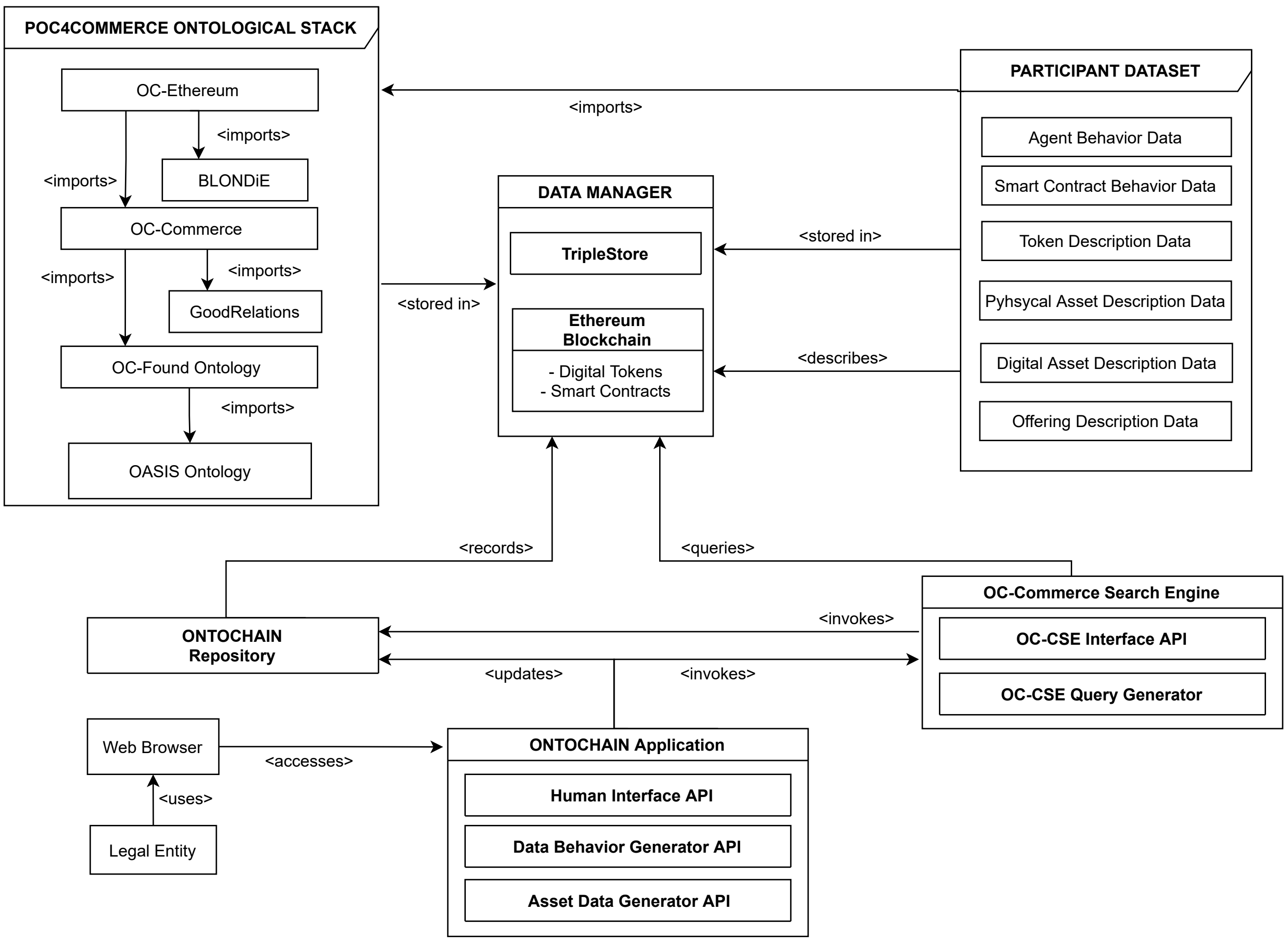

Figure 6: POC4COMMERCE architecture diagram

The schema points out the principal modules of the ecosystem idealized by POC4COMMERCE, namely, a) the **ontological stack** constituted by the three main layers for the principal stakeholders, i.e., participants, blockchains with related smart contracts and tokens, and commercial

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

offerings about the latter; b) **data** provided by participants and exploiting the data-schema provided by the ontological stack; c) the **data manager** responsible for storing and retrieving the stored data, constituted by triple-stores for RDF graphs. The latter module also comprises the Ethereum blockchain for storing smart contracts and related digital tokens; d) one or more **repository** tracking data produced by users; e) the *OC-CSE* search engine, building on user requests the suitable SPARQL queries compliant with their specified research parameters; f) ONTOCHAIN **applications** providing the required modules to generate data concerning agent behaviors, offerings and assets traded, and APIs to interact with the search engine; g) users and providers, represented by *legal entities* exploiting a web browser to produce and inspect data.

2.6 DETAILED DESIGN SPECIFICATION

We have seen that POC4COMMERCE relies on the semantic representation of commercial stakeholders through a stack of three OWL 2 ontologies. The first ontology, **OC-Found**, covers the participants of the ONTOCHAIN ecosystem and how they perform actions by means of their *behaviors* as demanded by the **OASIS** approach (see Section 1). To do so, OC-Found adapts OASIS to define general representations of the behaviors of principal actors such as final users, product and service providers. Templates are then exploited by users and providers to define their actual agent behaviors by extending them with customized elements such as products available, shipment and payment modalities. Describing the supply chain is in fact the main objective of the ontology **OC-Commerce**, which reuses the ontology **GoodRelations** to describe offerings associated with services and products deployed by providers. On top of OC-Commerce, the ontology **OC-Ethereum** describes the Ethereum blockchain and the behaviors of smart contracts deployed to emit, transfer and destroy digital tokens, together with related restrictions, constraints and limitations on such operations. Ethereum blocks and transactions are represented in OC-Ethereum by exploiting the description schemes provided by the ontology **BLONDiE** in order to deliver a complete semantic representation of the blockchain. From this point of view, OC-Ethereum can be easily incorporated into ontologies for other distinct blockchains, such as *Hyperledger Fabric* and *Stellar Lumens*. Moreover, ontologies for different vertical domains such as eHealth, eScience, smart cities, IoTs, can be deployed beside OC-Commerce, thus providing a comprehensive representation of the complex ONTOCHAIN reality.

Data provided by users is framed in the POC4COMMERCE ontological stack to describe the user's own services, smart contracts and products, aiming at publishing offers, joining commercial bids or exchanging tokens. By exploiting Semantic Web technologies, ontologies and related data are abstracted away from storage technologies. We contend that users and providers may store

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

and share off-chain data secured on the blockchain by exploiting one of the available technologies such as IPFS (see [6]) or *TheGraph* protocol[8], or ultimately running their own triple stores such as Neo4J or OpenLink Virtuoso — our ontological representation in fact is, by definition, independent from the underlying infrastructure.

In the POC4COMMERCE vision, dissemination of data is carried out by *repositories* delegated to simplify the mechanisms of accessing data. Repositories may have different implementations: for instance, repositories can be implemented by means of suitable smart contracts releasing tokens and pointing to RDF graphs stored on the user IPFS node or by means of indexer as in the case of the TheGraph protocol. The existence of repositories reduces data fragmentation and simplifies the construction of search agents by means of federation mechanisms. From this point of view, the **OC-Commerce Search Engine** relies on federation to query data produced by users. OC-CSE is comprises two essential modules, namely, a) the **OC-CSE Interface API**, implemented by exploiting the available API for Semantic Web applications such as Apache Jena,[9] OWL API,[10] Python RDFLib,[11] and Python OWLready 2,[12] to combine search parameters extracted from common and shared vocabularies produced by participants, and b) the **OC-CSE Query Generator**, which exploits the collected search parameters to build suitable SPARQL queries that are submitted to the indexed triple stores, and whose results are returned to the applications by the Interface API module.

Finally, any application running on the ecosystem performs two main tasks. The first task consists in contributing to the ONTOCHAIN ecosystem by providing a Semantic Web representation of both a) the participant behaviors and supply chains embedded in the description provided by the ontological stack of POC4COMMERCE, and b) the asset sold and exchanged through the ecosystem. For the latter task, the *Human Interface API* module assists the user on building his own behavioral representation and asset descriptions. Applications that automatically produce data may rely on two modules, the *Data Behavior Generator API* module, which provides the API required to generate behavioral representations of agents, and the *Asset Data Generator API* used to provide the ontological representations of assets and the related offerings. Applications can also run as stand-alone programs installed on users' (virtual) machines or as web applications accessible by standard web browsers and protocols. In both cases, human users, identified as legal entities, access applications by means of their digital identities and provides products and services

[8]https://thegraph.com/
[9]https://jena.apache.org/
[10]http://owlcs.github.io/owlapi/
[11]https://rdflib.readthedocs.io/en/stable/
[12]https://pypi.org/project/Owlready2/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

represented as agents in the POC4COMMERCE semantic representation mechanism.

2.7 INTERFACES WITH THE OTHER ONTOCHAIN BLOCKS

The high scalability and modularity of the POC4COMMERCE solution supports a full and flawless cooperation with other ONTOCHAIN blocks, at least in the directions of what follows.

ONTOCHAIN applications. Any ONTOCHAIN applications, especially the ones concerning the commercial domain, are representable by the ontological stack provided by POC4COMMERCE and hence indexed and searchable by the OC-CSE search engine. Core applications for the ONTOCHAIN ecosystem find a solid representation pillar for sharing data and communicate through that data.

ONTOCHAIN Semantic Interoperability. Since POC4COMMERCE's ontologies and search engine entirely rely on the OWL 2 language and on standard Semantic Web tools, a high interoperability of the resulting solution is achieved. A range of approaches can be practically taken to manage access to the POC4COMMERCE knowledge base, especially those guaranteeing trustworthy, privacy-preserving, secure, transparent, democratic and traceable mechanisms. Moreover, POC4COMMERCE benefits from ontological reasoning techniques and ontology verification processes.

ONTOCHAIN Ecosystem Economy. Both existing and novel businesses, even though semantically intricate and dynamically evolving, are supported by the digital marketplace conceived by POC4COMMERCE, since supply chains, both traditional and blockchain-based, both digital and physical, are entirely described, products and services are fully traceable and asset exchanges are consolidated by clear and unambiguous semantic descriptions.

ONTOCHAIN On-Chain and Off-chain Data Management. Modern solutions based on the balance of on-chain and off-chain data benefit from the ontological approach carried by POC4COMMERCE because the three building blocks identified by the ontological stack fit well with numerous data storage and data management approaches. Moreover, even if POC4COMMERCE is oriented to the Ethereum blockchain thanks to the OC-Ethereum ontology, any Turing-complete public ledger can be represented by exploiting the agent behavior representation mechanism and put beside OC-Ethereum, thus describing cross-chain applications.

ONTOCHAIN ecosystem scalability and integration. POC4COMMERCE proposes a

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

semantically deep and dynamic ecosystem describing not only the digital commerce vertical domain but, potentially, any deployment site thanks to the foundational nature of the OC-Found ontology and the high modularity of the ontological stack that exploits the current best practices in ontology engineering to deploy a scalable stack that is easy to integrate with.

3 IMPACT

3.1 BUSINESS MODEL DESCRIPTION

This Section starts off by updating the preliminary business model canvas of POC4COMMERCE as well as the sustainability strategy that were sketched in the project proposal — an obvious remark is that both are subject to continuous change and improvement while the project developments unfold. The Section continues by sketching the business value for ONTOCHAIN and other anticipated impacts.

3.1.1 Current business model canvas

The preliminary business model canvas is here tailored to the provision of the POC4COMMERCE functionalities (§2.4) as marketised services.

- Key exploitable results: hierarchical semantic modelling and ontological approach for blockchain enabled eCommerce, OC-Found, OC-Commerce, OC-Ethereum ontologies, design of OC-CSE software agent and related, general experience and expertise.
- Key partners: SWB, new academic spin-offs, all end-users operating in the agrifood eCommerce domain.
- Key activities: deployment and customisation of additional software agents, training and consultancy, interoperation with existing marketplaces.
- Key resources: technical infrastructures of the project team, academic know-how, practical experience and expertise.
- Value propositions: enabling a more efficient marketplace, pioneering new microeconomic eCommerce models, attracting more buyers and sellers to the digital world in general and to blockchain-based eCommerce in particular.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

- Customer relationships: making value propositions accessible to a wide range of potential customers through advertising campaigns and dedicated events, dedicated liaising with top customers to implement their desiderata, strategic partnership with field associations and consortia.
- Customer segments: natural persons, retailers, e-service providers, agrifood traders, logistics and transportation representatives.
- Cost structure: infrastructure and hosting, upgrades and maintenance, advertising, event organisation or participation.
- Revenue streams: bulk service subscription fee, enterprise-level subscription fee, consulting fees for requirement elicitation, customisation and training, service fees for customisation, advertising.
- Revenue model: free limited-functionality software application, free limited-time software application, ad-free premium subscription.

3.1.2 Current business model outline

The current business model canvas fuels up the current business model. Partner SWB plans to follow all revenue streams identified above, particularly through service fees for customisation, while keeping standard services free of charge as a strategy to enhance attractiveness.

Partner UNICT is best suited to offer consultancy on requirement elicitation for all customer segments as well as for customisation and training in general.

Subject to the actual revenues, a spin-off is anticipated precisely on the combination of such core products and business models.

3.1.3 Current sustainability strategy

The continuation of POC4COMMERCE after the 7-month duration of Phase 1 of Call 1 will ensure the medium-to-long term sustainability of the project outputs. It will entail the full implementation of the search engine OC-CSE to serve as an entry point for an ONTOCHAIN-based distributed marketplace of offerings on wheat as a start and, more in general, on the agrifood domain, additionally with the technical feasibility of interconnection with the iExec marketplace. People and organizations alike will intermingle on such a platform to exchange goods, products, and service in a trustworthy, treaceble, and sustainable ecosystem. More software agents will be

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

continuously conceived, defined and implemented to empower eCommerce and make the marketplace more profitable, such as a price-watch agent and a bulk-purchase agent, thus consolidating the role of SWB as enabler of a new micro-economy based upon trading of goods without overheads. SWB may pursue its revenue streams based upon a one-off subscription fee proportioned to the size of the subscriber. Sustainability of its activities will also come from selling publicity slots through advertisement boxes. It will seek funding at EU level, also participating in consortia with UNICT, leveraging the POC4COMMERCE success story. Sustainability on the side of UNICT stems from consolidation of its role at the forefront of, at least, Italian research on blockchain technology and semantic web. This will, in turn, motivate its participation and role in the Working Group on Blockchain of Italian "Consorzio Interuniversitario Nazionale per l'Informatica" (CINI) (http://dltgroup.dmi.unipg.it), thus facilitating the participation of UNICT to future consortia for application to funding both at Italian and at European level.

3.2 BUSINESS VALUE FOR ONTOCHAIN

As a consequence of the ontological approach, the main business value of POC4COMMERCE is the vertical application of the Semantic Web to eCommerce. Products and services that would have remained isolated gain boosted visibility and interoperability thanks to the semantic representation delivered by POC4COMMERCE. On one hand, product and service providers potentially reach a much larger audience of clients, since the selling offering is widespread and the match between demand and supply is facilitated and made more precise, also by exploiting guarantees from the blockchain technology. The resulting level of interaction of producers and consumers rise significantly — POC4COMMERCE makes their roles clear, thus removing present vagueness, for example, about process's time, product's quality, and, in particular, the facility's accommodation of the consumer's needs. On the other hand, clients gain a better opportunity to discover desired products and services at the best available prices and conditions, and also more quickly, by taking advantage of the full semantic representation of the supply chain.

Upon such bases, it seems fair to claim that POC4COMMERCE brings forth, with its ontological approach, a variety of business opportunities, coherently with the underlying implemented infrastructure. Data providers, data storage, and data search nodes in a totally decentralized infrastructure, for example, may apply fees for their work each time they process and honor a request. For example, data publishers are paid each time an ontological fragment is generated, data storage providers are paid when they store ontological fragments, whereas data searchers get their fees when they are engaged to perform SPARQL queries. Finally, providers may pay publishers each time an ontological fragment concerning selling offerings is made public. We believe

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

that each and everyone of these, separately or in combination, form viable business opportunities for the ONTOCHAIN partners as well as for the ONTOCHAIN Consortium as a whole. We even dare to envisage a short-to-medium time to market after the termination of POC4COMMERCE, subject to the shape and directions that the project will take upon the mentors' guidance.

We concede that it may be too early to define a business model to a greater level of detail. However, our confidence in our approach and aims grow day by day. We therefore remain entirely open to criticism and steering from the ONTOCHAIN Consortium, specifically in terms of the business impact of our results.

3.3 RELEVANCE TO BLOCKCHAIN IN GENERAL AND ONTOCHAIN IN PARTICULAR

POC4COMMERCE provides a semantic representation of Ethereum and of digital commerce carried on the blockchain by leveraging the most representative ontologies for modelling commercial stakeholders such as actors, smart contracts, offers, products, and tokens. In order to promote a sustainable, resilient, and trustworthy digital commerce, an ecosystem of modular ontologies describing each semantic compartment of eCommerce is required. We believe that commerce on or through the blockchain is a novel business opportunity that is gaining momentum mainly thanks to the exchange mechanisms of tokens in general and of NFTs in particular. However, probing the blockchain for identifying the desired token, the associated asset and its features, or the smart contract trading it and the conditions of trading, is often hard even though the source code of the related smart contracts is publicly available together with the transactions storing them, mainly hard-coded. Semantic descriptions of Ethereum smart contracts and related transactions in general, and of smart contracts related to token trading and associated with commercial means specifically, lie at the core of POC4COMMERCE. POC4COMMERCE contributes to many aspects of the ONTOCHAIN ecosystem. First at all, the ontological layers that POC4COMMERCE delivers make the ONTOCHAIN ecosystem readily functioning to build a sustainable, interoperable, and trustworthy environment for people and software to interoperate. The foundational ontology OC-Found provides a unifying canvas for all ONTOCHAIN participants and relationships between them, a substrate describing and connecting what really exists in ONTOCHAIN with the relevant stakeholders interoperating coherently in a heterogeneous context. OC-Found also lays the ground for the semantic interoperability of potentially innumerable domain-specific ontologies for the ONTOCHAIN ecosystem, such as those for eScience, eEducation, eHealth, eGovernment, eCommerce, eTourism, and eInfrastructures.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

3.4 ANY OTHER IMPACT E.G. TECHNOLOGICAL, SOCIO- ECONOMICAL, ENVIRONMENTAL

POC4COMMERCE impacts on how digital commerce is carried out in the Web 3.0 and beyond. Commerce on the digital representation of products requires affordable marketplaces where sellers and buyers may freely choose the services associated with their business activities. There are significant costs to select the required features of goods, e.g. where they are produced and stored, how they can be moved to the consumer: such costs inevitably concur to the business costs, namely to the final price paid by consumers. Therefore, the results of POC4COMMERCE contribute to a shift towards a novel micro-economic model where individuals and companies cooperate and coordinate, deciding the allocation and utilization of resources, and the subsequent effect on price, demand, and supply merely upon the basis of personal choices and without the intermediation of third-parties. It opens up new business opportunities for companies of any size because the absence of price profiteers reinstates the equilibrium of the relation between demand and supply that determines the competitive capability of any organization - thus re-establishing their decision power in setting the price of goods and services. Such principle is strengthened by decentralized marketplaces that directly connect consumers and sellers. For this reason, OC-Ethereum promotes the concept of a semantic blockchain that conjoins the high level of trustworthiness and transparency of a decentralized public ledger where economic parties interact with their own rules: no restrictions imposed by third parties and a machine interpretable representation of the knowledge is retrieved by meanings and not just by spellings. A semantic blockchain implies that smart contracts can be referenced without pre-existing knowledge of their deployment and of the underlying programming code: their functionalities are fully specified by formal and machine-understandable representations, thus realizing an interoperable environment where off-chain services interact with applications lying on various blockchains such as Ethereum, Hyperledger, and Stellar Lumens. The results of POC4COMMERCE also advance the standard procedures in ontology engineering and knowledge management, in particular over ontologies for representing agents and multi-agent systems.

4 IMPLEMENTATION

This section discusses how POC4COMMERCE provides its practicable and reliable contribution to the ONTOCHAIN ecosystem. Then, we show how a solid workbench for evaluating the overall success of the solution is deployed, how such a solution contributes to and, in turn, may benefit from the other Phase 1 winning projects and how our work plan will lead to successful achievements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

of the goals set for Call 1, while also looking at upcoming Call 2 and Call 3.

4.1 FEASIBILITY AND MODULARITY OF THE SOLUTION

As described in Section 2.6, POC4COMMERCE relies on well consolidated standard technologies to deliver both the ontological stack and the search engine. Specifically, the ontologies in the POC4COMMERCE knowledge base are implemented by exploiting the Semantic Web language OWL 2, the W3C standard for ontology engineering and developing, and serialized in the standard technologies JSON-LD and RDF/XML. Moreover, the foundational ontology OC-Found and the domain-specific ontologies OC-Commerce and OC-Ethereum are constructed on the TRL4 ontologies OASIS and BLONDiE and on the TRL9 ontology GoodRelations, thus ensuring the solid foundation of the ontological stack. Moreover, OASIS, BLONDiE, and GoodRelations are ontologies totally independent, freely adoptable for business purposes, and conceived for different missions: they are adopted by POC4COMMERCE to define a modular representation of the ONTOCHAIN world to be modelled, focused on the commercial domain but extremely relevant for any ONTOCHAIN deployment site. Indeed, the ontologies are adopted to define three distinguished, extendable, modifiable, and customizable layers for three knowledge domains, namely, agents and their interactions, commerce, and blockchains. Remarkably, the ontological stack allows developers and users to easily extend the number of layers thus covering different aspects of the digital commerce domain such as bidding mechanisms, payment systems, and delivering options, or modelling new domains such health, science, smart cities, and government. Finally, the OC-CSE search engine built on top of the ontologies is designed through consolidated programming languages such as Java and Python, and Semantic Web libraries, namely Java Apache Jena, Java OWL API, Python RDFLib, and Python OWLready 2. The search engine is conceived to find products, agents, and supply chains available on the ecosystem regardless of their implementative aspects and technologies adopted. Most notably, the data storage and management technologies that will be adopted for ONTOCHAIN infrastructures abstract away from the ontological approach, which fits any (de)centralized solutions. The search engine and any applications delivered for POC4COMMERCE rely only on the semantic representation provided by the ontological compartment ensuring a totally modular and plug-and-play ecosystem. In conclusion, the ontological approach of POC4COMMERCE does not affect business model or user reward mechanisms that will be finally adopted but, rather, will support any of them.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

4.2 REAL TIME PERFORMANCE OF THE SOLUTION (KPI AND EXPERIMENTAL EVALUATION)

The POC4COMMERCE ontological approach will be evaluated during its remaining lifetime through the KPIs stated in the original project proposal. The following additional KPIs (aKPIs) are also stated as further performance verification measures and will be met.

- **aKPI I. Ontology metric criteria defined and demonstrated on the ontologies OC-Found, OC-Commerce, and OC-Ethereum. At least 4 ontology metric criteria are adopted**. The literature provides many tools to evaluate the quality of ontologies [16, 25, 29, 30], in particular in the shape of ontology metrics. Ontology metrics are feature-based methods for evaluating ontologies that do not require machine learning and that do not involve users. Metrics are necessary to evaluate ontologies both during the design and implementation phase, thus allowing for fast and simple assessment of ontologies, thus ensuring both correct domain coverage and suitability of the ontologies. POC4COMMERCE adopts the most recent and reliable metric criteria to deliver the ontological compartment of the project, thus ensuring a high-quality representation system for the ONTOCHAIN ecosystem. Some of the considered metrics criteria are (though not limited to):
  - *Relationship richness*. Relationship richness is a percentage representing how much relationships between classes are rich with respect to all of the possible connections (inheritance and properties).
  - *Tree balance*. The tree balance metric is referred to how much class hierarchies differ in deepness. This may be related to the fact that some hierarchies are very deep whereas others are not.
  - *Attribute richness*. The attribute richness estimates the average number of attributes per class, which gives insight into how much knowledge about classes is represented in the model.
  - *Instance Coverage*. This metric indicates how much each class is populated.
- **aKPI II. Competency questions defined and applied to the ontologies OC-Found, OC-Commerce, and OC-Ethereum. At least 5 competency questions are addressed over all developed ontologies**. Competency questions constitute questionnaires in natural language, which help to clarify the context and the scope of ontologies. Appropriate competency questions are designed side by side with the development of the TRL4

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

ontologies OC-Found, OC-Commerce and OC-Ethereum. Competency questions aim to verify whether the ontologies are truly being developed towards the project objectives and are reaching the stated representational goals. Some of the suitable competency questions for the POC4COMMERCE ontologies are (though not limited to):

  - Given a blockchain, what are the available offerings about NFTs representing a specific type of asset (e.g., apples) with peculiar characteristics (e.g., *green* apples *from europe*)?
  - What are the offerings that can be purchased through specific payment methods (e.g., bank transfer, credit card, digital currency)?
  - What is the smart-contract generating the given NFT?
  - What is the supply chain of a specific product?
  - Which NFTs has been sold by a given seller?

- **aKPI III. SPARQL queries defined from competency questions and executed on the ontologies OC-Found, OC-Commerce, and OC-Ethereum. SPARQL queries formalized for all addressed competency questions**. To put into practice the competency questions and to make them concretely exploitable, they are formalized and translated into SPARQL queries that will be executed by suitable query engines within a *Continuous Integration* and *Continuous Delivery* (CI/CD) process involving the development of the ontologies.

- **aKPI IV. OWL 2 compliant reasoners executed on the ontologies OC-Found, OC-Commerce, and OC-Ethereum. At least 2 separate reasoners are used for consistency checking of all developed ontologies**. Logic-based semantic consistency of an ontology ensures that the ontology is *self-consistent*, i.e., it not contains contradictory statements. Consistency of deployed ontologies is verified by exploiting the last version of the most widespread OWL reasoners such as HermiT [14], Pellet, and FaCT++.

- **aKPI V. Data population of the ontologies OC-Found, OC-Commerce, and OC-Ethereum. At least 2 separate real-world datasets are used to validate all developed ontologies**. A core dataset is adopted to validate the ontologies against the real world of ONTOCHAIN ecosystem and provided by partners such as SWB and iExec thus testing the appropriateness of ontologies and its effective applicability.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

- **aKPI VI. Design and specification of the OC-CSE search engine through suitable UML diagrams. UML activity diagrams describing the specifications of the OC-CSE search engine are provided.** The TRL2 OC-CSE search engine, standing on top of the developed ontologies, is provided by leveraging the best practices and standards in software engineering, as well as the guidance deriving from the datasets provided by partners.

4.3 INTEROPERABILITY ASPECTS

The ontological approach pursued by POC4COMMERCE is based on standard Semantic Web tools and technologies: it fits adequately with a plethora of solutions concerning both storage and data management issues and applications built around the POC4COMMERCE stack. Indeed, tools and technologies for realising authorizations and digital identities, which eventually allow participants to join the ecosystem and identify themselves, may be provided both by the *HIBI.Human Identity Blockchain Initiative: Trustworthy*[13], and *Solid Verif*[14], and *OntoSsiVault- OntoDID and OntoVault: an ontology data and identity suite* projects.

Distributed data-storage systems relying on a balanced combination of off-chain and on-chain approaches as conceptualized by the GraphChain[15] project as well as the ISLAND[16] project are suitable to host the POC4COMMERCE foundational ontologies and the related knowledge produced and consumed by participants. In particular, data leveraging the ontological schema promoted by OC-Found, OC-Commerce, and OC-Ethereum, may be generated with the assistance of the *A Low Code Development Platform (LCDP)*[17] technology that may assist commercial parties to semi-automatically generate it.

The ontological representation of tokens emitted and exchanged on the blockchain as conceived by OC-Ethereum can be exploited by *TENACIOUS - Trustworthy sEmaNtic Aware marketplaCe for Interoperable clOUd Services*[18] services representable in OC-Found, whereas *OntoROPA: Ontology based ecosystem for trustworthy Records of Processing Activities*[19] shares our mentalistic notion of agent behaviors to build a standard ontology for ROPAs.

Finally, applications exploiting standard Semantic Web languages such as OWL 2 find in POC4COMMERCE a profitable and solid knowledge representation system. The *Reputable -*

[13]https://ontochain.ngi.eu/content/hibi
[14]https://ontochain.ngi.eu/content/solid-verif
[15]https://ontochain.ngi.eu/content/graphchain
[16]https://ontochain.ngi.eu/content/island
[17]https://ontochain.ngi.eu/content/lcdp-ont-app
[18]https://ontochain.ngi.eu/content/tenacious
[19]https://ontochain.ngi.eu/content/ontoropa

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

A provenance-aware Decentralized Reputation System for Blockchain-based Ecosystems project may rely on the OC-Found and OC-Ethereum ontologies for representing agents and smart contracts for the idealized reputation mechanisms for blockchains, the fungible tokens emitted on the blockchain as conceived by the *Carbon - A high performance cryptocurrency with carbon-negative coin generation* project are representable in OC-Ethereum, whereas high level applications such as the data-crawlers sketched by the *KUMO - A Newtork Crawler for Ethereum 2.0* and the *KnowledgeX- Trusted data-driven knowledge extraction* projects finds in POC4COMMERCE a wide range of representable agents and agent commitments.

4.4 IMPLEMENTATION PLAN

In order to achieve the objectives set by POC4COMMERCE, we follow the implementation plan summarized in Table 2, which inherits and upgrades the version that was submitted with the proposal. The scheduling marks as completed the work package considered in the first project proposal, namely WP1 (in green in Table 2), which has terminated, and the two related deliverabled (in green in Table 3), i.e, the *Survey on the State of the Art and Project Ambitions* (Deliverable 1) and the *Proposed Design Specification and Approach* (Deliverable 2), the latter being the present document. Hence, the plan focuses on future tasks, namely those from month 2 to month 7.

The upcoming effort sees three main WPs. Notable is the continuation of **WP4**, which consists in managing the internal activities, the cooperation with partner teams and with the ONTOCHAIN mentors, and is scheduled to last for the entire duration of the project. Two core WPs remain, **WP2**, aimed to deliver the ontological stack promised by POC4COMMERCE, and **WP3**, oriented to populate the constructed ontologies with the data produced by the partners, and design the OC-CSE search engine.

More in detail, WP2 takes two months (from month 2 to month 4) and comprises two main tasks, a) the construction of the foundational ontology OC-Found and b) the construction of the domain-specific ontologies OC-Commerce and OC-Ethereum. Within each task, the construction of the ontologies is flanked with the process of defining the tools required to valuate them, i.e., the definition of the competency questions and of the related SPARQL queries. Then, WP3 takes three months (from month 4 to month 7). During this period, the ontological stack will be tested against the data provided by the partners, in particular the Sicilian Wheat Bank and iExec Marketplace: on top of the results obtained, the OC-CSE will be designed and sketched so as to be ready for Call 2, during which the ONTOCHAIN prototypes will be delivered, and also for Call 3 as a solution for building a concrete marketplace for the real word. Finally, the effort devoted to the three WPs will culminate in the production of a scientific paper, which will be submitted to a highly ranked

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

journal.

For each task, Table 2 reports the time scheduled and effort required by the two project partners, UNICT and SWB. The results to be delivered are summarized in Table 3: the *Deliverable 3* is a document specifying in detail the approach adopted and the general description of the constructed ontologies and is produced at month 4; the *Deliverable 4*, finalized at month 6, includes the ontologies together with exhaustive documentation, examples, and tests; finally, *Deliverable 5* consists in the scientific paper that will be completed at month 7. The scheduling of the project activities is summarized in the Gantt diagram in Figure 7, which also includes the completed tasks and related deliverables.

Work Plan	Description	Start month	End month	UNICT Effort	SWB Effort
WP1. Conceptual Analysis					
WP2. Proposed Solution Design		2	4	24	8
T2.1 Construction of the foundational ontology	Definition of relevant competency questions and related SPARQL queries. Construction (design to prototype) of OC-Found	2	4	12	3
Construction of the domain-specific ontologies	Construction (design to prototype) of OC-Commerce and OC-Ethereum. Definition of the competency questions and of the related SPARQL queries	3	4	12	5
WP3. Prototype Demonstration		4	7	18	10
T3.1 Validation against real-world-data	Sourcing of data from Sicilian Wheat Bank and iExec Marketplace into OC-Commerce and OC-Ethereum	5	6	6	1
T3.2 OC-CSE	Design an eCommerce search engine for offerings as a software agent on OC-Commerce and OC-Ethereum	7	7	8	1

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

T3.3 Paper submission	Production of a paper describing all developments carried out on the ontologies OC-Found, OC-Commerce, OC-Ethereum, highlighting findings and drawing open problems (to address in subsequent calls)	7	7	8	1
WP4. Management		4	7	18	10
T4.1 Day-to-day operations and solution integration	Execution of project internal management activities with an emphasis on the persistent integration of draft findings	1	7	3	0
T4.2 Liaison with mentors	Execution of project external management activities with an emphasis on interaction with the NGI Ontochain mentors	1	7	3	0

Table 2: Implementation planning

N	Deliverable name	Description	Type	Deliv. month	Milestone
D1. State of the Art and Project Ambitions					
D2. Proposed Design Specification and Approach					
D3	Proposed solution design	Design specification and detailed approach description for OC-Found, OC-Commerce and OC-Ethereum, with informal descriptions of competency questions	PUB	4	MS2, end of M4. End of Phase 2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

D4	Prototype demonstration	Prototypes of OWL ontologies OC-Found, OC-Commerce and OC-Ethereum, with exhaustive documentation, examples and SPARQL queries, test against real-world data from Sicilian Wheat Bank and iExec. Design of OC-CSE	PUB	6	MS2, end of M4. End of Phase 2
D5	Paper	Paper describing all developments carried out,highlighting findings and drawing open problems	PRI (till acceptance)	7	MS3, end of M7. End of Phase 3

Table 3: Deliverable planning

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

WP/Deliverable/ Milestone Number	Task Number	Name	Start Month	End Month	Month Distribution						
					1	2	3	4	5	6	7
WP1		**Conceptual analysis**	1	2							
	T1.1	Writing of a survey on state-of-the-art and project ambition	1	2							
D1		State-of-the-Art and Ambition		1	End of month						
	T1.2	Identification of foundational stakeholders	1	2							
	T1.3	Identification of domain-specific stakeholders	1	2							
	T1.4	Writing of a research and innovation project proposal	2	2							
D2		Full research and innovation project proposal		2		End of month					
MS1		Successful completion of Phase 1		2		End of month					
WP2		**Proposed solution design**	2	4							
	T2.1	Construction of the foundational ontology	2	4							
	T2.2	Construction of the domain-specific ontologies	3	4							
D3		Proposed solution design		4				End of month			
MS2		Successful completion of Phase 2		4				End of month			
WP3		**Prototype demonstration**	4	7							
	T3.1	Validation against real-world-data	4	6							
	T3.2	OC-CSE	5	6							
D4		Prototype demonstration		6						End of month	
	T3.3	Paper submission	7	7							
D5		Paper		7							End of month
MS3		Successful completion of Phase 3		7							End of month
WP4		**Management**	1	7							
	T4.1	Day-to-day operations and solution integration	1	7							
	T4.2	Liaison with mentors	1	7							

Figure 7: Gantt diagram of the implementation plan

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

CONCLUSIONS

The overall goal of POC4COMMERCE is to promote a sustainable, resilient, and trustworthy eCommerce by leveraging the modern literature and embracing it in an epistemological process that delivers a family of ontologies, compliant with the best ontological metrics criteria, modelling different degrees of knowledge for the ONTOCHAIN ecosystem, vertically focusing on the commercial vertical domain. The ontologies are populated with data from the considered test services, hence the size of the deployment is realistic, that of the project partner Sicilian Wheat Bank (SWB) and the iExec Marketplace, to confirm the requested interoperability and domain coverage. The ontological consistency is verified by means of the most popular OWL 2 reasoners and its quality checked by relevant competency questions and related SPARQL queries suitably constructed. POC4COMMERCE culminates by showing how a software agent profits from the formal, shared, and unambiguous descriptions of the stakeholders provided by the ontological approach. While the agent is designed to find goods, products, and services in an ONTOCHAIN-enabled marketplace on behalf of end-users such as people and organizations, it merely aims at reinforcing the prototype and is only one of innumerable others that could be defined consistently and coherently upon the basis of the semantic representation that the project builds.

The team that is executing the project relies on his experience matured in the field of ontology engineering over the years and, in particular, in the context of Theory of Agents, Internet of Things, blockchains, internet security, and software development in industrial contexts. The expected impact is very large. The SME partner in the team, the Sicilian Wheat Bank (SWB), will dramatically enhance its business by exploiting the project results, namely by building a digital marketplace for any type of agricultural good. SWB's enhanced core product will make it possible for organizations and final users to be on a direct line and for traders to publish their offerings about any service revolving around exchange and trading on food, including transportation, delivery, transformation, certification, and quality assurance - all without third party's overheads. UNICT will consolidate its role as main knowledge provider and driver of all POC4COMMERCE technologies, thus reinforcing its role as a leading academic institution in the project areas. Therefore, the benefits of the ONTOCHAIN approach on the core activities of both UNICT and SWB, even beyond the lifetime of POC4COMMERCE, are very clear. At the same time, ONTOCHAIN will also find a practical use case in eCommerce and a deployment site in SWB, and this is appreciable through the variety of business opportunities that the ONTOCHAIN Consortium as a whole or its individual partners could profitably engage in.

POC4COMMERCE has only just started to walk on its feet, and ... the best achievements are yet to come!

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

References

[1] D. Allemang and Hendler J. Semantic Web for the Working Ontologist: Effective Modeling in RDFS and OWL. *Elsevier*, 2011.

[2] J. Ashraf, O.K. Hussain, and F.K. Hussain. Empirical analysis of domain ontology usage on the web: Ecommerce domain in focus. *Concurr. Comput.: Pract. Exper.*, 26(5):1157–1184, April 2014.

[3] F. Baader, I. Horrocks, C. Lutz, and U. Sattler. *An Introduction to Description Logic*. Cambridge University Press, 2017.

[4] T. Berners-Lee, R.T. Fielding, and L.M. Masinter. Uniform Resource Identifier (URI): Generic Syntax. RFC 3986, January 2005.

[5] M. Birbeck. Introduction to RDFa. *A List Apart*, Juni 2010. zuletzt eingesehen am 06.04.2011.

[6] D. Cantone, C.F. Longo, M. Nicolosi-Asmundo, D.F. Santamaria, and C. Santoro. Ontological smart contracts in oasis: Ontology for agents, systems, and integration of services. In *To app. in: Proceedings of IDC 2021, The 14th International Symposium on Intelligent Distributed Computing, 16-18 September, Scilla, Reggio Calabria, Italy*, 2021.

[7] D. Cantone, C.F. Longo, M. Nicolosi-Asmundo, D.F. Santamaria, and S. Santoro. Towards an Ontology-Based Framework for a Behavior-Oriented Integration of the IoT. In *Proceedings of the 20th Workshop From Objects to Agents, 26-28 June, 2019, Parma, Italy, CEUR Workshop Proceeding Vol. 2404*, pages 119–126, 2019.

[8] R. Cyganiak, D. Wood, and M. Lanthaler. RDF 1.1 Concepts and Abstract Syntax. Technical report, W3C, 2014.

[9] M. Doerr, C. Ore, and S. Stead. The CIDOC Conceptual Reference Model: A New Standard for Knowledge Sharing. In *Tutorials, Posters, Panels and Industrial Contributions at the 26th International Conference on Conceptual Modeling*, volume 83, pages 51–56. Australian Computer Society, Inc., 2007.

[10] B. DuCharme. *Learning SPARQL*. O'Reilly Media, Inc., 2011.

[11] M. Duerst and M. Suignard. Internationalized Resource Identifiers (IRIs). RFC 3987, January 2005.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

[12] R.T. Fielding and J. Reschke. Hypertext Transfer Protocol (HTTP/1.1): Message Syntax and Routing. RFC 7230, June 2014.

[13] A. Gangemi, N. Guarino, C. Masolo, A. Oltramari, and L. Schneider. Sweetening Ontologies with DOLCE. In Asunción Gómez-Pérez and V. Richard Benjamins, editors, *Knowledge Engineering and Knowledge Management: Ontologies and the Semantic Web: 13th International Conference, EKAW 2002 Sigüenza, Spain, October 1–4, 2002 Proceedings*, pages 166–181. Springer, 2002.

[14] B. Glimm, I. Horrocks, B. Motik, G. Stoilos, and Z. Wang. HermiT: An OWL 2 Reasoner. *Journal of Automated Reasoning*, 53(3):245–269, 2014.

[15] N. Goldmann. E-commerce. *Journal of Internet Banking and Commerce*, 26(3):286–295, 2021.

[16] A. Gómez-Pérez. Ontology evaluation. In *Steffen Staab and Rudi Studer, editors, Handbook on Ontologies, First Edition*, chapter 13, pages 251–274. Springer, 2004.

[17] R. Guha, Rob McCool, and Eric Miller. Semantic search. In *WWW '03: Proceedings of the 12th international conference on World Wide Web*, pages 700–709, New York, NY, USA, 2003. ACM.

[18] M. Hepp. Goodrelations: An ontology for describing products and services offers on the web. In Aldo Gangemi and Jérôme Euzenat, editors, *EKAW*, volume 5268 of *Lecture Notes in Computer Science*, pages 329–346. Springer, 2008.

[19] P. Hitzler, M. Krötzsch, B. Parsia, P.F. Patel-Schneider, and S. Rudolph. OWL 2 Web Ontology Language Primer. W3C Recommendation, World Wide Web Consortium, October 2009.

[20] T. Hofweber. *Logic and Ontology.* Edward N. Zalta (ed.), The Stanford Encyclopaedia of Philosophy (Summer 2018 Edition), 2018.

[21] J. Jovanovic and E. Bagheri. Electronic commerce meets the semantic web. *IT Prof.*, 18(4):56–65, 2016.

[22] G. Klyne and Jeremy J. Carroll. Resource description framework (RDF): Concepts and abstract syntax. Technical report, W3C, 2 2004.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

[23] F. Manola and E. Miller, editors. *RDF Primer.* W3C Recommendation. World Wide Web Consortium, February 2004.

[24] D. Oberle, N. Guarino, and S. Staab. *What is an ontology?* Handbook on Ontologies, 2nd edition. Springer, 2009.

[25] L. Obrst, W. Ceusters, I. Mani, S. Ray, and B. Smith. The evaluation of ontologies. In *Christopher J.O. Baker and Kei-Hoi Cheung, editors, Revolutionizing Knowledge Discovery in the Life Sciences*, chapter 7, pages 139–158. Springer, 2007.

[26] P.F. Patel-Schneider. Analyzing schema.org. In P. Mika, T. Tudorache, A. Bernstein, C. Welty, C. A. Knoblock, D. Vrandecic, P. Groth, N.F. Noy, K. Janowicz, and C.A. Goble, editors, *International Semantic Web Conference (1)*, volume 8796 of *Lecture Notes in Computer Science*, pages 261–276. Springer, 2014.

[27] Protocol Labs. The Interplanetary File System (IPFS). `https://ipfs.io/`.

[28] M. Stonebraker and J. M. Hellerstein. Content integration for e-business. In Sharad Mehrotra and Timos K. Sellis, editors, *SIGMOD Conference*, pages 552–560. ACM, 2001.

[29] Samir Tartir, I. Budak Arpinar, Michael Moore, Amit P. Sheth, and Boanerges Aleman-Meza. OntoQA: Metric-based ontology quality analysis. In *Proceedings of IEEE Workshop on Knowledge Acquisition from Distributed, Autonomous, Semantically Heterogeneous Data and Knowledge Sources*, 2005.

[30] A. Tello and Asunción Gómez-Pérez. Ontometric: A method to choose the appropriate ontology. *J. Database Manag.*, 15:1–18, 2004.

[31] H. E. Ugarte Rojas. A more pragmatic web 3.0: Linked blockchain data. In *Google Scholar*, 2017.

[32] World Wide Web Consortium. SWRL: A Semantic Web Rule Language Combining OWL and RuleML, 2004.

[33] World Wide Web Consortium. RDFa Primer: Bridging the human and data webs, October 2008.

[34] World Wide Web Consortium. SPARQL 1.1 Query Language, 2013.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338

[35] World Wide Web Consortium. RDF 1.1: On Semantics of RDF Datasets, 2014.

[36] World Wide Web Consortium. RDF Schema, Frebruary 2014.

[37] World Wide Web Consortium. Linked data platform 1.0, 2015.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957338