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NGI ONTO CHAIN

Blockchain for the Next Generation Internet

IMPACT CREATION OF ONTOCHAIN FOUNDATIONS (OPEN CALL 2)

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D4.8 IMPACT CREATION OF ONTOCHAIN FOUNDATIONS (OPEN CALL 2)

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AUTHORS	Souvik Sengupta (IEXEC) Anthony Simonet-Boulogne (IEXEC) Ambre Toulemonde (IEXEC)
REVIEWERS	Vlado Stankovski (UL) Thanasis Papaioannou (AUEB)
ABSTRACT	This deliverable presents the impact of the 13 projects selected in the ONTOCHAIN Open Call 2 and summarizes the keys results, the innovation, the possibles evolution and the most relevant KPIs achieved for each project.
KEYWORDS	KPI, impact creation, interoperability, innovation, human-centric evolution, NGI

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Participant number	Participant organisation name	Short name	Country
1	EUROPEAN DYNAMICS LUXEMBOURG SA	ED	LU
2	UNIVERZA V LJUBLJANI	UL	SI
3	IEXEC BLOCKCHAIN TECH	IEXEC	FR
4	INTELLISEMANTIC SRL	IS	IT
5	ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS – RESEARCH CENTER	AUEB	EL
6	ELLINOGERMANIKO EMPORIKO & VIOMICHANIKO EPIMELITIRIO	GHCCI	EL
7	F6S NETWORK LIMITED	F6S	IE

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EXECUTIVE SUMMARY

This document is the deliverable "D4.8 Impact creation of ONTOCHAIN Foundations (Call#2)" funded under the Horizon 2020 Research & Innovation program "ONTOCHAIN - Trusted, traceable and transparent ontological knowledge on blockchain".

This deliverable summarizes the impact of thirteen projects, seven short projects for a 5-month period and six long projects for a 10-month period, selected during the Open Call 2. These projects have been funded and executed from November 2021.

The objectives of this deliverable are to measure the benefits of using the ONTOCHAIN framework as enriched by developing the selected OC2 projects and identifying its limitations. This deliverable can also provide inputs and suggestions for the following Open Call 3.

This deliverable is based on the results produced by Open Call 2 projects and their final deliverable D4 that are partially used in this document.

For each project, the deliverable provides:

- The key functional results and the most relevant KPIs.
- The innovations achieved the possible future improvements.

It is also mentioned that three projects (PS-DSA, ADOS and ONTOSPACE) of the Open Call 2 might potentially patent their solution by carrying out further research, features or evolution, and one project (BOWLER) actively studies in detail the process for patenting their solution. Other Open Call 2 projects do not intend to patent their solutions.

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ABBREVIATIONS

AI	Artificial Intelligence
API	Application Programming Interface
DAO	Decentralized Autonomous Organization
DApp	Decentralized Application
DID	Decentralized Identity
DLT	Distributed Ledger Technology
EVM	Ethereum Virtual Machine
GDPR	General Data Protection Regulation
IDE	Integrated Development Environment
IoT	Internet of Things
IPFS	InterPlanetary File System
KPI	Key Performance Indicators
NFT	Non-Fungible Token
NGI	Next Generation Internet
OASIS	Ontology for Agents, Systems, and Integration of Services
SDK	Software development KIT
SSI	Self-Sovereign Identity
TDD	Thing Description Directory
WoT	Web of Things
W3C	World Wide Web Consortium

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1 INTRODUCTION

During the ONTOCHAIN project[1], three open calls have been launched to fund projects enabling to develop the ONTOCHAIN blockchain ecosystem. The two first calls are intended to provide functionalities and the last one to extend applications.

This deliverable presents the impact creation of projects selected during the Open Call 2 (OC2) carrying out during the second year (from the 15th July 2021 to the 15th September 2021) of the ONTOCHAIN project. Thirteen projects have been funded and executed from November 2021: seven short projects for a 5-month period and six long projects for a 10-month period.

The objective is to provide the evaluation of results issued by OC2 projects in terms of functional and non-functional requirements in order to measure the benefits and the limits of using the ONTOCHAIN framework. This deliverable can be also used as inputs for the Open Call 3 (OC3) to help participants of the OC3 in designing their solution.

The OC2 includes six topics in which two projects are selected. A proposal under a different topic could also be submitted in "Open topic", as long as it serves as a building block of the ONTOCHAIN infrastructure and the overall ONTOCHAIN vision and objectives, excluding applications specified in OC3.

This deliverable is based on material provided in the deliverable D4 of the OC2 selected projects. The rest of this deliverable is organized as follows:

- Chapter 2 presents the different topics and the methodology used to identify the added value of the OC2.
- Chapter 3 summarizes the keys results, the innovation, the possible evolutions and the most relevant KPIs achieved of each OC2 project.
- Chapter 5 concludes this deliverable and outlines next steps.

2 ONTOCHAIN OPEN CALL 2

In this section, we recall the six topics and the results of ONTOCHAIN OC2. We also present the different KPIs that are described for each project in Section 3.

[1] https://ontochain.ngi.eu

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2.1 TOPICS AND RESULTS

The objective of OC2 is to implement components for ONTOCHAIN platform, guided by new real use-case or further extending the use cases and the architectural features planned by the end of the Open Call 1 (OC1). The results provided by the projects selected in OC2 can be used to measure the benefits of using ONTOCHAIN framework and to identify the limitations.

To this end, the OC2 includes these following 6 topics:

- Topic 1 - Decentralised oracles for ONTOCHAIN
- Topic 2 - Market mechanisms for ONTOCHAIN
- Topic 3 - ONTOCHAIN interoperability & API Gateways
- Topic 4 - ONTOCHAIN Network design and scalability
- Topic 5 - Semantic based marketplaces for ONTOCHAIN
- Topic 6 - Data provenance in ONTOCHAIN

Topic 1 aims to implement oracle prototypes that can interact with the ONTOCHAIN infrastructure and provide necessary data for the operation of its applications.

The goal of Topic 2 is to implement prototype services in the scope of advanced decentralized market and business-enabling mechanisms that offer win-win situations for all involved stakeholders, and are in line with the overall ONTOCHAIN objectives for trustworthy services/products exchange and trustworthy content handling.

Topic 3 must ensure that the different chains with different protocols, to serve different applications and business cases of the ONTOCHAIN network integrate smoothly together and with the outside world.

Topic 4 aims to build an ONTOCHAIN client based on Ethereum that is a stable and well tested system for data transactions and has a cost-effective network for the operation of its applications.

The goal is Topic 5 is to design and implement prototypes that will provide ontologies management and setup for decentralized semantic matching of demand and supply for different use case scenarios (e.g., apartments, land, cars, etc).

Topic 6 aims to manage metadata associated with the history of data, for auditing and for data lakes/aggregators (i.e., repositories of data belonging to multiple owners), data traders and business processes (especially supply chain management).

A proposal under Open Topic is also considered as long as it serves as a building block

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of the infrastructure and to the overall ONTOCHAIN vision and objectives. Note that the proposal cannot address the ONTOCHAIN applications specified in OC3.

Among the 76 proposals submitted, only 13 proposals were selected after the evaluation process, leading to an overall success rate of 17%: 6 long projects for a priod of 10 months and 7 projects as short projects for a period of 5 months. For short projects, 7 projects were selected instead than 6, given the quality of proposals and the availability of funds.

Table 1 summarizes the results of ONTOCHAIN OC2 by providing the number of projects submitted and selected per topics, the selected third parties profile and the countries of these third parties. Table 2 presents the selected long and short projects per topics.

2.2 ADDED VALUE FROM ONTOCHAIN OPEN CALL 2

This deliverable summarizes keys results of the thirteen projects that have been selected during the OC2. The results are extracted from the final deliverable D4 of each project.

For each project, the following information are provided:

- The key functional results and the most relevant KPIs.
- The innovations achieved and the possible future improvements.

The most relevant results of each project are described in relation to KPIs that are categorized as follows:

- KPIs related to interoperability and standardization, including the use of standards in the solutions, the possibility to propose new standards from the solutions.
- KPIs related to the innovation in semantics and blockchain, including the eventual patentability of new innovative proposals.
- KPIs related to a more human-centric evolution of the Internet, including the privacy / anonymity of the solution.
- KPIs related to a more decentralized NGI, from the application point of view or from the data point of view.
- KPIs related to new forms of interaction and immersive environments for NGI users, including new interaction paradigms and new kind of applications.
- KPIs related to the implementation, including code simplicity and testability coverage.

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ONTOCHAIN Open Call 2		
Total number of project selected	13	
Total number of long projects (10 months)	6	
Total number of short projects (5 months)	7	
Total number of projects selected by topics		
Topic 1: Decentralized Oracles for ONTOCHAIN	2	
Topic 2: Market Mechanisms for ONTOCHAIN	2	
Topic 3: ONTOCHAIN Interoperability & API Gateways	2	
Topic 4: ONTOCHAIN Network Design and Scalability	2	
Topic 5: Semantic Based Marketplaces for ONTOCHAIN	2	
Topic 6: Data Provenance in ONTOCHAIN	2	
Open Topic	1	
Selected third parties profile		
Group of individual(s) and organization(s)	1	
Group of individuals (team)	0	
Group of organizations (consortium)	7	
Single organization (legal entity)	5	
Countries represented among the third parties selected		
Spain	4	29%
Germany	2	14%
Italy	2	14%
The Netherlands	1	7%
Slovenia	1	7%
Estonia	1	7%
Poland	1	7%
France	1	7%
Sweden	1	7%

TABLE 1: ONTOCHAIN OPEN CALL 2 RESULTS.

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Topic	Proposal
Topic 1: Decentralized Oracles for ONTOCHAIN	○ **DESMO-LD** - Decentralized Smart Oracles for Trusted Linked Data (LONG) ○ **ADOS** - AirChain Decentralized Oracle System: an advanced AI-based oracle system for securing offchain IoT data integrity when injecting in the blockchain (SHORT)
Topic 2: Market Mechanisms for ONTOCHAIN	○ **PRINGO** - Private Incentives for Common Goods (LONG) ○ **CARECHAIN** Supporting CARE through micro-insurances using blockchain (SHORT)
Topic 3: ONTOCHAIN Interoperability & API Gateways	○ **PXC** - Perun-X: Efficient Cross-Chain Infrastructure for ONTOCHAIN (LONG) ○ **MFSSIA** - Multi-Factor Self-Sovereign Identity Authentication (SHORT)
Topic 4: ONTOCHAIN Network Design and Scalability	○ **OntoSpace** - A stable, scalable, efficient, and cost-effective network for OntoChain (SHORT) ○ **GEONTOLOGY** - A geo-aware network protocol for for enabling trustable cross-border operations and data exchange in a global digital economy (LONG)
Topic 5: Semantic Based Marketplaces for ONTOCHAIN	○ **DKG** - Decentralised and Scalable Knowledge Graph Economy Tools Supporting the "Trusted, traceable and transparent ontological knowledge on blockchain - ONTOCHAIN" (LONG) ○ **BOWLER** - Blockchain-Oriented Warehouse & Low-Code Engine and Reasoner (SHORT)
Topic 6: Data Provenance in ONTOCHAIN	○ **PS-SDA** - Provenance services with Smart Data Agreements (LONG) ○ **NFTWATCH** FOR ONTOCHAIN (SHORT)
Open Topic	○ **NFTSwap** - Bull-Bear-Token as Price-Building-Mechanism for Asymmetric NFT-Markets (SHORT)

TABLE 2: SELECTED PROJECTS PER TOPICS OF ONTOCHAIN OPEN CALL 2.

3 DETAILED IMPACT CREATED BY OPEN CALL 2 RESULTS

In this section, we presents the keys results and the most relevant KPIs of each project, as well as their main innovation and the possible future improvements.

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3.1 DESMO-LD

Funded in: Open Call 2 - Topic 1
Duration: 10 months
Description: DESMO-LD aims to provide a fully integrated distributed solution for consuming IoT external data, enriched with Web of Things semantics and data model, inside the ONTOCHAIN. This addresses the call's objectives of designing new trustful decentralized Oracles to poll semantic data from off-chain data sources. Besides, DESMO-LD introduces novel strategies to solve the above mentioned problems thanks to the heavy deployment of standard ontology and semantic oriented consensus algorithms for data quality and trustworthiness.

3.1.1 Key results and Relevant KPIs

The keys results and relevant KPIs of the DESMO-LD project are the following:

- Related to the interoperability and standardization

a) It is planned to provide support for different blockchains and allow IoT querying from contracts on one chain to TDDs registered in another.
b) The architecture is generic enough to be reused in different blockchain technologies. However, the implementation is bound to iExec platform.
c) DESMO-LD is in the process of being developed inside the W3C Web of Things Discovery standard.

- Related to the innovation

It is possible to interact with external IoT resources from smart contracts.

- Related to a more human-centric evolution of the internet

a) The size of decentralized storage depends on the number of registered TDDs.
b) The solution is still in development and resulting in one demo application that serves also as a front end.

- Related to a more decentralized NGI

Using the Thing Description DESMO-LD allows users to describe complex relations between devices and abstract real-world systems.

- Related to new forms of interactions

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The DESMO-LD decentralized application can be used to query registered devices. Those devices might be electric vehicles or energy meters.

3.1.2 Innovation and Possible Evolutions

The **key innovations** of the DESMO-LD are the following:

- The solution exploits W3C Web of Things standard ontology to describe devices. Thanks to the highly protocol agnostic descriptive nature of the WoT ontology, the system has the potential to onboard a wider number of IoT solutions compared to its competitors.
- WoT, as an open standard, reduces the risk of a siloed Oracles solution with a high registration implementation cost.
- The employment of the WoT interaction model which can open new applications for Smart Contracts. The WoT interaction model gives the ability to directly control real world devices through the "invokeaction" operation. This aspect is usually neglected when it comes to Oracle design and implementation because serving sensor or telemetric data is more profitable.
- DESMO-LD system includes support for spatial queries that connects directly with WoT ontology metadata.

Some of the **possible evolutions** of DESMO-LD include:

- Introducing a sophisticated machine learning technique to analyze the retrieved data in the validation algorithm that could improve the quality of data.
- Improving the frontend with default ontologies for the common use cases.
- Asking the oracle network to keep track of a particular sensor value during a period of time.
- Invoking an action on a device or a group of devices.
- Integrating the token economics with the ONTOCHAIN token and services.
- Improving DApp and Desmo SDK command line access with detailed help messages and usage information.

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3.2 ADOS

Funded in: Open Call 2 - Topic 1
Duration: 5 months
Description: ADOS aims at developing an advanced solution for a distributed system of oracles in IoT scenarios. IoT sensors present some promising options to improve security, reliability, and authenticity of the information provided by oracles, to be explored via cutting-edge technologies like Artificial Intelligence thanks to anomaly detection, for instance, and the application of advanced identity verification procedures for each particular IoT device. ADOS provides ONTOCHAIN with an oracle solution which increase the reliability, the security and the authenticity of any information injected to the ledger.

3.2.1 Key results and Relevant KPIs

The keys results and relevant KPIs of the ADOS project are the following:

- Related to the interoperability and standardization

AOM (ADOS Ontology Model) has been proposed as a new setup of ontologies for AI distributed computing with IoT-based data.

- Related to the innovation

As new innovative ONTOCHAIN use case, the implementation of AOM is used for distributed AI computing in the Blockchain by using iExec.

- Related to a more decentralized NGI

AirTrace platform, as a Blockchain of IoT platform can inherently work as a digital-twin enabler where added values like blockchain are offered.

- Related to new forms of interactions

An architecture that supports distributed computation of GNN-based (Graph Neural Networks) models for anomaly detection in Blockchain of IoT scenarios has been implemented.

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3.2.2 Innovation and Possible Evolutions

The **key innovations** of the ADOS are the following:

- A protocol that integrates Graph Neural Networks for Anomaly Detection capabilities in a distributed oracle system of Workers in iExec platform, leveraging correlations between different sensor measurements in IoT Networks to spot potential anomalies.
- Capturing complex inter-sensor relationships and detecting and explaining anomalies which deviate from these relationships by using AI-based technologies that can exploit underlying, non-visible properties of sensors that typically correlate when these anomalies show up.
- A specific protocol to regularly update the model weights as well as necessary metadata according to continuous AI model training and its subsequent storage in IPFS and/or S3, from which model parameters are taken by the pool of workers.

Some of the **possible evolutions** of ADOS include:

- Keeping evolving the technology with direct customers to improve the value proposal of ADOS via OKR (objective key results), as a high-level strategy alignment for the company, as well as a reinforced SCRUM-based methodology using JIRA Software. A project manager (José María López) and a Full-stack developer (Andrés Ruiz) have been hired to evolve the platform faster while documenting all changes in the platform.

3.3 PRINGO

Funded in: Open Call 2 - Topic 2
Duration: 10 months
Description: PRINGO will provide a platform aimed at escaping from this curse in certain digital industry verticals, by realigning incentives in common goods economies so that private agents obtain benefits as significant as in private goods markets if their actions provide real value to the commons. The projects initial focus is to develop a robust link between common goods and the videogames industry. As the 2021 boom in Non-Fungible Tokens (NFT) proved, users love owning digital assets (a song, a sword in a videogame), and trading them in decentralized open markets. The rules that govern these markets are public (based on open-source code deployed to a blockchain), allowing entire decentralized economies to be built around them.

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3.3.1 Key results and Relevant KPIs

The keys results and relevant KPIs of the PRINGO project are the following:

- Related to the interoperability and standardization

A Decentralized Autonomous Organization governance layer, called molochDAO, has been deployed to define a governance layer.

- Related to the innovation

a) The following new use cases have been implemented: improve financing, mixed NFTs that incorporate video game properties and real-world assets, and the governance layer to manage and control the operating rules of the platform.
b) Living Assets that is a layer-2 technology by Freeverse.

- Related to a more decentralized NGI

The new decentralized publishing platforms that have been implemented are a DAO, a Marketplace and a Dashboard.

- Related to new forms of interactions

a) The Governance layer aligns the interests of the parties and ensures that the minting of NFTs and the updates or evolution of their attributes are carried out according to the rules.
b) The platform offers applications that can be used in any sector or business model that takes advantage of the potential of living NFTs and requires a layer of governance.

3.3.2 Innovation and Possible Evolutions

The **key innovations** of the PRINGO project are the following:

- Rethink new economic models by designing a platform that allows applications to easily construct models with private incentives aligned with those of the commons and by exploring how to use tokenomics-based mechanisms through a layer of decentralized government.
- Onboarding new stakeholders such as the common goods curators.
- New market mechanism to generate new incentives through the direct sale of digital NFTs representing their curated assets, through fees on the second-hand market, drive long-term care by evolving the NFT in line with actual developments.

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- Incorporate a layer 2 scaling solution named Freeverse to manage NFT minting, updating and evolution workflows.
- Improved scalability to support millions of daily active users with constantly evolving NFTs.
- Analyze the viability and potential of real-world assets.
- Represent real and unique value of NFTs by maintaining a link of the NFT property values to the real-world asset it represents.
- NFTs evolution properties, *e.g.* to mimic changes in the actual physical asset such as improvement, deterioration, etc.
- Governance layer based on decentralized autonomous organizations (DAO) enabling a community control to ensure the creation of NFTs in an ethical manner and guarantee the sustainability of the game.
- Allow other platforms, solutions or technologies to leverage the platform's functionalities. The proof of concept has been able to validate the ease of integration with Metaverso, generating new opportunities for technological development.

Some of the **possible evolutions** of PRINGO include:

- Developing the functionality to export NFTs to other platforms.
- Taking advantage of the functionalities of the smart contracts deployed in layer 1.
- Developing an end-user applications.
- Improving several features such as UI/UX, MultiUniverse - login and link email, notifications to the members, force change metamask network or a warning message, etc.
- Developing new functionalities of the governance layer, *e.g.* submitWhitelistProposal / submitGuildKickProposal, processWhitelistProposal / processGuildKickProposal, ragekick / withdrawBalances, etc.

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3.4 CARECHAIN

Funded in: Open Call 2 - Topic 2
Duration: 5 months
Description: Some micro-insurances are based on parametric triggers for quick payouts depending on measurable factors, e.g., policies for farmers based on damage a particular type of crop is likely to suffer under specific conditions; when those are met, the farmer receives compensation. CARECHAIN aims to build an online platform and an environment for the execution of smart contracts for contracting and managing parametric micro-insurances. To this end, CARECHAIN will leverage results from research in DLTs, including blockchain, DAGs/tangles and oracles.

3.4.1 Key results and Relevant KPIs

The keys results and relevant KPIs of the CARECHAIN project are the following:

- Related to the interoperability and standardization

a) Smart Contracts from Carechain are developed with Solidity, so it allows to work with all technologies that work with this technology and several consensus protocols.
b) Carechain uses two Ethereum Standards and update it with new functionalities (ERC735, ERC930).

- Related to the innovation

a) A DLT platform has been created for the contracting and management of parametric microinsurance.
b) The new technology ADOS is used to verify trustness from sensors.

- Related to a more human-centric evolution of the internet

a) Trust is necessary in Carechain project as there are economic and insurance exchanges where it requires special attention. To ensure that the values received from the sensors are correct, the ADOS technology is used. It identifies erroneous values or attacks on the sensor system via an artificial intelligence system.
b) All private data of both insurers and users is not stored in public storage or distributed ledger, in order not to store any sensitive data in blockchain. In a future evolution, it is intended to work with personal data in distributed ledger.
c) Two applications have been deployed.

- Related to a more decentralized NGI

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An application for a real-world use case has been implemented to digitally represents a physical insurance contract.

- Related to new forms of interactions

a) An environment has been designed and implemented to execute smart contracts for parametric microinsurance based on the distributed ledger. This guarantees to users the application of coverage when meeting contract conditions.
b) Microinsurances and similar financial operations are one of the most security and trust demanding sections for online operations, creating a platform for microinsurance contracting and managing automated service, with security, traceability and trust using DLT technologies.

3.4.2 Innovation and Possible Evolutions

The **key innovations** of the CARECHAIN are the following:

- Carechain allows the dynamic creation of both clause templates with specific clauses being a fully dynamic application and applicable to any use case of insurance companies, it can even be fully compatible with legal contracts.
- Smart Contracts dynamically create insurance through clauses of a legal insurance contract defined in the Smart Contracts. Smart Contracts will be the reflection in the virtual world of a parametric microinsurance itself.
- Oracles are used for ingesting data from the parameters considered in the clauses defined in the smart contract. This oracle works periodically, changes state and saves this information from the real world in a traceability way in Blockchain.
- A REST API is available for access to the different functionalities that allows exchange information via JSON. This also allows the integration of the platform into Ontochain ecosystem, and third parties will be able to create their own customized apps to access to Carechain.
- A new Insurtech solution that bring users a new way to manage insurances in a more secure and agile way, reducing transaction costs, and eliminating physical displacement of users.

Some of the **possible evolutions** of CARECHAIN include:

- Adding self-sovereign digital identity to the project to allow the automation of signatures between users and to add authentication to the information generated by the sensors.
- Adding a new layer of Smart Contracts that allows the use of parametric micro-

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insurance with private information that can comply with GDPR.

- Introducing mechanisms for the use of cryptocurrencies to automate payments.
- Adding the possibility of converting microinsurance to NFTS.

3.5 PXC

Funded in: Open Call 2 - Topic 3
Duration: 10 months
Description: PXC aims to build a decentralized and trustless channel network in which transactions from one ledger to another can be performed at minimal cost. In addition to this feature, the framework allows for arbitrary logic to be executed within a channel, leading to potential cross-chain contracts and more advanced applications for industry and finance. In this setting, the trust assumptions are minimized and incentives for node operators are carefully designed.

3.5.1 Key results and Relevant KPIs

The keys results and relevant KPIs of the PXC project are the following:

- Related to the interoperability and standardization

a) The project performs payments between different ledgers with a different technology than Interledger.
b) The blockchain needs to be EVM-compatible at the moment and supporting exchange between Non-EVM and EVM-blockchains is planned for the future.
c) Activities are ongoing to standardize state-channel protocols.

- Related to the innovation

a) A bridge between different ecosystems enabling asset and information transfer has been built.
b) It is possible to commercialise exchange of serialised information on a blockchain.

- Related to a more human-centric evolution of the internet

a) The concept or perun - state channel was stated in a scientific paper including provable security.
b) Personal data are neither collected nor stored. The only information needed is the

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blockchain-wallet address which is anonymous by nature.
c) A backend, hub and frontend are implemented and two smart contracts are deployed for each chain.

- Related to a more decentralized NGI

PXC creates state channels for transfering value and information between blockchains that is temper- and censorship-proof.

- Related to new forms of interactions

PXC application involves human interaction in the field of interoperability and finance.

3.5.2 Innovation and Possible Evolutions

The **key innovations** of the PXC are the following:

- A scalable layer 2 for ONTOCHAIN and other ecosystems such as Hyperledger Fabric.
- A secure, scalable and open cross-chain layer to connect ONTOCHAIN with other ecosystems and vice versa.
- A demonstrator showcasing cross-chain token swaps.
- A simplified API allows developers to utilize state channels for web and mobile applications as well as cross-chain transactions.

Some of the **possible evolutions** of PXC include:

- Horizontally scaling the solution to non-EVM-compatible blockchain systems.
- Vertically scaling the solution to the internet of things space and hence make it available for machine-two-machine communication.
- Extending the demonstrator by additional backends.
- Implementing a so-called multi-hub integration to allow the interaction of several different hubs in the DApp competing for end-users and is de-facto a further decentralization of the product.
- Making all of the developed and described progress available on the mainnets.

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3.6 MFSSIA

Funded in: Open Call 2 - Topic 3
Duration: 5 months
Description: MFSSIA offers an alternative to public key infrastructures called Authcoin, using customizable challenges and Multi-Factor Authentication (MFA) and blockchain technologies for storing authentication-related data, and hence provide transparency, trustworthiness, and immutability of data.

3.6.1 Key results and Relevant KPIs

The keys results and relevant KPIs of the MFSSIA project are the following:

- Related to the interoperability and standardization

a) The MFSSIA system is implemented in Ethereum with proof of work and integrates iExec oracles proof of contribution.
b) IEEE Blockchain leads several standardization efforts for blockchain and it is aimed to propose new MFSSIA relevant initiatives.

- Related to the innovation

a) New innovative ONTOCHAIN reasoning technologies is given with the challenge/response-lifecycle evaluation in MFSSIA.
b) The MFSSIA implements a novel application of DKG-based semantics capturing for cases that require MFSSIA for trust establishment and also for expressing respective challenges.

- Related to a more human-centric evolution of the internet

a) Privacy is achieved by hashing all exchanged data between MFSSIA, the oracles, and DKG instances.
b) Many GB of decentralized storage could be consumed in case of heavily diffusion of MFSSIA.
c) With the elaborate running case previously defined, the number of potential number of potential MFSSIA applications is large.

- Related to a more decentralized NGI

a) A challenge-set marketplace could be considered as a type of new social network that has been tentatively implemented.

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b) A start of implementation of a new decentralized publishing platform for the challenge sets has been done.
c) The partnering with ADOS in the IoT domain can apply to the project.

- Related to new forms of interactions

MFSSIA is an implementation for the domain of identity. In future works, MFSSIA can be applied in use cases for other domains such as education, energy, finance, etc.

3.6.2 Innovation and Possible Evolutions

The **key innovations** of the MFSSIA are the following:

- The challenge/response-lifecycle evaluation with the use of decentralized knowledge graphs and blockchain oracles.
- The creation of a challenge-set marketplace.
- The identity authentication system is designed to scale without the state-of-the-art limitation (currently, less than 5 challenges).
- The integration of iExec oracles allows for the quick supply of evaluation data for the challenge responses.
- Collecting the distributed data sources for posing a challenge and also for the evaluation with the automating means of blockchain decentralized knowledge graphs and oracles, promises to save a lot of time and costs versus conventional human-driven bureaucratic means.

Some of the **possible evolutions** of MFSSIA include:

- Integrating with other existing ONTOCHAIN projects such as ADOS to provide trust between devices integrated into IoT during subsequent lifecycle and PiSwap to determine the legitimate origin of a respective NFT.
- Being a key DApp for enabling Web3 by providing the ability of self-sovereign identity authentication in crypto-wallets.
- Producing an open-access journal paper that explains the position of MFSSIA in the rising machine-to-everything (M2X) economy. MFSSIA can establish trust in individualis, organisations and devices/systems in M2X economy.

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3.7 ONTOSPACE

Funded in: Open Call 2 - Topic 4
Duration: 5 months
Description: Ontospace aims to deliver a stable, scalable, efficient and cost-effective network for Ontochain built on the foundations created in the project GraphChain (OC1) and on the internal projects of the consortium members related to graph databases, semantic web solutions, and blockchains. The project aims to create a new kind of Ethereum client, a collection of high-performance services, a tightly integrated property graph engine, and a set of architectural rules enabling the construction of the third generation blockchain ecosystem.

3.7.1 Key results and Relevant KPIs

The keys results and relevant KPIs of the Ontospace project are the following:

- Related to the interoperability and standardization

a) The current EVM modification is compatible with all possible smart contracts and consensus protocols, since only one opcode was changed.
b) In the future, the Interwoven hash standardization is planned to be proposed.
c) Future standards are discussed in the W3C Read Write Web Community Group that potentially uses them.

- Related to the innovation

New Vicious Circle Free Interwoven Hash algorithm for RDF graphs written for Java used to prove immutability of graphs stored in Graphchain system.

- Related to a more human-centric evolution of the internet

a) New version of Graphchain is developed with authentication based on Metamask plugin that is using Ethereum accounts as a method of authenticating users, thus only users public key may be exposed to the world.
b) The size of storage in Graphchain solution is limited only by the capacity of Blazegraph (the triplestore of choice used Graphchain) which is about 50 billion triples on single machine. Note that Graphchain can be horizontal scaled.
c) Two applications have been deployes: Ontonode the core part of Graphchain solution and VCFIH new version of Interwoven Hash algorithm with protection against Vicious Circles.

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- Related to a more decentralized NGI

Graphchain is a distributed graph database protected by blockchain mechanisms that not only guarantees immutability and security of the data but also allows to use load balancing on multiple nodes to improve performance.

3.7.2 Innovation and Possible Evolutions

The **key innovations** of the Ontospace are the following:

- The creation of a blockchain solution for the storage of graph data - most importantly without the use of oracles.
- The use of a modified Besu client, which through the introduction of a new opcode allows to achieve oracle less state while maintaining compatibility at the level of protocols.
- The introduction of a new hash algorithm, which is a significant improvement in relation to the previously used solutions.
- A mechanism of graph synchronization is introduced and enables to reduce the required server resources needed to smoothly carry out the entire process - this is especially important in the case of graphs containing a lot of data.
- The authentication mechanism based on MetaMask is introduced. It is a recognized and valued solution that allows us to guarantee uniqueness, security and accessibility for the user from the functional side. The use of MetaMask is also closely related to the roles that users can play within the created ecosystem.

Some of the **possible evolutions** of Ontospace include:

- Introducing of the tokenization system. Due to the depegging of stablecoins, it is interesting to know the safe ways of tokenization projects and the solutions they offer.
- Testing blockchains whose purpose is to process and store data. These blockchains are based, among others, on consensus algorithms such as Proof of Storage and Proof of Space.

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3.8 GEONTOLOGY

Funded in: Open Call 2 - Topic 4
Duration: 10 months
Description: GEONTOLOGY proposes a protocol called Proof of Offset (POO) which enables higher data access control by geolocation, accountability and data exposition minimisation. Thereby, GEONTOLOGY brings new opportunities for data security and privacy management, such as users awareness, via allowing to Apps to use this protocol/service to inform about the real country of origin for a data portability/exchange transaction request. The potential uses and benefits from POO are envisioned as a core component for any networking architecture of the Next Generation Internet, e.g. DLT/blockchain, and beyond 5G.

3.8.1 Key results and Relevant KPIs

The keys results and relevant KPIs of the GEONTOLOGY project are the following:

- Related to the interoperability and standardization

a) Contribution to the Proof of Offset algorithm and integration with smart data models in FIWARE.
b) Participation in ETSI NGSI-LD (data models) and IEEE P2510 (IoT data access and quality).

- Related to the innovation

The new use case of Geolocation verification as a service has been implemented.

- Related to a more human-centric evolution of the internet

a) Over 90% classification capacity for country-level geolocation is possible.
b) Two applications have been deployed: geolocation of monitors and access for data spaces.

- Related to a more decentralized NGI

GEONTOLOGY empowers service users to check that the declared location of services matches reality, hence improving the overall trust and reliability of applications in the Next Generation Internet.

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3.8.2 Innovation and Possible Evolutions

The **key innovations** of the GEONTOLOGY are the following:

- Innovative Geolocation verification algorithm enabling 2 phases solutions which goes from country level (phase 1) to city level (phase 2).
- The algorithm is network agnostic and is highly reliable over fibre, cellular, wired and wireless networks.
- The algorithm is highly scalable for a global scale working over network layer, compared to other proof of location services based on MAC layer (level 2) which limits the solution to a coverage area.
- The integration into FIWARE ecosystem is enabling a unique opportunity to be exploited in several DLT networks.

Some of the **possible evolutions** of GEONTOLOGY include:

- Focusing on GAIA-X and Data Spaces market opportunities, as geolocation constraints are part of the regulations and services agreements.
- Integrating GEONTOLOGY as part of the IDSA connector and the data spaces implementation of FIWARE.

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3.9 DKG

Funded in: Open Call 2 - Topic 5
Duration: 10 months
Description: OriginTrail Decentralized Knowledge Graph (DKG) harnesses the power of two technologies, blockchain and knowledge graphs, to enable turning data into assets and making those assets discoverable, verifiable, and valuable. Currently supported by an open network of over 2.500 nodes hosted by both individuals and businesses globally, the DKG has been deployed in a variety of industries, ranging from compliance to pharmaceuticals. Building upon ONTOCHAIN infrastructure components, the core development team of OriginTrail, Trace Labs, has expanded the core functionality of the DKG in the ONTOCHAIN project to: ○ Align it entirely with ONTOCHAIN core protocol functionalities (identity management and authorization, secure decentralized data storage, certification, and knowledge graph semantic services such as verifiable data linking using cryptographic connectors). ○ Introduce a set of service-layer applications as a toolkit for builders of applications known as Knowledge Incentivisation Tools (kTools for short).

3.9.1 Key results and Relevant KPIs

The keys results and relevant KPIs of the DKG project are the following:

○ Related to the interoperability and standardization

a) kTools are generic tools that work with OriginTrail DKG and can as such be deployed in any EVM-compatible blockchain that has DKG deployed (currently Ethereum, Gnosis, Polygon and pending deployment on Polkadot).
b) In developing kTools further standardized approach of deploying them will be proposed through OriginTrail public RFCs (request for comments) documentation. Further standardization efforts can then be pursued in W3C/GS1 and similar organization.

○ Related to the innovation

a) The following new use cases have been implemented: Linked Data, Peer-to-peer information sharing and autonomous communication systems.

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b) The immutable linked data sharing as well as Fairswaps verifiable exchange mechanisms have been included in the implementation of the OriginTrail DKG.

- Related to a more human-centric evolution of the internet

a) The specific tools developed through ONTOCHAIN project rely on trusted technologies and standards such as W3C DIDs, RDF and academically reviewed trusted protocols such as Fairswap. The Trust Assessment Effectiveness applies to specific applications utilizing the Ontochain DKG kTools.
b) kTools operate with DID compliance, allowing implementations that protect anonymity of users.
c) The deployed application demonstrates integration of the kTools through a Web3 dapp, as well as integration ability with existing marketplaces (such as Uniswap and NFTSwap of ONTOCHAIN).

- Related to a more decentralized NGI

a) kTools developed within ONTOCHAIN are driving more knowledge publishing to the OriginTrail DKG a decentralized network for publishing and monetizing knowledge.
b) The developed knowledge tools have been built to work with the new version of OriginTrail DKG which introduces a concept of UAL (universal asset locator) allowing identification of any asset, both physical or digital.

- Related to new forms of interactions

a) kTools improve the ownership experience for anyone owning an asset in the Internet by allowing them to store (kWallet), monetise (kTokens, kMarketplace) or obtain it (kTenders).
b) kTools are fully compatible with all implementations on the OriginTrail DKG which include healthcare, interoperability, social impact and supply chain.

3.9.2 Innovation and Possible Evolutions

The **key innovations** of the kTools developer tool stack are the following:

- New innovative Ontochain use cases based on trusted data exchange and monetization, provided through a toolkit known as Knowledge Tools.
- Novel approach for data resources price discovery utilizing market forces through tokenized data assets.
- Novel approach for data discovery and requests based on a Knowledge Tender market mechanism.

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Some of the **possible evolutions** of kTools include:

- Implementing kTools-based applications on the new version of OriginTrail DKG with planned release in 2022 on Polkadot and the OriginTrail Parachain.
- Engaging the OriginTrail community to test and make use of the kTools code for their experimentation and implementations.
- Ensuring composability with other Web3 solutions (*e.g* Ontochains NFT Swap, Ocean protocol, DeFi tools, etc.).
- Improving the developer experience to make it easier for implementation and extension with use of code scaffolding tools and improved documentation.

3.10 BOWLER

Funded in: Open Call 2 - Topic 5
Duration: 5 months
Description: BOWLER implements an innovative, low-code, end-to-end, web-enabled, integrated development environment (Web-IDE). With BOWLER application programmers who are not well-versed in blockchain technology can model smart-contract enabled applications and generate code automatically. BOWLER can also assists in testing and quick deployment and delivery to the clients. In ONTOCHAIN, BOWLER will be tailored to support setting up decentralized marketplaces (including their underpinning mechanisms) and non-fungible token (NFT) dApps.

3.10.1 Key results and Relevant KPIs

The keys results and relevant KPIs of the BOWLER project are the following:

- Related to the interoperability and standardization

a) Smart contracts have implemented for Solidity (Ethereum) and Hyperledger.
b) Extensions to the OASIS TOSCA have been proposed.
c) The project has been presented in IEEE International Conference on Software Architecture workshop on Foundations of Infrastructure Specification and Testing and TOSCA Monthly Meeting (March 2022).

- Related to the innovation

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a) Smart contracts with external oracles (iExec) in NFT settings have been integrated in the project, using low-code IDE devops for festival NFTs.
b) RDF/OWL has been implemented to render NFT smart contracts as a baseline for reasoning/discovery.
c) A new model-driven approach to annotate basic SOLIDITY code with semantics in RDF has been developed.
d) The semantic engine can serve as the baseline to model and store ontologies as NFTs.

- Related to a more human-centric evolution of the internet

The BOWLER IDE can be used to compose and deploy dApps.

- Related to a more decentralized NGI

a) Smart contracts composed with blueprints in BOWLER can be applied for decentralized services and data products.
b) Decentralized social networks could in concepts be composed with blueprints in BOWLER.
c) Decentralized publishing platforms could in theory be composed with blueprints in BOWLER.
d) Digital twins (via NFTs), and particularly back-end services and dApps can be partially realized with blueprints in BOWLER.

- Related to new forms of interactions

a) UI dev is based on the Web3.0 paradigm and interactions are possible with browser-based GUI and mobile devices.
b) Real-world NFT ticketing solutions for the leisure industry have been implemented.

3.10.2 Innovation and Possible Evolutions

The **key innovations** of the BOWLER are the following:

- BOWLER will enable application programmers who are not well-versed in blockchain technology (and smart contracts) to model smart-contract enabled applications, whilst BOWLER takes care of code generated and quick deployment and delivery to their clients.
- BOWLER is instrumented with semantically enriched SOLIDITY modelling facilities that will enable reasoning about models, reuse of pre-existing dApps/smart contracts (as blueprints), and improved search facilities.
- BOWLER experiments with a radically new tokenized business model that will al-

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low ONTOCHAIN participants and clients to influence the future development of BOWLER, and get access to the BOWLER, promoting a win-win model for BOWLER and the ONTOCHAIN ecosystem at large.

Some of the **possible evolutions** of BOWLER include:

- Extending our IDE with advanced, automatic testing capabilities to check consistency and correctness of smart contracts using automated tests (and test cases). Testing will include not only contract verification, but also regression testing scenarios to improve BOWLERs power in real-world dApp settings.
- Developing a multi-cloud deployment and redeployment module, including a monitoring facility, to optimize the performance of smart contracts along a series of policies (environmental, security, scalability/performance).
- Extending the semantic engine: the BOWLER ontology so that it is capable of dealing with the full range of smart contracts, a semantic reasoning (including blueprint composition and decomposition) to further benefit from the semantic annotation approach implemented in the current version of the BOWLER and a template marketplace where users and other stakeholders can contribute and monetize their work and by that greatly expand the value offered by the platform.

3.11 PS-SDA

Funded in: Open Call 2 - Topic 6
Duration: 10 months
Description: The PS-SDA software stack implements the Data Exchange Agreement (DEXA) protocols. It uses emerging messaging standards based on DIDComm[2] that provides a secure, private communication framework built on top of Decentralised Identifiers (DIDs). The DIDComm Messaging defines how messages are composed into the larger primitive of application-level protocols and workflows while seamlessly retaining trust. Any Data Intermediary (e.g. iGrant.io) can adopt DEXA protocols to serve a marketplace.

3.11.1 Key results and Relevant KPIs

The keys results and relevant KPIs of the PS-SDA project are the following:

- Related to the interoperability and standardization

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a) Two consensus mechanisms are used: proof authority (Indy/EBSI) and proof of work (Ethereum).
b) The data agreement (DA) schema is standardized as part of ISO 27560 and driven via DIF Data Agreement WG.
c) Several participation in events: 1) Active in ISO standardization of ISO 27560 in working draft meetings and national vote ballot review, 2) MyData Conference 2022 (21-22 June) in a panel on automation of consent, 3) Round table of COST EU workshop (13-15 June) on privacy issues in distributed social knowledge graphs and 4) RWOT event for standardizing DEXA protocols.

- Related to the innovation

a) Data provenance resulting in legal compliance and digital rights management apart from automated DDA signing from a decentralized marketplace/dataspace.
b) The project implements immutable data exchange records for provenance.

- Related to a more human-centric evolution of the internet

a) Every DA is signed by the data sources (DS) and is tied to a legal basis, enabling full transparency and control.
b) A data protection impact assessment (DPIA) is built into creating a DA.
c) BBS+ algorithms during data exchange encryption.
d) The decentralized storage includes 100s of agents, each 0.5 GB in size.
e) 18 applications have been deployed, including a full dApp.

- Related to a more decentralized NGI

PS-SDA's major contribution is establishing governance according to data regulations (primarily the GDPR), automating and simplifying the process. The solution proposed is decentralized, building on top of SSI standards.

- Related to new forms of interactions

a) The PS-SDA functionality into an end-user data wallet has been implemented.
b) Two decentralized apps have been implemented (but not on ONTOCHAIN): (1) the data wallet (https://datawallet.igrant.io/) to carry one's personal data and exchange it at ease and (2) Data4Diabetes (https://www.youtube.com/watch?v=nt7VZBoXsvQ) works as a virtual pancreas enabling individuals with diabetes to live without the stress and workload of keeping the blood sugar at bay.

3.11.2 Innovation and Possible Evolutions

The **key innovations** of the PS-SDA are the following:

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- Connecting data provenance to data regulatory compliance, fully auditable using a cryptographic signature.
- Dynamic data sharing agreement handling, enabling a new level of scalability and interoperability: With the DEXA suite, organizations can dynamically sign up with data disclosure agreements (DDAs) without a direct trust relationship with any third party, accelerating the creation of data exchange ecosystems dynamically.
- Reduced governance efforts to establish cross-border data ecosystems like what is being laid out in the European Health Data Space.

Some of the **possible evolutions** of PS-SDA include:

- Bringing forth standards globally via communities such as the Decentralized Identity Foundation (DIF) and the MyData Operator working group.
- Working on the specific use case in the health domain, such as the Data4Diabetes that iGrant.io has already started working on with partners in Sweden.
- Utilizing the power of data provenance via data exchange agreements in establishing a governance framework via data marketplaces or data spaces.
- Introducing a data-sharing dashboard with enhanced customer experience using DEXAs.
- In the context of business processes, the existing decentralized identifier DID:mydata could easily be associated with a digital token in a supply chain to track and verify the exchanged data between DS and data using services (DUS), DUS and another one, etc.

3.12 NFTWATCH

Funded in: Open Call 2 - Topic 6
Duration: 5 months
Description: The NFT market is booming and is lacking both specialised data vendors and data models to analyse it. The information is spread online, onchain, in multiple marketplaces. NFTWATCH is an open-source project aiming to help the collect and aggregation of all NFT related information.

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3.12.1 Key results and Relevant KPIs

The keys results and relevant KPIs of the NFTWATCH project are the following:

- Related to the interoperability and standardization

a) The solution is independent of the implementation of smart contracts.
b) An ontology of NFTs has been delivered trying to integrate all the dimensions of an NFT.

- Related to the innovation

Provide new way of trust in the origin of NFTs via a classification and scoring system.

- Related to a more human-centric evolution of the internet

a) The authenticity of the contents is precisely scrutinized by the solution. Furthermore, a clear separation between metadata from the marketplace, the blockchain and those created by NFTWatch is maintained. In particular, NFTWatch checks that the data displayed by the marketplaces are corroborated by the blockchain.
b) The solution deals with public data.
c) One application has been deployed.

- Related to a more decentralized NGI

Several decentralized evolution for the solution have been considered such as decentralised computing technologies for storing and accessing data, decentralised social networks and decentralised publishing platforms.

- Related to new forms of interactions

NFTWATCH enables more trusted interactions in decentralized marketplaces by providing buyers with factual data about the available assets.

3.12.2 Innovation and Possible Evolutions

The **key innovations** of the NFTWATCH are the following:

- NFTWatch is a data aggregator capable of consolidating "offchain" data from marketplaces, social networks, and the digital work itself, and "onchain" data collected on the blockchain, such as the code of the smart contract, the list of purchase/sale transactions taking place or the addresses of the wallet interacting around the NFT.

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- NFTWatch can send data to algorithms that can automatically classify the work, calculate confidence scores in the origin of the NFT or analyze the quality of its code.
- The solution has its place with all market players, such as a large CAC40 group looking to prepare its first NFT launch, an investor wanting to estimate the real value of its NFT portfolio, or a high-end marketplace concerned with offering only trusted NFTs.

Some of the **possible evolutions** of NFTWATCH include:

- Improving the NFT classifier to facilitate the analyze and tag processes of artwork.
- Improving the calculation of the confidence score by including the transaction criteria for example.
- Aggregating more marketplaces and more blockchains in order to provide the largest NFT search platform.
- Using a decentralized storage system.
- The commercial development of the platform is envisaged.

3.13 NFTSWAP

Funded in: Open Call 2 - Open Topic
Duration: 5 months
Description: NFTSWAP (or PiSwap) allows users to instantly buy and sell NFTs by swapping them with a smart contract, very similar to UniSwap. This is achieved in two steps. A liquidity provider can open a market for a specific NFT. It allows investors to participate in the market for the underlying NFT by betting on its price development. Through this mechanism investors can participate in NFTs that are either very illiquid or too expensive to participate in. Lastly, this mechanism sets a price for the NFT that is currently accepted by the market.

3.13.1 Key results and Relevant KPIs

The keys results and relevant KPIs of the NFTSWAP project are the following:

- Related to the interoperability and standardization

a) Projects can read the on-chain data.

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b) Protocols can use on chain decentralized protocols.
c) A standard/draft could be proposed depending on the market adoption.

- Related to the innovation

The protocol is an evm-agnostic layer 1 technology.

- Related to a more human-centric evolution of the internet

a) There is no self-created content and the accuracy for subjects is provided by on-chain-data.
b) It is a blockchain application and access is granted via Web3 authentication.
c) The decentralized storage of NFTSWAP solution is 0.05 GB.
d) One application has been deployed.

- Related to new forms of interactions

The protocol is able to predict unpriced assets by using crowdsourced sentiments. This is not limited to financial instruments but to almost any digitized asset. Setting up new prediction markets it is very important to incentivize prediction participants in a suitable and market addressing matter.

3.13.2 Innovation and Possible Evolutions

The **key innovations** of the NFTSWAP are the following:

- New way of prediction in unpriced asset markets.
- The protocol creates separated two-sided markets for each single asset: splitting items of interest into separately and inverse tradable bull-bear-token-pairs. It is the first protocol offering this approach and is highly inspired by the older and closed-end Augur-protocol or the Balancer-approach.
- Almost any digitized prediction-market could benefit by the deployed tool.

Some of the **possible evolutions** of NFTSWAP include:

- Integrating metaverses and its items would improve the scope of usage and the market acceptance.
- Integrating customized smart contracts will enable the users of the protocol in setting up customized markets with customized incentives for participation.
- Supporting additional chains due to the evm-agnostic protocol approach. Beside the Ethereum chain the protocol is able to be deployed on Avalanche, Finance Smart

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Chain, Fantom, Harmony, Polygon and others based on the EVM-code.

4 SUMMARY OF OPEN CALL 2 IMPACT

N°	KPI	Target	Current value
1.1	Trust Assessment Effectiveness, e.g. accuracy for subjects or for content.	Accuracy: 97%	Correctness and authenticity of data (CARECHAIN, NFTWATCH), provable security (PXC), 90% country-level classification capacity (GEONTOLOGY), trusted technology, standards, academic review (DKG), signature and legal basis of the data sources (PS-SDA)
1.2	Privacy/anonymity metrics, e.g. effective anonymity set size, entropy, inference probability, differential privacy guarantees.	Probabilistic Inference for Specific Subjects < 1/1000	private data exchanges (MFSSIA, PS-SDA, PXC), user anonymity and authentication (PXC, DKG, Ontospace), no recording of private data (PXC, CARECHAIN)
1.3	Number of of zero knowledge proof protocols	> 1	1 (PS-SDA)
1.4	User satisfaction from ONTOCHAIN fairness: right incentive to contribute and fair remunerations for resource contribution	high	
1.5	GBs of decentralized storage	> 50 TBs	Depend on TDD number (DESMO-LD), many for heavily diffusion (MFSSIA), 100s of agents each 0.5 GB in size (PS-SDA), 0.05 GB (NFTSWAP)
1.6	Number of apps deployed, number of people employing decentralized services, number of people involved in ONTOCHAIN ecosystem	> 5, > 50, > 100 (all until the end of the project)	28 applications (DESMO-LD, CARECHAIN, Ontospace, GEONTOLOGY, DKG, PS-SDA, NFTWATCH, NFTSWAP),

TABLE 3: IMPACT #1: SHAPE A MORE HUMAN-CENTRIC EVOLUTION OF THE INTERNET.

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N°	KPI	Target	Current value
2.1	Trust assessment complexity	Scalable, i.e. Sublinear/Linear to the number of subjects evaluated and/or info involved, independent from blockchain ecosystem size	Scalable mechanisms: Ados for trustness from sensors (CARECHAIN), scoring system (NFTWATCH), classification for geolocalization (GEONTOLOGY), provable security (PXC), signature and legal basis of the data sources (PS-SDA), standard and academic review (DKG)
2.2	Identity Verification complexity	Independent from the blockchain ecosystem size.	Scalable mechanisms: blockchain-wallet address for authentication (PXC, DKG, Ontospace), MFA (MFSSIA)
2.3	Privacy-aware and secure data exchange complexity	Secure/privacy/cryptographic protocols should not depend on the size of the distributed ledger.	Scalable mechanisms: Hash, encrypt or off-chain data exchanges (MFSSIA, PS-SDA, PXC), no recording of private data (PXC, CARECHAIN), blockchain-wallet address for anonymity (PXC, DKG, Ontospace)

TABLE 4: IMPACT #2: SCALABLE BLOCKCHAIN BASED SOLUTIONS FOR ENSURING TRUSTWORTHY CONTENT AND INFORMATION EXCHANGE.

N°	KPI	Target	Current value
3.1	Interledger APIs	Provide	Web and mobile applications and cross-chain transactions (PXC),
3.2	Allow for different consensus protocols and smart contract implementations	Allow	EVM-compatible (PXC, Ontospace, DKG, CARECHAIN), several smart contract implementations (BOWLER), for several consensus protocols (PS-SDA), independant of the smart contract implementation (NFTWATCH) and (ongoing) being used in different blockchains (DKG, PRINGO), EVM-agnostic (NFTSWAP)
3.3	Number of proposed standards/drafts	>= 3	1 (PS-SDA) and 6 ongoing (DKG, PXC, MFSSIA, Ontospace, DKG, NFTSWAP)

TABLE 5: IMPACT #3: PROMOTING INTEROPERABILITY AND STRENGTHENING THE ROLE OF EUROPE IN INTERNATIONAL STANDARDISATION.

N°	KPI	Target	Current value
A1.1	New innovative ONTOCHAIN use cases	20	13 (provided by the 13 OC2 projects)
A1.2	New innovative ONTOCHAIN energy-efficient reasoning technologies	5	1 (PXC)
A1.3	New ways to serialise ontologies and semantics on blockchain	5	4 (DESMO-LD, ADOS, DKG, BOWLER)
A1.4	Other (unimaginable) new approaches to implement immutable semantics and reasoning	10	2 (DKG, BOWLER)

TABLE 6: ADDITIONAL IMPACT #1: ONTOCHAIN WILL CONTRIBUTE TO THE CATCHING UP PROCESS AMONG EUROPEAN AND INTERNATIONAL INITIATIVES (I.E. BLOCKCHAIN OBSERVATORY, EC BLOCKCHAIN INITIATIVE, NGI, INATBA).

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N°	KPI	Target	Current value
A2.1	Social welfare	positive social welfare	
A2.2	Number of investors/fund raisers interested in the ONTOCHAIN platform	>100	
A2.3	size of professional network engaged in the ONTOCHAIN platform	>100	
A2.4	Number of people following news from ONTOCHAIN platform	>1000	

TABLE 7: ADDITIONAL IMPACT #2: ONTOCHAIN WILL CONTRIBUTE TO THE DELIVERY OF A SUSTAINABLE AND SOCIETALLY-TRIGGERED NEXT GENERATION INTERNET FRAMEWORK TO ENSURE DIVERSITY, PLURALISM AND THE RIGHT TO CHOOSE.

N°	KPI	Target	Current value
A3.1	New decentralised computing technologies for storing and accessing data	3	7 (DESMO-LD, ADOS, PRINGO, CARECHAIN, MFSSIA, GEONTOLOGY, DKG)
A3.2	New decentralised social networks	2-3	
A3.3	New decentralised publishing platforms	2-3	
A3.4	New Digital Twin technologies	2-3	3 (PRINGO, CARECHAIN, NFTWATCH)

TABLE 8: ADDITIONAL IMPACT #3: ONTOCHAIN WILL ASSIST TOWARDS THE AVOIDANCE OF CONCENTRATION OF DATA AND INFORMATION IN A FEW PLATFORMS (FROM AN ECONOMIC AND SOCIETAL PERSPECTIVE).

N°	KPI	Target	Current value
A4.1	Number of of new human to Internet interaction paradigms developed in the use cases of ONTOCHAIN	5	2 (CARECHAIN, GEONTOLOGY)
A4.2	Number of of decentralized apps in ONTOCHAIN that involve human interactions in education, energy, finance, governance, healthcare, identity, interoperability, mobility, privacy, public sector, real estate, social impact, supply chain	10	5 (PRINGO, CARECHAIN, MFSSIA, DKG, PSSDA)

TABLE 9: ADDITIONAL IMPACT #4: ONTOCHAIN WILL PROVIDE NEW FORMS OF INTERACTION AND IMMERSIVE ENVIRONMENTS FOR NEXT GENERATION INTERNET USERS.

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5 CONCLUSIONS

The thirteen projects selected during the ONTOCHAIN OC2 have provided several impacts related to the interoperability, the innovation, a more human-centric evolution of the internet, a more decentralized NGI and new forms of interactions, while addressing the objectives of this call. Indeed,

- for Topic 1, DESMOD-LD and ADOS implement decentralized oracles to assure the high-quality and reliability of off-chain data, one of the objectives for ONTOCHAIN. Moreover, DESMOD-LD could onboard a wider number of IoT solutions thanks to deployment of standard ontology and semantic oriented algorithms, and ADOS uses AI-based anomaly-detection capabilities to enhance data reliability for IoT and any source of data.
- for Topic 2, PRINGO and CARECHAIN provide platforms with an easy procedure and usage for developing unbiased and trustworthy digitized assets, targeting by the ONTOCHAIN project. Moreover, PRINGO provides new use cases with common goods curators and videogame developers, and a governance layer to handle rules of the platform. For Carechain, it enables a dynamic and traceable creation of smart contract that can also be relevant for other use cases (farm and supply chain).
- for Topic 3, PXC and MFSSIA aim the interoperability need for data from different protocols, as expected in ONTOCHAIN, based on a secure cross-chain solution for PXC and a PKI infrastructure for MFSSIA. In particular, PXC enables payments and any logic to be executed in a state channel leading to bridge different ecosystems, and MFSSIA creates challenge/response-lifecycle marketplace that can be used in other domains (education, energy, etc.).
- for Topic 4, Ontospace and GEONTOLOGY present protocols to improve the security and reliability of data storage and data access, one of the challenges presented by ONTOCHAIN. Indeed, Ontospace uses distributed graph database to guarantee immutable and secure data, and GEONTOLOGY implements secure data access control via POO protocol with a classification capacity for country-level and city-level.
- for Topic 5, DKG and BOWLER provide several functionalities for the ONTOCHAIN framework. DKG proposes a toolkit for trusted data exchange and monetization, and BOWLER a Web-IDE to deliver trustworthy and quick deployment of smart contract solutions.
- for Topic 6, PS-SDA and NFTWATCH address one of the ONTOCHAIN objectives of guaranteeing secure and trust data provenance. PS-SDA implements DEXA protocol with standards and cryptographic algorithms according to data regulation, that is scalable and interoperable, and NFTWATCH ensures trust in NFT data collected from marketplace and blockchain via a new classification and scoring system.

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- and for Open Topic, NFTSwap proposes a new way of prediction to make pricing and items more reliable and to provide more transparency for newly minted items. NFTSwap splits items of interest into separately and inverse tradable bull-bear-token-pairs.

Each project also suggests several improvements and possible evolutions such as developing new functionalities or integrating other existing ONTOCHAIN projects.

Three projects (PS-DSA, ADOS, ONTOSPACE) of the Open Call 2 might potentially patent their solution by carrying out further research, features or evolution, and one project (BOWLER) actively studies in detail the process for patenting the solution. Other OC2 projects do not intend to patent their solutions.

Note that, KPIs described in this deliverable have been relevant indicators for projects in OC1 and OC2, and will be also reused for the OC3 projects.

Finally, the solutions provided in this OC2 extend the ONTOCHAIN ecosystem and provides new use cases. The results of the thirteen projects selected in OC2 can be relevant inputs for OC3 projects.

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