Progress towards Federated Logistics through the Integration of TEN-T into A Global Trade Network

D2.15 Integration and Interoperability of proprietary Blockchain Systems for Seamless Global Trade Workflows v1

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1 According to PLANET's Quality Assurance Process

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Glossary of terms and abbreviations used

Abbreviation / Term	Description
EGTN	EU-Global T&L Networks
T&L	Transport & Logistics
LL1	Living Lab 1
LL2	Living Lab 2
UC1	Use Case 1
UC2	Use Case 2
GDPR	General Data Protection Regulation
FA	Fungible asset
NFA	Non-Fungible asset
ILP	Interledger Protocol
ZKPs	Zero Knowledge Proofs
COSSP	COSCO Spain
PoV	Port of Valencia
PoR	Port of Rotterdam
LSP	Logistics Service Provider
PI	Physical Internet
T&L	Transport & Logistics

1 Executive Summary

This deliverable reports on the integration and interoperability of proprietary Blockchain systems that have the potential empower organisations across the entire T&L supply chain to collaborate seamlessly. The report aims to inform any stakeholder or consortium of stakeholders involved or interested in the design of innovative, cross-organisational EU-Global T&L networks, but also any stakeholders interested in the deployment of Blockchain interoperability solutions in T&L or any other field where the use of smart contracts can be applied.

The report presents the design, architecture, interfaces, and initial implementation of the Blockchain 'front end' which will be part of the open cloud based EGTN platform, that aims at unifying multiple back end blockchain systems. The types of data to be exchanged between different Blockchain systems, both static (master) and transactional, are also presented.

The design of the EGTN Blockchain component was primarily influenced by the requirements and business scenarios that were developed during close and frequent interactions with the partners from the Living Labs. The methodology employed involves a thorough investigation of the current state-of-the-art in the emerging topic of Blockchain interoperability and a mapping of the different technological solutions against the PLANET Blockchain requirements.

The EGTN Blockchain component, that is currently under development, aims to highlight the benefits of Blockchain to the Physical Internet (PI) paradigm. These include better tracking of data across T&L networks, safer contract execution through smart contracts and increased security protection through encryption. To add to the above, Blockchain interoperability is a great enabler for the PI, as it offers the ability for existing disparate blockchain systems to interoperate and share data regarding shipping manifests, smart contracts, customs declarations, transport events and so on. In that regard, the nature and ethos of how Blockchain technologies operate can bring huge benefits to cross-organisational T&L networks that wish to take a step closer to the Physical Internet.

2 Introduction

2.1 Mapping PLANET Outputs

Purpose of this section is to map PLANET's Grant Agreement commitments, both within the formal Deliverable and Task description, against the project's respective outputs and work performed.

Table 1: Adherence to PLANET's GA Deliverable & Tasks Descriptions

PLANET GA Component Title	PLANET GA Component Outline	Respective Document Chapter(s)	Justification
DELIVERABLE			
D2.15 Integration and Interoperability of proprietary Blockchain Systems for Seamless Global Trade Workflows v1	Initial design and implementation of the Blockchain 'front end' which will be part of the EGTN platform, that will unify multiple back end Blockchain systems. Specify types of data, both static (master) and transactional for redirection of the common EGTN Blockchain.	Chapters 3-6	Chapters 3 and 5 describe the requirements based on the Blockchain use cases in the LLs. Chapters 4 and 5 cover Blockchain interoperability, which aims at unifying multiple Blockchain systems. Chapter 6 focuses on the Blockchain 'front-end' and the specifications of the data types.
TASKS			
ST2.5.1 Interfaces to multiple Proprietary Blockchain Systems for Seamless Global Trade	This task focuses on the need for EGTN actors to share data and functionality in order to operate in unified and consistent ways.	Chapters 4 (4.4), 5 (5.2)	Chapter 4 covers Blockchain interoperability, while section 4.4 presents the technological framework that was chosen, so that actors can share functionality in a unified manner. Chapter 5 focuses on the Blockchain interoperability use cases within PLANET and section 5.2 focuses on the functional requirements.
	Consequently, this subtask provides a universal front end to pre-existing Blockchain systems and installations from T&L and SC actors to facilitate the business objectives presented in the LLs.	Chapters 5 (5.3 and 5.4), 6 (6.1)	Sections 5.3 and 5.4 present the business scenarios as these were defined together with the LL partners. Chapter 6 presents the architecture of the Blockchain 'front-end'.

2.2 Deliverable Overview and Report Structure

The deliverable is organised in separate chapters as follows:

- Chapter 3 presents briefly the Blockchain solutions involved in Work Package 3 of the PLANET project. These are explained in more detail in the respective Deliverables, namely D3.1 *LL1 Specification and Baseline measurements* and D3.3 *LL2 Specification and Baseline measurements*.
- Chapter 4 contains a detailed description of the current state-of-the-art in Blockchain interoperability. A comparison table that includes all the solutions that are on offer at the time of writing this report is presented and explains the rationale behind the technology of choice for the EGTN Blockchain component.
- Chapter 5 presents the functional requirements of the EGTN Blockchain components, as well as the business scenarios that it addresses. The non-functional requirements are included in D2.1 *Open EGTN Platform Architecture v1* (submitted in month 16). The PI workflows involved in the Living Labs are described in more detail in *D2.17 EGTN smart contracts and associated PI motivated workflows in the context of SLA management v1*.
- Chapter 6 describes the software architecture of the Blockchain component, deployment details, data structures and integration points with the rest of the EGTN platform. The associated smart contracts are presented in *D2.17 EGTN smart contracts and associated PI motivated workflows in the context of SLA management v1.* The EGTN Blockchain component makes the data available through a REST API to be presented on the Human Machine Interface of the EGTN Dashboard. The EGTN dashboard is described fully in D2.19 *Unified HMIs implementation and technical documentation v1*.
- Chapter 7 presents the value that the Blockchain offers towards the realisation of the Physical Internet.
- Finally, Chapter 8 concludes this report by summarising the key outcomes and presenting the points that will be included in the final deliverable D2.16 (due month 30).

3 T&L Blockchain systems in PLANET

Task 2.5 aims to unify different Blockchain systems by creating a unified Blockchain 'front-end' that envisages how data silos can be broken and in turn different systems by different organisations with different roles in the T&L value chain can seamlessly collaborate and automatically exchange contracts and data in digital format. This section describes the Blockchain systems that will be used in T2.5 and are deployed within PLANET by different T&L partners. The next subsections provide more input regarding the use cases behind the development of these systems as well as their business objectives.

3.1 Introduction

The emergence of Blockchain was hailed by the T&L community as an innovative solution that has the potential to overcome several challenges, such as the complexity of trade and customs processes, traceability of shipments, transparency, trust, and confidentiality between different stakeholders and so on. In the context of PLANET, the following Use Cases focus on the exchange of transport documents in digital form in compliance with all characteristics set out by public authorities and regulations to be recognised as valid transport documents. These documents are traditionally used by shippers, consignees, road hauliers and public authorities in paper form, a method that raises several issues especially when compared to the digital versions of the documents.

3.2 Maritime and Freight Forwarders Blockchain communities

In LL1, the roles of maritime port, shipping lines and freight-forwarders are played by Fundación Valenciaport, COSCO and DHL, respectively. From a theoretical perspective, maritime ports, shipping lines and freight-forwarders should have an individual Blockchain platform, i.e., the shipping community Blockchain, the port community Blockchain and the Iberia FF community Blockchain for managing the exchange of information related to maritime and terrestrial transportation flows.

Given that one single shipping line and the port of PLANET LL1 are involved in this use case, for simplicity reasons the exchange of information between the Port of Valencia and COSCO for both maritime and terrestrial segments is carried out through the development of a common Blockchain network based on Hyperledger Fabric that targets the digital twin representation of maritime and terrestrial events between the shipping line and the maritime port. LL1 Use Case 1 (UC1) partners join this Blockchain network, which is based on a distributed ledger solution designed to enable container data sharing between globally interconnected supply chains, seaports container participants and the hinterland.

In line with the Maritime Blockchain network, LL1 also operates a second Blockchain network that enables the exchange of information related to terrestrial transportation between warehouse providers, freight-forwarders, and the last-mile delivery companies. This second Blockchain is also based on Hyperledger Fabric and brings together all LL1 Use Case 2 (UC2) partners, namely DHL and CityLogin, in a private, permissioned Blockchain network.

3.2.1 Business Objectives

The main challenge of the T&L communities is to enable transparency of logistics events, traceability of cargo along the supply chain and more efficient inter-organizational workflows. Towards this direction, stakeholders employ the Blockchain technology to provide an interoperable network for secure data sharing from terminal to hinterland, thus enabling better and faster interconnectivity when selecting a hinterland transport mode. Specifically, maritime and freight forwarders in LL1 employ Blockchain to support the following:

- Process digitalization, guaranteeing paperless transactions and reducing operational time, costs of paper-based processes and human errors
- Real-time information exchange among actors involved in the supply chain
- Customer experiences improvement, by bringing trust, transparency, and collaboration

- Supply chain visibility increase by having access to real time data
- Logistics cost reduction
- Revenue increase
- Increase process efficiency/automation (related to smart contracts)
- Operational productivity improvement
- Information more accessible and easier to interpret from a distance
- Security Information
- Increase traceability of material supply chain
- Strengthen corporate reputation through providing transparency of information and processes
- Improve credibility and public trust of data shared
- Reduce potential public relations risk from supply chain malpractice
- Stakeholders' engagement
- Analytics (It can help create forecasts and predictions based on previous data, and it can allow users to pinpoint lags in the supply chain)

3.3 Digitalisation of Documents in the Port of Rotterdam

BlockLab provides a Blockchain-based platform for the digitalisation of documents required for logistics along the trade corridors that are connected by the Port of Rotterdam hub (LL2). Special attention is placed upon the rail transport between China and Rotterdam, plus sea and road transport between Rotterdam and the UK, USA, and Rhine-Alpine corridor. The platform allows clients to create virtual multimodal shipments based upon their international trade activities. Clients and authorised stakeholders are allowed to add, view and transfer ownership of the documents required for these shipments. Among these stakeholders are port authorities, customs authorities, logistic service providers, freight-forwarders, consignors, and consignees. Through the digitalisation of the information flow the platform aims to streamline shipment processes, which in turn shall reduce process lead times, labour, waiting times and disputes. Shipment associated information and events shall be made efficiently accessible, distributed, and secured in real time.

The platform facilitates the digitisation of the following logistic documents:

- (Electronic) Road Transport Document ("e-RTD", or "e-CMR"), required for road freight transport within the European Union
- (Electronic) Bill of Lading ("e-BL"), required for international sea freight transport
- (Electronic) Rail Transport Document ("e-CIM"), required for international rail freight transport

Additionally, the features of the platform shall be extended to further enrich the digital information flow with:

- Trade documents such as purchase orders, commercial invoices and booking requests
- Customs declarations required for the United Kingdom
- Phytosanitary certificates from the Dutch food and consumer product safety authority (NVWA)

In all the aforementioned documents the platform provides cryptographically secured proof-of-integrity, proof-of-origin, and proof-of-existence using the public Ethereum Blockchain, while keeping commercially sensitive data anonymous and secure in accordance with the GDPR.

3.3.1 Business Objectives

The first business objective that needs to be addressed by the BlockLab platform is to streamline the logistics and customs processes through the digitalisation of the - currently paper-based - stream of documents required in these processes. Digitalisation leads to reduction of physical handling, loss, distribution, tampering, as well as reduction of disputes and human errors, which are all often caused using documents in paper form.

Digitalisation not only reduces human labour, but it also introduces a digital information flow enriched with real-time data.

The second business objective is to enable the exploitation of this rich digital information flow for synchro-modal dynamic management and real-time optimisation of logistics. The expected outcomes include increased transport asset utilisation rates, shorter transit times, and reductions in freight idle times.

4 Analysis of Blockchain Interoperability Frameworks

This section summarises the current state of the art in interoperability between Blockchain networks. Following that, it compares the different state-of-the-art solutions based on the PLANET requirements, as these were set out in WP1, and finally it includes the methodology behind the choice of technology to be used in the EGTN Blockchain component.

4.1 Background

Interoperability is the capacity of computer systems to exchange and use data, but also the capacity to transfer an asset between different systems while keeping the state and uniqueness of the asset consistent. In the case of Blockchain systems, interoperability is an emerging hot topic both in the academia and in industry. Blockchain interoperability ranges from relatively simple - i.e., interoperability between smart contracts on the same ledger - to very complex – i.e., inter-Blockchain interoperability or between a Blockchain network and a legacy system. A different challenge that Blockchain interoperability addresses is to enable data exchanges between a public Blockchain where pseudonymous data are used and a private Blockchain where transactions require user identification. Multiple teams around the world are currently looking to solve the challenge of sharing transactions across Blockchain networks using advanced methods and proposing innovative solutions [1] [2] [3].

The objects exchanged in any Blockchain interoperability scenario can be of three types [4]:

- *FA*: Fungible asset (value token/coin), i.e., cannot be duplicated on different ledgers - e.g., currency and ERC 20 tokens [5].
- *NFA*: Non-fungible asset, i.e., cannot be duplicated on different ledgers, it is unique, and it cannot be swapped - e.g., ERC 721 tokens [6]
- *D*: Data – can be duplicated on different ledgers.

The employed interoperability framework should guarantee that *FA*s and *NFA*s have only one valid representation of a given asset in the system. On the other hand, Data (third type above) exchanged in an interoperability scenario can be duplicated on different ledgers.

According to surveys and analysis in the literature [7] [8] approaches looking to achieve Blockchain interoperability can be classified into the following high-level categories: **Public Connectors, Blockchain of Blockchains, and Hybrid Connectors**. Each category can be further divided into sub-categories based on defined criteria while each category serves specific use cases. The Public Connectors are mostly cryptocurrency-related and deal with the movement of Fungible values from one ledger to another. The Blockchain of Blockchains category includes custom architectures that provide reusable data, network, consensus, and contract layers for the creation of customised Blockchain infrastructures and serve general use cases. The Hybrid Connectors approach is an attempt at delivering a “Blockchain abstraction layer” [9] - that would be a “Blockchain front-end” in the case of PLANET - capable of exposing a set of uniform interfaces that allow stakeholders to interact with Blockchain systems without the need of using different APIs.

The EGTN platform follows a “Hybrid Connectors” approach for the architecture of its Blockchain service, as it interconnects existing backend systems and exposes universal, standardised interfaces to actors of the supply chain. Moreover, the abstraction layer exposed by the EGTN Blockchain service enables the provision of T&L-related data to the EGTN dashboard for visualisation.

4.2 State of the Art in Blockchain Interoperability

In this section, the state-of-the-art frameworks, protocols, and platforms that are used in the process of applying Blockchain interoperability solutions are presented.

4.2.1 SOFIE Interledger component

The SOFIE Interledger component is an outcome of the H2020 SOFIE project[2], which ended in December 2020. The codebase is open source on GitHub[3]. Through the Interledger component, activity on an Initiator ledger triggers activity on one or more Responder ledgers in an atomic manner. It supports different types of ledgers (e.g., Ethereum, Hyperledger Fabric, Hyperledger Indy, KSI) and can be used in multiple use cases which fall under both the Hybrid Connectors and the Public Connectors categories, such as:

- *Transferring Data* from one ledger to another.
- *Storing Data Hashes* in a (private) ledger while a hash of the information is consequently stored in a (public) ledger at suitable intervals using the Interledger component to benefit from the higher level of trust in a public ledger.
- *Game Asset Transfer* implements a state transfer protocol, which is used to manage in-game assets: the assets can either be used in a game or traded between gamers. In both activities, a separate ledger is used and the Interledger ensures that each asset is active in only one of the ledgers.
- *Hash Time Locked Contracts (HTLCs)* describes how to use the Interledger to automate the asset exchange between two ledgers using Hash Time-Locked Contracts (HTLCs).

The PLANET WP2 partners involved in T2.5 (EGTN Distributed Ledgers and Smart Contracts) are in close contact with the engineers of the SOFIE Interledger component to identify possible extensions of the codebase to better support the T&L use case. More details on this matter are presented in section **Error! Reference source not found.**.

4.2.2 Hyperledger Cactus

The Hyperledger Cactus[4] project began in 2020, when Fujitsu open-sourced its tool for Blockchain interoperability under the umbrella of the Hyperledger and Linux Foundation. It is currently an Incubation Hyperledger project[5], yet there is a clearly defined roadmap, which means that it will soon be qualified to pass to the Graduated status.

Cactus is a plugin-based framework which aims at providing developers with an abstraction layer over protocol-specific implementations and in this manner allow for interoperability. This empowers solutions to adapt to new protocols and make transactions involving multiple public and/or permissioned ledgers more easily. Roughly speaking, Cactus consists of "business logic plugins," which coordinate cross-Blockchain integration and "ledger plugins," which facilitate connections to specific ledgers. It supports multiple Blockchain systems, namely Hyperledger Besu/Fabric/Indy/Sawtooth/Iroha, Corda, Geth, and Quorum and it can be used in diverse use cases such as car trade, electricity trade, Ethereum to Quorum asset transfer, money exchanges, and integration of existing food traceability solutions.

The key principles behind Cactus are the following:

- *Plugin architecture*: It maximises flexibility and future-proofing through plug-in architecture.
- *Secure by Default*: It avoids the need for explicit actions from users to have a secure Cactus deployment.
- *Toll Free*: Users should not be required to use tokens for transactions and Operators should not be required to take a cut of individual transactions.
- *Low Impact Deployment*: It does not interfere with or impede existing network requirements.

More details on the software architecture and the technical specification of Cactus can be found in subsection **Error! Reference source not found.**.

[2] Horizon 2020 SOFIE project, No 779984, Secure Open Federation for Internet Everywhere, https://www.sofie-iot.eu/
[3] SOFIE Interledger repository, https://github.com/SOFIE-project/Interledger
[4] Hyperledger Cactus, https://www.hyperledger.org/use/cactus
[5] Hyperledger Project Lifecycle, https://tsc.hyperledger.org/project-lifecycle.html

4.2.3 Interledger protocol

The Interledger Foundation[6] is building pathways to financial access and opportunity across the world, towards a more equitable and creative global society through an open payments network in which anyone can seamlessly earn, share, buy, sell, and trade with anyone else in the world. To that end, it developed the Interledger Protocol (ILP)[7], an open-source protocol and W3C standard[8], designed to connect cryptocurrencies (Bitcoin, Ethereum).

Although ILP initially focused exclusively on cryptocurrency-related ledgers, nowadays, it is technology-agnostic, defining a "lowest unit common denominator" across distributed ledgers, Blockchains, fiat payment networks, and the ILP packet. As an open-source protocol, it connects all types of ledgers, from digital wallets and national payment systems to others. The end goal is to transact easily with anyone, no matter the location nor the currency. ILP allows you to receive money from any ledger, without setting up accounts on many different services.

The Interledger protocol is not based on Blockchain, yet it employs some key concepts of Blockchain technologies, such as the decentralised design and cryptography-based security. Unfortunately, the ILP does not support non-Fungible tokens (such as ERC 721 tokens) and it cannot integrate with existing Blockchains, since each one must be adapted accordingly to use ILP.

4.2.4 COSMOS

Cosmos, launched in 2019, is a decentralised network of independent parallel Blockchains, called Zones. Zones are based on Tendermint[9], a fast and secure Byzantine Fault-Tolerant consensus engine, along with a peer-to-peer network gossiping protocol. Zones can transfer data to other Zones directly or via hubs. Hubs minimise the number of connections between Zones and avoid double spending.

The communication between hubs and the central Cosmos Network (Cosmos hub) uses the Inter Blockchain Communication (IBC) protocol to allow Zones to interact with other Blockchains. Blockchains are connected in a hub and spoke model to the Cosmos Hub, as indicated in Figure 1.

Figure 1: COSMOS hub and spoke model for connectivity

[6] Interledger Foundation, https://interledger.org/
[7] Interledger Protocol, https://interledger.org/rfcs/0027-interledger-protocol-4/
[8] Interledger Payment Method, W3C, https://w3c.github.io/webpayments/proposals/interledger/
[9] Tendermint, https://tendermint.com/

COSMOS falls under the Blockchain of Blockchains category, which means that it needs to set up a separate Blockchain as the main chain and sustain all the communication and synchronisation complexity, since each Zone maintains its own state. Moreover, the support of additional non Tendermint-based Blockchain systems is a complex process that can be achieved via Peg zones, a functionality provided by COSMOS.

4.2.5 Polkadot

Polkadot[10] is a sharded heterogeneous multi-chain architecture that enables external networks as well as customised layers i.e., "parachains" to communicate, thus creating an interconnected internet of Blockchains. The network uses an environmentally friendly proof of stake consensus algorithm and follows practices similar to the COSMOS network. It can be used to interconnect permissionless and permissioned ledgers while high scalability can be achieved using sharding by spreading transactions across the parachains -i.e., the equivalent to COSMOS Zones - allowing them to process transactions in parallel. It uses the Relay Chain, which is the central connector, that functions similarly to the Cosmos Hub and all other Blockchains need to connect to the Relay Chain. It also uses bridge-chains, as can be seen in Figure 2, to connect to other type of ledgers in the same manner that COSMOS uses Peg zones.

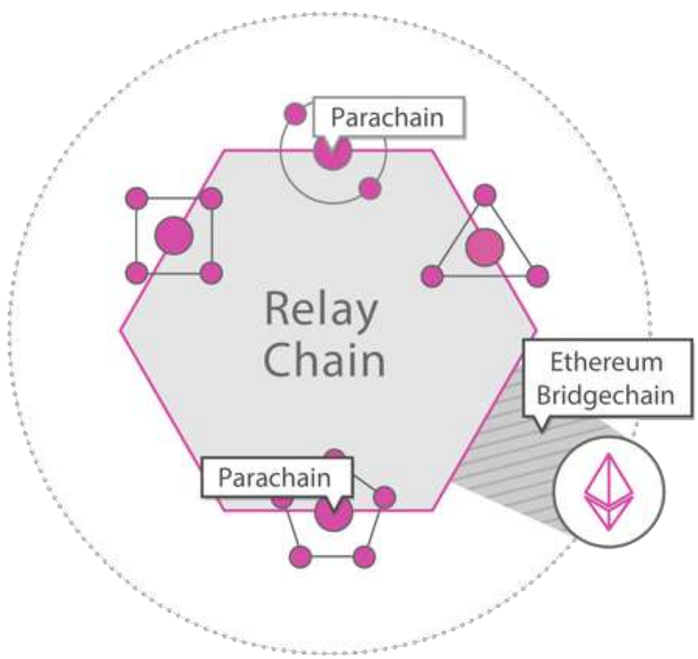

Figure 2: Polkadot Bridge-Chains Architecture

4.2.6 Baseline

The Baseline Protocol[11] aims to address privacy issues to encourage enterprise adoption of the public Ethereum. The Baseline Protocol is an open-source initiative - started in 2020 and backed by big companies such as EY, Consensys, Microsoft - that combines advances in cryptography – e.g., Zero Knowledge Proofs (ZKPs) -, messaging, and Blockchain to deliver secure and private business processes at low cost. The protocol enables confidential and complex collaboration between enterprises without leaving any sensitive data on-chain.

[10] Polkadot, https://polkadot.network/

[11] Baseline Protocol, https://docs.baseline-protocol.org/

Baseline addresses the challenge that modern enterprises face for secure and private synchronisation of systems of records and provides a low-cost, universal, strongly tamper-resistant solution that can prevent locking companies out of valid operations protocol. These requirements strongly suggest the use of a public Blockchain, or Layer-2 network anchored to a public Blockchain. It uses Ethereum Mainet as a single point of reference for Blockchains, or local systems of record (Mongo, Oracle, SAP).

Despite the privacy-by-design principles and the strong cryptography that is employed, Ethereum is a public network, therefore enterprises may be sceptical to store private data (even with ZKPs in place). Moreover, Baseline faces still all the Ethereum-related challenges and restrictions, such as reduced scalability, reduced performance, weak finality, and fees for transactions.

The work is governed as an EEA Community Project[12] and it is managed by OASIS[13].

4.3 Interoperability Characteristics Comparison Table

The table below summarises the characteristics of the Blockchain interoperability state-of-the-art frameworks, which were described in the previous paragraphs:

Framework	Released	Category	Licence	Description and Use Cases	Link
SOFIE Interledger	December 2020	Hybrid Connector	Open source	Supports events-based synchronisation between multiple types of blockchains. Features standardised interfaces and a connectors-based architecture. Use cases include transferring data from one ledger to another, connecting public and private ledgers and HTLCs.	SOFIE
Hyperledger Cactus	March 2020	Hybrid Connector	Open source	A plugin-based framework which aims at providing developers with an abstraction layer over backend blockchain systems. It features a business logic plugin which coordinate cross-blockchain integration and connectors to multiple types of blockchains.	Cactus
Interledger	2015	Hybrid Connector	Open source	A web-based payments infrastructure that allows greater global financial inclusion. It is a protocol connecting consortium/private ledgers and public ledgers. Use cases: • Asset transfer or exchange • Synchronising two ledgers	Interledger
COSMOS	Mar 2019	Blockchain of Blockchains	Open source	Based on Tendermint protocol, with a main chain (COSMOS hub) to connect multiple other Tendermint-based (Zones)	COSMOS

[12] Enterprise Ethereum Alliance (EEA) projects, https://entethalliance.org/eeacommunityprojects/

[13] OASIS, https://www.oasis-open.org/open-projects/

				or other kind of Blockchains (Peg Zones). Each Zone maintains its own state.	
Polkadot	Nov 2019	Blockchain of Blockchains	Open source	Primarily described as a scalable heterogeneous ''multi-chain'', it attempts to introduce a new, overarching relay-chain, upon which many so-called "parachains" can be built. It uses sharding to increase scalability. Concept very similar to COSMOS.	Polkadot
Baseline	March 2020	Hybrid Connector	Open source	Coordinating records between legally separated entities. Maintain data integrity between two different databases of two different Orgs • CRM, Customer relationship management • ERP, Enterprise Resource Planning	Baseline

Table 2: Blockchain Interoperability Frameworks Comparison

4.4 Ideal Candidate for the EGTN platform

Public Connectors focus on public Blockchains and cryptocurrencies, therefore they cannot be considered as candidate technologies to achieve Blockchain interoperability in PLANET. Regarding the Blockchain of Blockchains category, while the provided features can be desirable for end-users, frameworks that fall under this category do not interoperate with each other. Taking this into account, end-users are forced to choose between existing solutions, leading to sub-optimal leveraging of available resources. Furthermore, the Blockchain of Blockchains category involves the cost of transaction fees to keep the network in operation and to sustain a business model across several Blockchains, thus rendering its applicability questionable given enterprise Blockchain systems.

At the time of writing this deliverable, the SOFIE Interledger component is the ideal candidate to support the requirements, as these were set out by the PLANET partners, and at the same time to fit the specification of the EGTN platform. It adopts the Hybrid Connectors approach that provides an abstraction layer to underlying Blockchain systems. Furthermore, it supports integration with several Blockchain systems, such as Hyperledger Fabric and Ethereum - which are the two Blockchain systems used by the LL stakeholders - but also provides integrations with several other Blockchain systems. SOFIE also features an extensible plugin-based architecture.

However, the recent arrival and progression of Hyperledger Cactus over the past few months as well as its great potential meant that it should also be included in the experimentation process. Preliminary deployments and hands-on experimentation using SOFIE have already been conducted to assess the framework in terms of usability and security. In parallel, Hyperleder Cactus is also under examination and is undergoing extensive investigation by the engineering team of PLANET to validate the stability, scalability, and security of its codebase, given its incubation status. The final decision (either continue using SOFIE or migrate to Cactus) will be taken in the coming months and presented in the final deliverable D2.16 (due month 30). The decision will depend on the following criteria:

- Stability and usability of Cactus

- Added value brought by Cactus compared to SOFIE
- Amount of effort required to migrate from SOFIE to Cactus.

This decision will not affect the high-level software architecture, interfaces and data exchanged as presented in section 6, given that the design and protocols in both frameworks follow similar approaches.

5 Blockchain Interoperability in PLANET

This section provides business scenarios on how Blockchain interoperability can simplify, standardise and streamline interorganisational workflows by overcoming the issues raised by proprietary Blockchain systems within privately-owned Supply Chain ecosystems. The business scenarios presented here aim to showcase how these issues can be technically addressed using the PLANET Living Labs as the testing ground for Blockchain interoperability.

In essence, the following paragraphs describe the business scenarios within PLANET that require the exchange of data between existing Blockchain systems through a common interface, together with the respective requirements of the Blockchain interoperability service of the EGTN platform. The business scenarios were developed through a series of close interactions with the partners from the respective Living Labs.

5.1 Introduction

The Blockchain technology is used by several stakeholders of PLANET within specific LLs to enable trust in networks of untrusted participants. Smart contracts are also employed to automate, accelerate, and safeguard processes that require complex manual operations by multiple stakeholders of different organisations. The Blockchain interoperability service that will be deployed in the EGTN platform provides common interfaces to enable the exchange of data and events between existing backend Blockchain systems and to simplify, standardise and streamline interorganisational workflows. It also exposes all these information on the EGTN dashboard - which is developed in Task 2.6 - to increase transparency and openness of the entire supply chain.

The scenarios that will use the Blockchain interoperability service of the EGTN platform and will validate its architecture – as part of the EGTN blueprint architecture - were identified after intensive workshops among the PLANET partners and in close collaboration with the LLs. They are presented in the following sections.

5.2 Blockchain interoperability requirements

In this section a Usage-Actors-Requirements approach is used to define the requirements for the EGTN Blockchain service, as similarly followed in D2.1 for the entire EGTN Platform. Figure 3 shows the relationship between each usage scenario of the platform that will involve some actor and have some functional requirements. As per the non-functional requirements of the EGTN Blockchain service, they are included in the comprehensive list of D2.1. Each functional requirement is then classified as per the Must-Should-Could-Won't key (as outlined in Table 3).

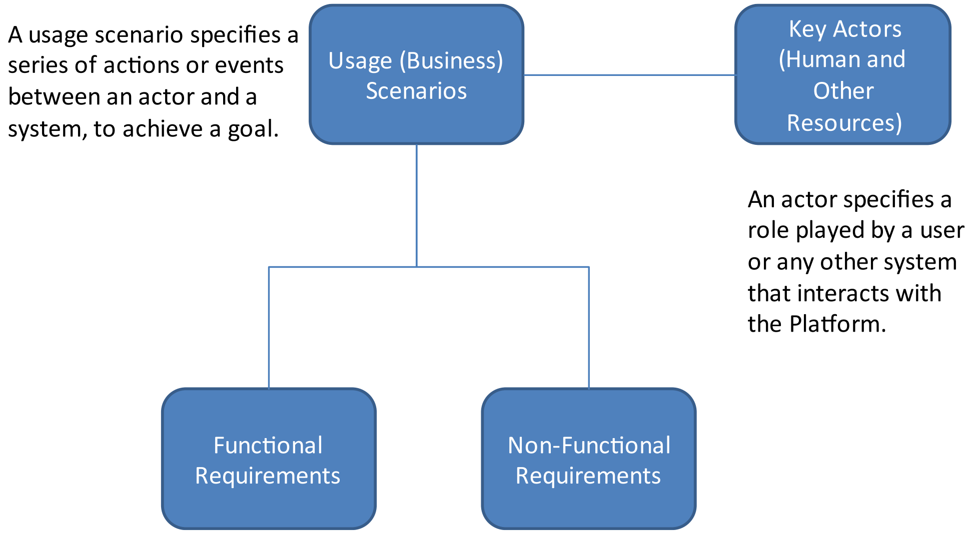

Figure 3; Usage-Actors-Requirements Approach

Key	Description
M	MUST: Describes a requirement that must be satisfied in the final platform for the platform to be considered a success.
S	SHOULD: Represents a high-priority item that should be included in the platform if it is possible. This is often a critical requirement but one which can be satisfied in other ways if strictly necessary.
C	COULD: Describes a requirement which is considered desirable but not necessary. This will be included if time and resources permit.
W	WON'T: Represents a requirement that stakeholders have agreed will not be implemented in the current project but may be considered for the future).

Table 3: Must-Should-Could-Wont Key Legend

The scenarios that require the exchange of Blockchain transactions through unified interfaces of the EGTN platform are summarised in Table 5 through Table 7. The actors of the scenarios that interact with the EGTN Blockchain Service are presented in Table 4, while they are extensively described in D2.17 for each interoperability workflow.

Actor	Id	Actor	Id
1. Requestors	RE	**6. Depositaries**	DEA
2. Carriers	CA	**7. Service Requestors**	SR
3. Shippers	SH	**8. Service Providers**	SP

4. Consignees	CO	**9. Logistics Service Providers**	LSP
5. Depositors	DEO	**10. System administrator**	SA

Table 4: EGTN Blockchain Service Actors

Business Scenario	ID	Functional Requirement	Key Actors Involved	Category
A. Exchange of Transport Order information to interconnect maritime actors, shipping lines, logistics operators and last-mile delivery	A.1	Provide interfaces to interconnect different Blockchain systems	SA	S
	A.2	Allow redirection of transactions from/to different Blockchain systems	SA	M
	A.3	Provide interfaces to the IoT layer to consume events and data that will trigger smart contracts	SA	M
	A.4	Define common data structures to be exchanged	RE, CA, SH, CO, DEO, DEA, SR, SP, LSP	S

Table 5: Business Scenario A: Interconnect maritime, warehouse providers and last-mile delivery

Business Scenario	ID	Functional Requirement	Key Actors Involved	Category
B. Integration and Synchronisation of Maritime Ports	B.1	Provide unified interfaces to interconnect different Blockchain systems	SA	S
	B.2	Allow redirection of transactions from/to different Blockchain systems	SA	M
	B.3	Provide interfaces to the IoT layer to consume events and data that will trigger smart contracts	SA	M
	B.4	Define common data structures to be exchanged	RE, CA, SH, CO, DEO, DEA, SR, SP, LSP	S

Table 6: Business Scenario B: Interconnect Port of Valencia with Port of Rotterdam

Business Scenario	ID	Functional Requirement	Key Actors Involved	Category
C. Visualise Blockchain data from diverse backend T&L systems	C.1	Enable interfaces with the EGTN dashboard	SA	M
	C.2	Forward incoming transactions to the EGTN dashboard	SA	M
	C.3	Enable interaction of the stakeholders with the backend Blockchain systems	RE, CA, SH, CO, DEO, DEA, SR, SP, LSP	C

Table 7: Business Scenario C: Blockchain data visualisation

5.3 Exchange of Transport Order

This use case simulates a merchant scenario where COSSP manages shipments from Asia to Spain (Port of Valencia) while the inland transport is managed by DHL Spain and CityLogin. As described in the requirements section (section 5.2), the backend Blockchain systems of the two communities must exchange information about the cargo details and events related to the container arrival at the port or the pick-up of the container from the warehouse.

In terms of the Blockchain technology, two backend Blockchain systems are involved, each one simulating the community of the LL1's use cases. The first community - representing UC1 - involves the maritime port (Port of Valencia) and the shipping lines (COSSP) while the second one represents UC2 and involves the warehouse providers (DHL) and the last mile delivery (CityLogin).

The interactions between the stakeholders of the scenario are shown in Figure 4.

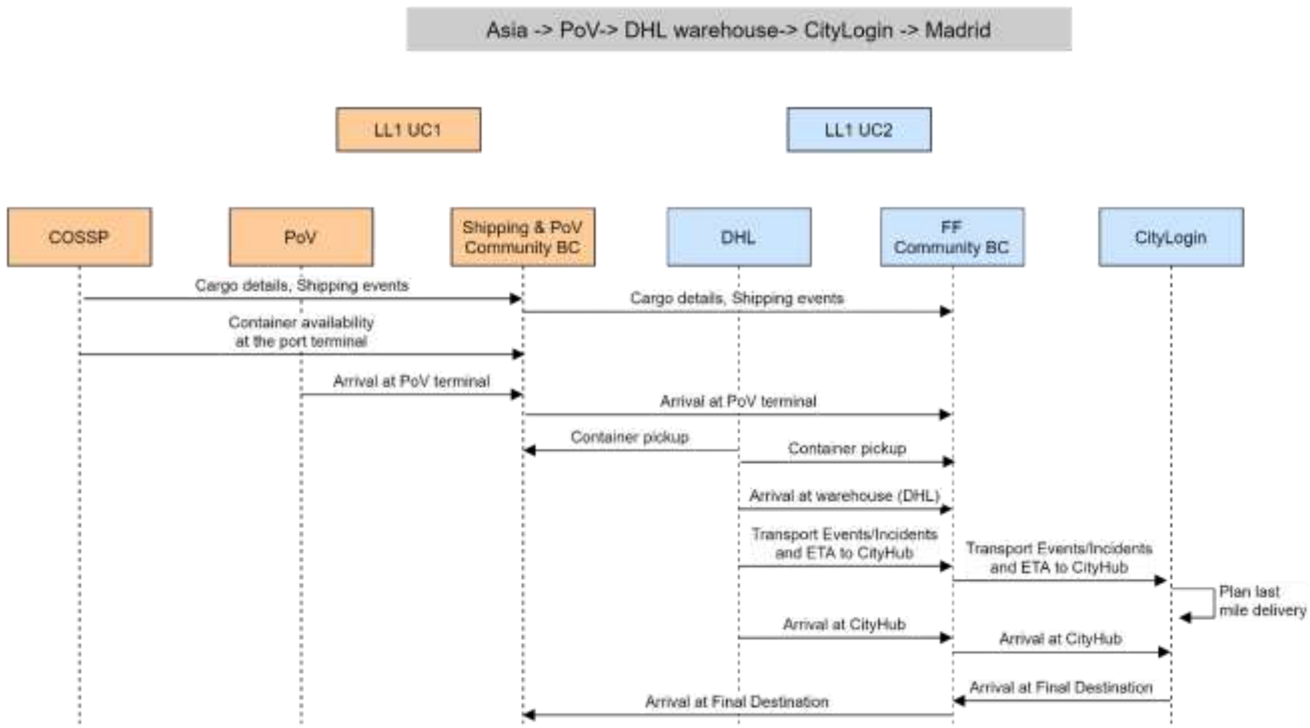

Figure 4: Exchange of Transport Order scenario

The scenario involves several types of actors, including but not limited to requestors, carriers, shippers, and consignees, who interact with both the Blockchain systems to share data or retrieve information. More details on the participants and their interactions can be found in D2.17. In terms of technology used, both communities use the Hyperledger Fabric framework to deploy private permissioned networks and employ smart contracts to interact with the ledger in a secure and trusted manner.

5.4 Integration and Synchronisation of Maritime Ports

Blockchain technologies are used by LL2 partners and specifically by the Port of Rotterdam for the digitisation of logistics documents and targets the exchange of information between shipping lines, logistics operators and the Port of Rotterdam. Interoperability between the Blockchain networks of the two ports – Port of Valencia in LL1 and Port of Rotterdam in LL2 - is achieved through the Blockchain network of the logistics operators, namely DHL, as can be seen in Figure 5.

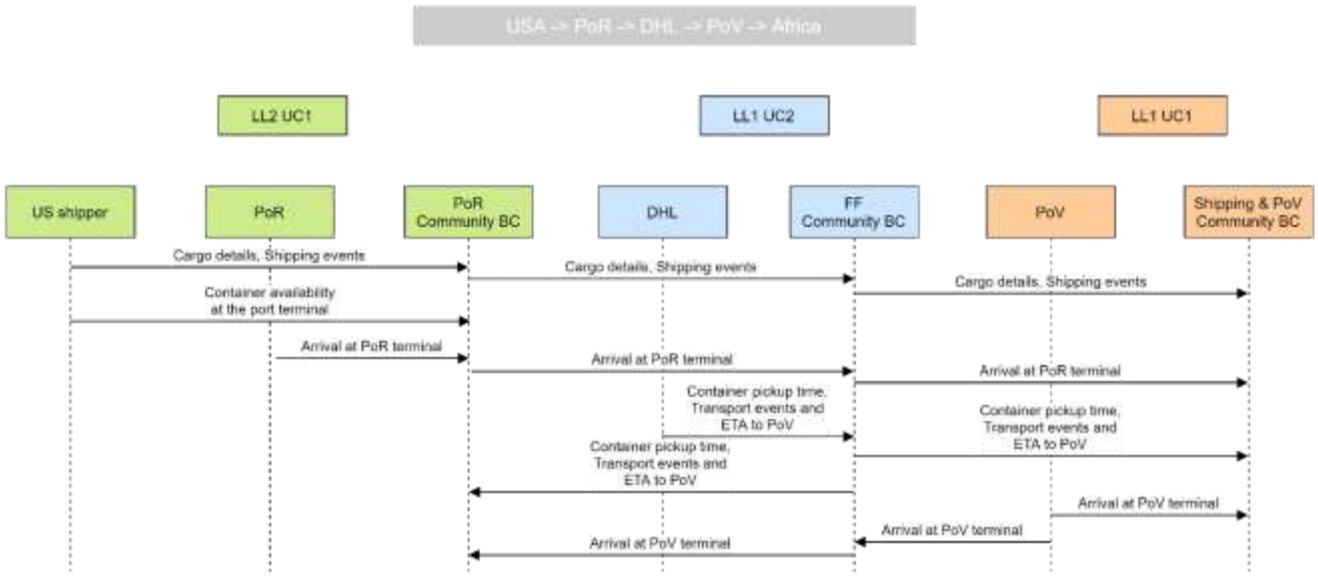

Figure 5: Exchange of Road Transport Document scenario

The interoperability framework aims to enable the exchange of information related to cargo dispatching, cargo reception and terrestrial transportation between any two maritime ports that may use different documents for the same or similar purpose as well as different standards. The idea behind is that Blockchain interoperability should accommodate a solution that addresses all the aforementioned issues successfully.

In the context of PLANET, PoV and PoR use different road transport documents; Port of Valencia uses the Unified Transport Document (UTD, or DUT as the Spanish acronym) while the Port of Rotterdam uses the electronic Road Transport Document (eCMR). Using this electronic document, information and events related to road freight transport can be shared across both platforms enabling road transport optimisation between the Port of Rotterdam and Port of Valencia. A practical example of a possible optimisation scenario could be the following:

The road segment of an international shipment involves the following steps. A truck picks up the freight at the Port of Rotterdam and the driver issues an e-CMR. Information about the dispatch, destination, ETA, freight volume and weight are immediately shared across the integrated Blockchain platforms of LL1 and LL2. Connected warehouses and logistics service providers at the Port of Valencia are now empowered to anticipate the incoming cargo and reserve storage or transport space for the next segment of the shipment, while the freight is in transit.

The EGTN Blockchain Service acts as a proxy between the two ports, which exchange hashes of the documents along with metadata through their Blockchain systems, with the actual documents being shared through the EGTN Platform and retrieved only by trusted actors. In terms of standards, PoV uses the Blockchain in Transport Alliance (BiTA)[14], while Port of Rotterdam use GS1 standards[15]. The EGTN Blockchain Service adopts a mix of the above standards to define a common data model and accommodate the different structures.

[14] https://www.bita.studio
[15] https://www.gs1.org/standards

6 Blockchain 'front-end' as part of the EGTN platform

This section describes the software architecture of the EGTN Blockchain component, the deployment details, data structures as well as the integration points with the open cloud based EGTN platform.

6.1.1 Blockchain Service Architecture

The goal of the EGTN Blockchain component is twofold. On the one hand, it aims to interconnect existing Blockchain systems hosted and operated by different T&L stakeholders with IoT or other data (weather news, schedules) coming from the EGTN Connectivity layer. More details on the EGTN Connectivity layer and the related data can be found in D2.1 *Open EGTN Platform Architecture v1*. On the other hand, it aims to expose that data to the EGTN dashboard to increase the transparency of the supply chain and take a step towards the realisation of the PI concept. The EGTN dashboard is described fully in D2.19 *Unified HMIs implementation and technical documentation v1*.

The high-level architecture of the EGTN Blockchain component is presented in Figure 6, in which events from LL Blockchain systems, IoT data and other T&L-related data are pushed to the EGTN platform through standardised connectors. The EGTN Blockchain component makes the data available through a REST API to be presented on the web interfaces of the EGTN Dashboard.

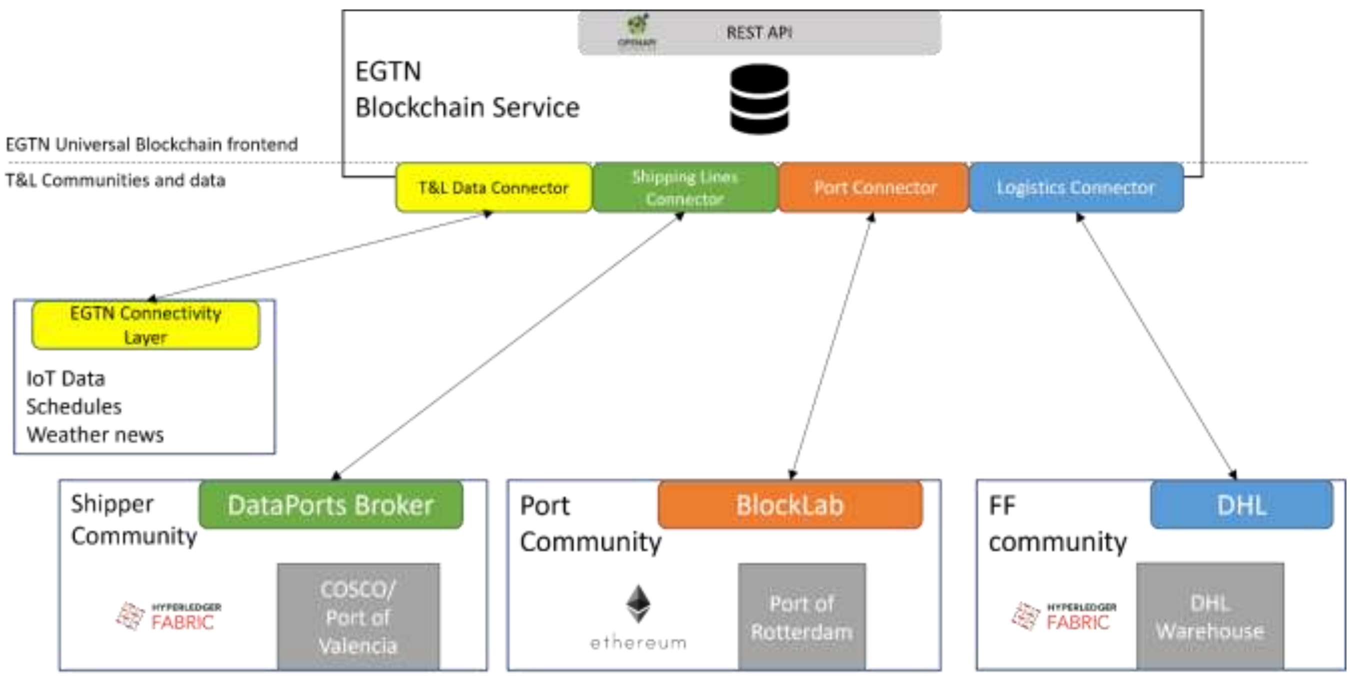

Figure 6: EGTN Blockchain Service Architecture

6.1.1.1 *EGTN Blockchain Service as an Enabler for Interoperability*

The following workflow describes how the integration between the backend Blockchain systems in PLANET shall be achieved. The numbered steps in the workflow align with the numbered steps in the diagram in Figure 7.

1. A Logistics Service Provider/External platform/Stakeholder uploads logistics document (*doc*) and attaches it to their shipment on the BlockLab system.
2. The Document Vault generates the hash of the document, *doc-hash*, and forwards the *doc-hash* + document owner's Blockchain address + non-sensitive metadata (e.g., e-CMR's non-sensitive data) to the Notary Contract on the public Ethereum testnet.

3. The Connector of the EGTN Blockchain Service listens for timestamped transactions (events) of the Notary Contract and retrieves the *doc-hash.*
4. The *doc-hash* is forwarded through the Document Interface to the BlockLab System to retrieve the actual document.
5. The EGTN Blockchain Service makes a request to the BlockLab API, attaching the access token and the *doc-hash* to retrieve the original document.
6. If the requested party is authorised by the document owner, the API releases the document content in JSON format.
7. The EGTN Platform makes the document available in the Kafka Service.
8. The doc is forwarded to the PoV Blockchain system.

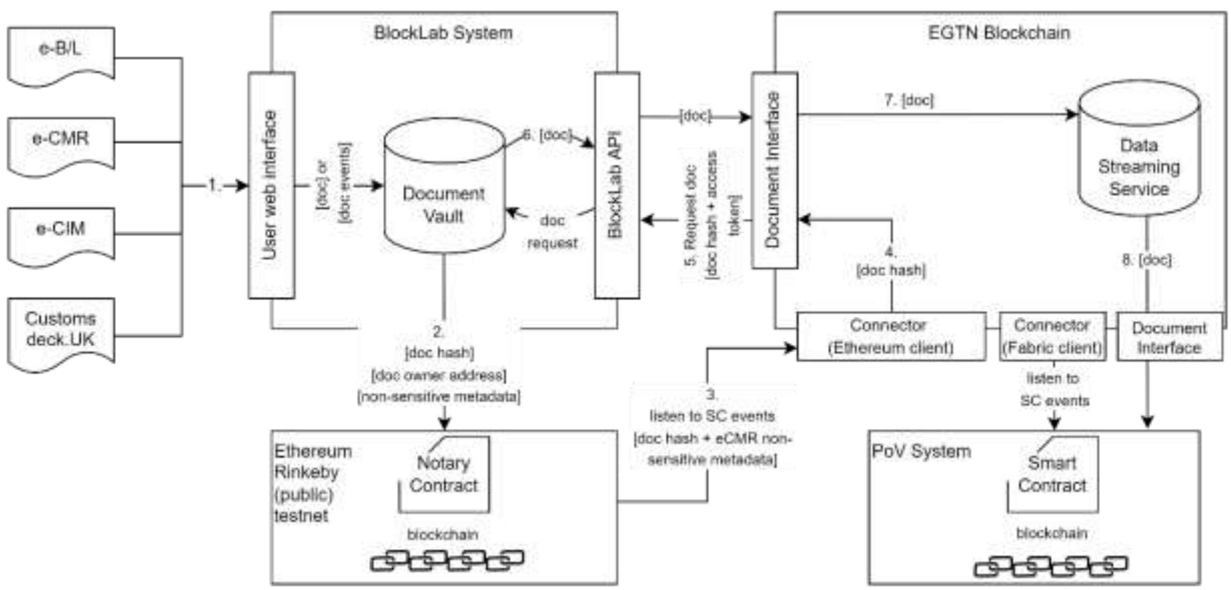

Figure 7: Integration of Ports Blockchain Systems (Rotterdam and Valencia)

6.1.2 Common Semantic Models and Data types

The interoperability scenarios in PLANET require trustful exchange of data through Blockchain, while static and transactional data are stored in the distributed ledger through dedicated smart contracts. The analysis of the data employs additional smart contracts and IoT data from the EGTN platform. This section presents all data identified, both static and transactional, for redirection through the EGTN Blockchain component.

6.1.2.1 Exchange of Transport Order

A common semantic model has been designed for the Blockchain data that will be exchanged by maritime and terrestrial actors aiming at assisting the sharing of Transport Orders in the supply chain ecosystem and standardising interorganisational workflows. The targeted services and the associated events provided by these Blockchain systems are:

Transport events:

- **Transport order:** Event that determines the establishment of a transport contractual agreement between the requestor and the carrier. It includes instructions related to the transport and information related to the cargo, transport units and the parties involved. The event is registered either by the requestor or the carrier.

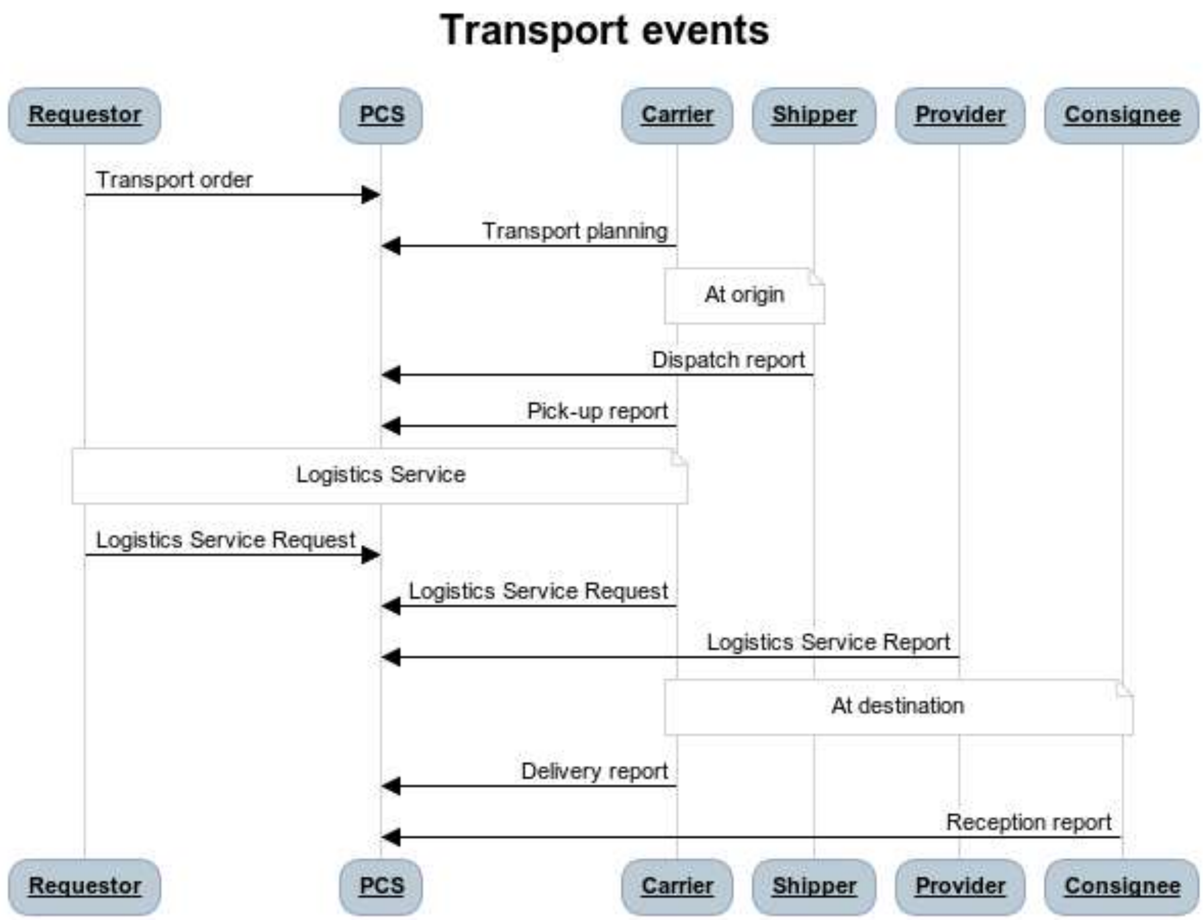

Figure 8: Transport Events

- **Transport planning:** Event generated by the carrier that informs on the transport planning, offering information and details over the transport mean that will be used for conveying the cargo and the estimate date for the movement. This event could be generated after a scheduling process with the depots or terminals of shipping or for the delivery of cargo and/or transport units.
- **Dispatch report:** Event generated by the shipper for the cargo and/or transport unit shipping when the carrier transports the cargo from the origin.
- **Pick up report:** Event generated by carriers when they receive the cargo or transport unit from the shipper at the origin.
- **Logistics Service Request:** Event generated by the requestor of a logistic service for receiving the logistics service during the transportation of the cargo or transport units. The logistics service order can be requested either by the requestor or the carrier.
- **Logistics Service Report:** Event generated by the logistics service provider for confirming the execution of the service.
- **Delivery Report**: Event generated by the carrier at the place of destination at the moment of delivering the cargo or the transport units to the consignee.
- **Reception report:** Event generated by the consignee at the place of destination at the moment of receiving the cargo or transport units from the carrier.

Storage Events

- **Stock-in order:** Event generated by the depositor that sets the establishment of the contractual agreement with the depositary for receiving the cargo and/or transport units and proceeding to the storage and safe-keeping of the cargo at their facilities.
- **Discharge order:** Event generated by the carrier that informs about the cargo and/or transport units that need to be discharged from the transport means at the facilities of the depositary. In the case of railway operations, this event will provide information on the composition of the train that arrives to the manoeuvre facilities.
- **Stock-in report:** Event generated by the depositary at the moment of receiving the cargo or transport units for its storage and safe-keeping.
- **Discharge report:** Event generated by the depositary at the moment of performing the discharge or reception of cargo and/or transport units brought by the transport means.
- **Logistics Service Order:** Event generated by the requestor of the logistics service to provide this service during the storage of the cargo and transport unit.
- **Logistics Service Report:** Event generated by the service provider confirming the execution of the service.
- **Stock-out order:** Event generated by the depositor to inform the depositary about the collection of the cargo and/or transport unit. This event sets the establishment of the contractual agreement with the depositary to receive the cargo and/or transport units and proceed with its storage and safe keeping at their facilities.

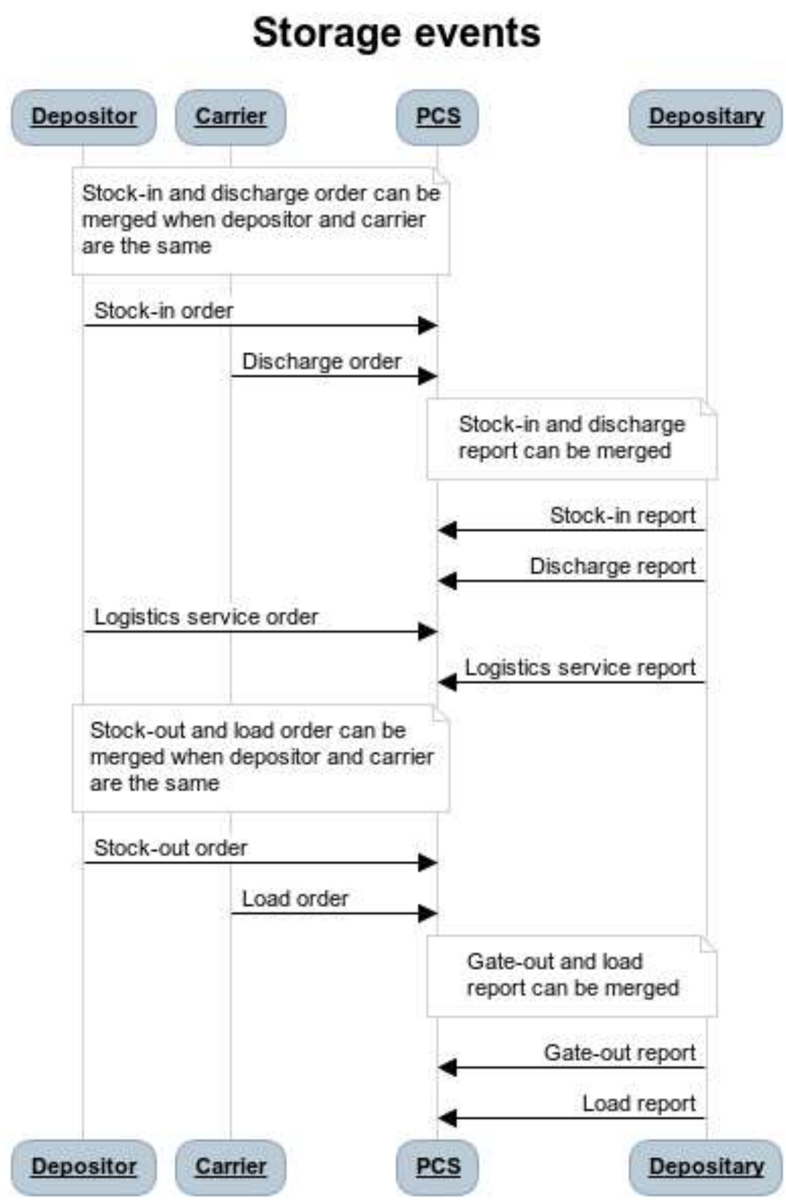

Figure 1. Storage events

- **Loading order:** Event generated by the carrier for the cargo and transport units that need to be loaded or shipped on the transport mean by the depositary at their facilities. In case of railway operations, this event will provide information about the composition of the train that has to leave the manoeuvre facilities.

- **Stock-out report:** Event generated by the depositary at the moment of delivering the cargo and/or transport unit for its transportation.
- **Loading report:** Event generated by the depositary at the moment of loading the cargo and/or transport units at the transport means.

Affected by these events, UC1 and UC2 Blockchains will deal with representations of the physical world at both tangible and intangible domains, also known as digital twins. The digital twins considered within this semantic model are:

- **Delivery of cargo and/or transport units.** Information about the delivery under the transport contractual agreement.
- **Storage of cargo and/or transport units.** Information about the storage of cargo and/or transport units in a specific facility. Transport units are those assets used for the transportation of cargo through different transport means (e.g., containers).
- **Transportation mean trip** for one or several cargos and/or transport unit deliveries for moving cargo from the origin point to the destination point.
- **Transportation means** that carry out the trips (e.g., trucks) for transporting cargo.
- **Documents, customs procedures, or services.**
- **Storage facilities** for cargo and transport units inside and outside the port facilities. These facilities can provide information related to the available capacity for the scheduling procedures during the planning phase.
- **Billing charges** in relation to transport, storage or services applied to the cargo, transport units, transportation, storage, services, document management or customs procedures.
- **Encoded data** on any physical attribute either tangible or intangible.

6.1.2.2 Integration and Synchronisation of Maritime Ports

Regarding the Integration and Synchronisation of Maritime Ports scenario, the data to be exchanged through the Blockchain systems of the ports can be found below:

- **Place/city of pickup**. Precise locations cannot be shared due to GDPR and potential data sensitivity, e.g., Rotterdam
- **Place/city of delivery.** This is similar to the city of pickup.
- **Date of pickup.** e.g., 08-11-2021.
- **Date of delivery. e**.g., 10-11-2021.
- **Number of packages.**, e.g., 3.
- **Gross weight of packages.** Total weight of goods including packaging, e.g., 1000 kg.
- **Volume of packages.** Quantity e.g., 4 m^3
- **Transport order reference number.** Arbitrary string of characters specified by Logistics Service Provider (LSP).
- **Type of packages.** Category of goods, e.g., euro pallet, container.
- **Document type.** Reference to the type of document, e.g., transport order or eCMR, e.g., 7.
- **Document hash.** Arbitrary string of characters (reference and integrity check for docs in port's vault).
- **Issue date.** e.g., 06-11-2021 (confirmation of the transport order and valid signature).

6.1.3 Technical Implementation

The initial technology framework identified to support the PLANET requirements as these were described in section 5.2, as well as the business scenarios defined in collaboration with the Living Labs and were presented in sections 5.3 and 5.4, was SOFIE Interledger. In the meantime, the Hyperledger Cactus framework emerged as a new and very promising addition to the Hyperledger ecosystem, and as a consequence the PLANET team is closely following its developments. The EGTN Blockchain service will be based on SOFIE, unless Cactus i) proves to be stable enough to be used in the near future, ii) brings more value than SOFIE to the solution, and iii) it required reasonable efforts to migrate from SOFIE. Having said that, both frameworks are presented below in detail.

The **SOFIE Interledger component** is an output of the H2020 SOFIE project - previously described in section 4.2.1 - that enables activity on an Initiator ledger to trigger activity on one or more Responder ledgers in an atomic manner. The ledgers can be of the same or different types (e.g., Ethereum, Hyperledger Fabric, Hyperledger Indy, or KSI), and once triggered, the Interledger passes a customisable payload from the Initiator ledger to the Responder ledger(s).

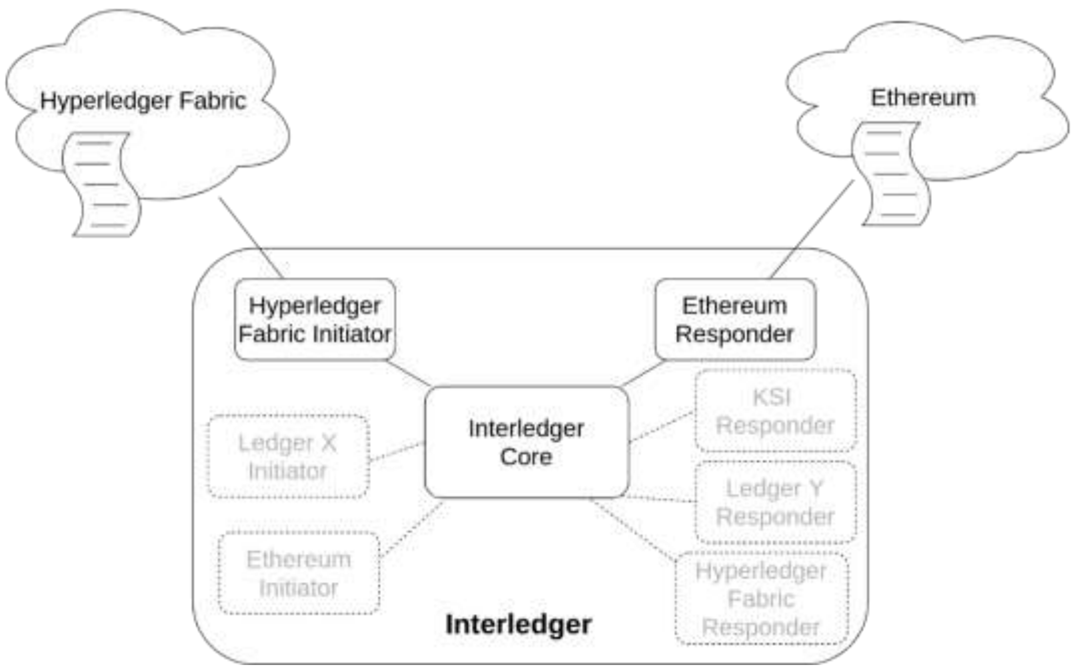

Figure 9: SOFIE Interledger Architecture

In case the EGTN Blockchain service uses the SOFIE Interledger component, Initiators and Responders for both directions need to be implemented as the interfaces with the backend systems (Figure 9). The Initiator/Responder interfaces play the role of the Connector interface of the EGTN Blockchain service (see Figure 6). In addition to this, a smart contract needs to be deployed in each side as the interface listens for events and forwards them to the Interledger Core (the core service of the EGTN BC component). Even though the SOFIE Interledger implementation could be considered as a centralised approach hosted by a single node, the database in the Core can be replaced by a permissioned Blockchain network, e.g., Hyperledger Fabric, where each organisation can host a node to ensure decentralisation.

On the other hand, **Hyperledger Cactus** is an advanced and powerful framework that supports the development of applications on top of the interoperability layer. Users can submit transactions and the business logic residing at the Cactus component manages the forwarding of transactions to the appropriate ledgers. It also handles verification and validation of transactions coming from the underlying ledgers, before replying to the user.

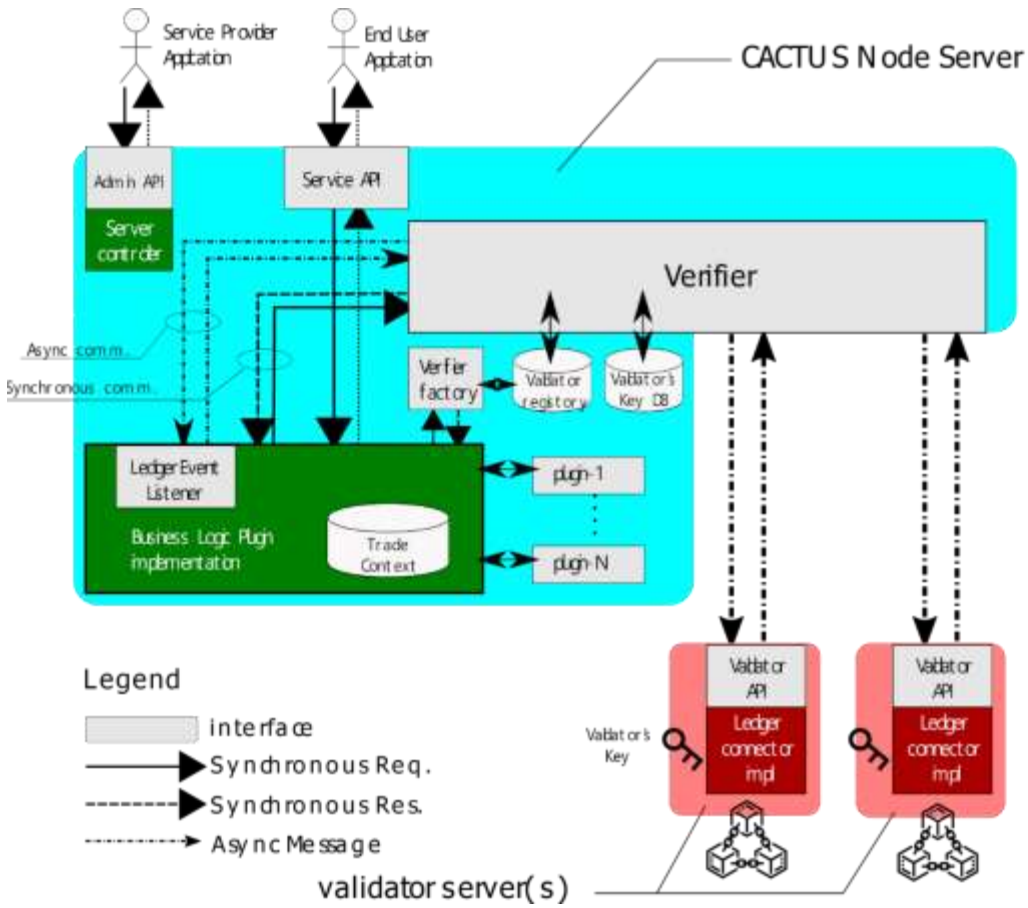

Figure 10: Hyperledger Cactus Architecture

The Cactus Validators, as can be seen in Figure 10, will play the role of the Connectors of the EGTN Blockchain Service architecture (see Figure 6).

6.1.4 Integration and interfaces within the EGTN Platform

The Blockchain component of the EGTN Platform acts as the integration point of the three different entities, the Connectivity Layer, the connected Blockchain systems of T&L organisations and the Analytics Layer. It also exposes data to the EGTN Dashboard to increase the visibility of inter-organisational workflows.

The backend Blockchain systems of the PLANET stakeholders are the main components that interact with the EGTN Blockchain to exchange static data about the dispatch, the destination, the freight volume/weight, and transactional data, such as logistics events. The data exchange is happening through commonly agreed smart contracts which act as the interface between the distributed ledgers of the stakeholders.

Another interface of the Blockchain component within the EGTN Platform is its connection with the IoT infrastructure through the Apache streaming service. As described in D2.1 and D2.3, IoT data is ingested into the Platform through an event streaming service (Kafka Cluster of 24TB), which aggregates heterogeneous data and makes them available to other services in a scalable and reliable manner. The Blockchain component registers to specific Apache Kafka topics to listen to logistics events, which in turn trigger smart contracts and inform automated and trustful decisions through their decentralised execution.

Finally, the Blockchain component interacts with the Prediction component of the Analytics layer to strengthen the reliability of the IoT data that trigger the smart contracts execution. As described in section 5.3 of D2.17, the combination of prediction models and smart contracts provides a sophisticated approach for reliable prediction, and it is a powerful tool that assists T&L stakeholders in several use cases.

More details on this topic, including the final version of the interfaces of the EGTN Blockchain component, with the IoT infrastructure as well as with the EGTN Dashboard, will be given in the final version of this deliverable.

6.1.5 Deployment

An initial version of the EGTN Blockchain service has been deployed in an experimental environment to assess the SOFIE Interledger component (repository can be found on GitLab[16]). Connections to dummy backend Blockchain systems simulating the real Blockchain systems of the LLs are - at the time of writing this report – work in progress. As described in the previous sections, a parallel activity has been initiated to investigate the Hyperledger Cactus codebase and identify the potential of migrating to this technology. The final version of the component will be deployed on the EGTN infrastructure and will be integrated with the rest of the services. The final specifications and the details on the technical implementation will be described in the final version of this deliverable (D2.16 due in month 30).

[16] EGTN BC Interoperability, https://gitlab.com/planet-h2020/egtn-bc-interoperability

7 The importance of Blockchain to the PI

The advent of Blockchain has brought modern T&L networks into a new era. Blockchain has the potential to redesign informational and financial flows, both of which supplement physical flows in the supply chain [10]. Most importantly, the adoption of the latest distributed ledger technologies in T&L networks laid the groundwork for innovative cross-organisational, collaborative, data sharing platforms.

At this point it is worth highlighting the key characteristics of Blockchain [11]:

- Decentralisation. Instead of one central node, control over a transaction is distributed among the peers.
- Digital Signature. Transactions take place using unique digital signatures that rely on public and private keys, which in turn offer an authentic proof of ownership.
- Chain of Blocks. Transactions are stored in blocks using cryptographic methods.
- Data integrity. Data cannot be tampered with, as complex algorithms and consensus ensure data immutability and safety.

The Physical Internet (PI) is an emerging T&L paradigm that can be defined as *an open global logistics system founded on physical, digital, and operational interconnectivity through encapsulation, interfaces, and protocols* [12] . It is driven by technological, infrastructural, and business innovation, hence the emergence of smart contracts and their application in modern T&L networks is highly intertwined with the evolution of the PI. Indeed, Blockchain features, and functionalities have the potential to meet PI implementation requirements as well as overcoming key PI barriers and deficiencies [13]. The main advantages behind the PI are summarised in Figure 11. Hasan et al. highlight that despite the advantages the PI may offer, it cannot continue relying on centralised networks nor on the existence of a leading authority. In this way, the PI will be able to proliferate only if it is a distributed and community driven concept and approach.

This is one of the main reasons why Blockchain and smart contracts have entered the scene [14]. The benefits of the PI become even greater through Blockchain technologies, as they offer better tracking of data across T&L networks, safer contract execution through smart contracts and increased security protection through encryption. Significantly, it is not only these benefits that make Blockchain a great enabler for the PI, but the nature and ethos of how Blockchain operates. On top of that, it offers the ability for existing disparate blockchain systems to interoperate and share data regarding shipping manifests, smart contracts, customs declarations, transport events and so on. This solution is offered using Blockchain Interoperability, an emerging research and technology topic that is a fundamental component of the EGTN Platform and the PLANET project.

Another important aspect that shall contribute to the success of the PI is the inclusion of data integrity, protection, and sovereignty. All T&L stakeholders as data providers expect to maintain sovereignty over sensitive data especially in relation to data consumers i.e., other T&L actors (authorities, customs, other logistics companies). However, data sovereignty concepts are currently mainly provided by (closed) communities with their own specific solutions [15]. In addition to this, ensuring the integrity and protection of the data across the supply chain is of paramount importance. The advantages of Blockchain, as mentioned above, offer the potential to overcome these challenges.

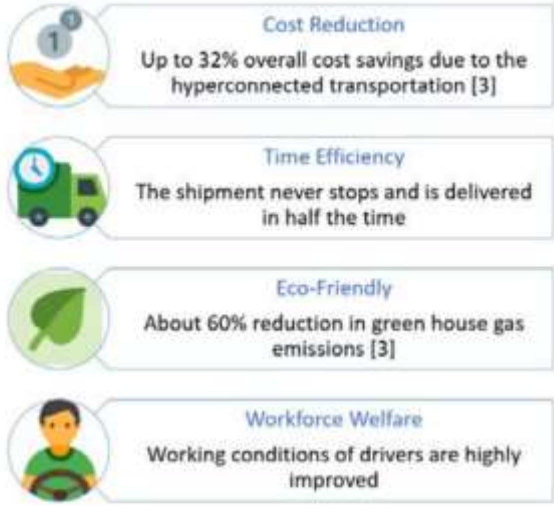

Figure 11: Advantages of the PI by Hasan et al. [14]

In this context, an important hurdle the PI needs to overcome is the current attitudes and mindset of T&L stakeholders. Companies still prioritise more traditional procedures in international and interorganisational exchanges. Convincing T&L actors to participate in the PI paradigm and showing them that it can be mutually financially beneficial to do so, while at the same time they can still maintain their competitive advantage and do not lose private data. In this sense, the data integrity characteristic of Blockchain can be instrumental, by increasing stakeholders' confidence in technology and willingness to share data. To unveil maximum advantages of blockchain in terms of rapid and trusted information sharing, a sufficient number of participants (critical mass) of a blockchain-based platform is required [16].

The real power of blockchain also lies in scenarios when changes or unforeseen events occur at some point within the supply chain and certain actions need to take place (e.g., rerouting of goods). Significant reductions in terms of time and overhead can be achieved using automated smart contracts. In such occurrences and given the appropriate permissions, any relevant actor (e.g., freight forwarder) may access the newly updated information. This is explained in more detail in D2.17 *EGTN smart contracts and associated PI motivated workflows in the context of SLA management v1*.

Significantly, the combination of Blockchain with other technological advancements such as IoT data and AI models can make the step towards the realization of the PI even smaller, by decreasing reaction time to such events (especially the use of real-time IoT data) and increasing efficiency in smart contract negotiations (through AI predictive models). Both solutions are integrated in the EGTN Platform along with Blockchain. Specific scenarios were developed, and solutions designed within the PLANET project to showcase the potential of the interplay between IoT, AI and Blockchain, which are included in D2.17.

The combination of Blockchain and the PI is also capable of achieving triple bottom line sustainability; that is social, economic, and more importantly environmental gains [10]. This is quite a milestone for a T&L network, as the existing TEN-T network is not linked to the EU's green strategy and does not consider innovations.

In short, many supply chain and T&L stakeholders use and exploit proprietary blockchain systems within their own, equally proprietary, ecosystems. This causes coordination and collaboration issues within the entire workflow. For instance, the clearance of goods in border crossings is often slow and susceptible to manipulation thanks to non-transparent border administration procedures and lack of coordination between different border agencies. Blockchain solutions and especially interoperability between different systems addresses such issues heads-on by simplifying, standardizing, and streamlining interorganisational workflows.

8 Conclusions and Work Ahead

The purpose of this report was to present the ongoing work on Subtask 2.5.1 Interfaces to multiple Proprietary Blockchain Systems for Seamless Global Trade. More specifically, this deliverable offered a detailed account of the methodology and current progress on the design and development of the EGTN Blockchain component.

The methodology followed involved an investigation into the current state-of-the-art on the topic of Blockchain interoperability, and a comparison of the proposed technical solutions based on the requirements and business scenarios that were developed in close collaboration with the partners of the Living Labs. Based on the selected technologies, the architecture of the EGTN Blockchain solution was developed, while the static and transactional data that are going to be exchanged between the different Blockchain systems via the EGTN component were selected in coordination with the LL partners.

The EGTN Blockchain component offers a solution that addresses the issues raised by the lack of collaboration and coordination between different T&L and supply chain stakeholders, as they all use their own, proprietary Blockchain solutions. More specifically, the solution offers integrity and immutability of the data throughout the entire workflow, automated and safe contract execution using smart contracts (more on this in D2.17), reduction of overheads and time delays, and a distributed and community-driven approach. In that regard, the EGTN Blockchain component is a great enabler for the PI concept.

The final version of this deliverable (D2.16) will report on the entire development process of the EGTN Blockchain component, as well as the findings and outcomes of its integration within the Living Labs. Moreover, it will include detailed information on the deployment process – so that interested parties can easily reuse or extend the developed solution - as well as any other findings that will be discovered along the way.

9 References

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