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

D2.16 Integration and Interoperability of proprietary Blockchain Systems for Seamless Global Trade Workflows final version

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1 According to PLANET's Quality Assurance Process

Table of Contents

List of Figures

List of Tables

Glossary of terms and abbreviations used

Abbreviation / Term	Description
ABI	Application Binary Interface
DSS	Decision Support System
eCMR	electronic Convention on the Contract for the International Carriage of Goods by Road
EGTN	EU-Global T&L Networks
FF	Freight Forwarder
HL	Hyperledger
LL1	Living Lab 1
LL2	Living Lab 2
UC1	Use Case 1
UC2	Use Case 2
LSP	Logistics Service Provider
SLA	Service Level Agreement
PI	Physical Internet
PoR	Port of Rotterdam
PoV	Port of Valencia
T&L	Transport & Logistics

1 Executive Summary

This deliverable is the second and final report on the integration and interoperability of proprietary Blockchain systems as part of the PLANET project. The report aspires 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 in which the use of smart contracts can be applied.

Blockchain Interoperability offers the potential to empower organisations across the entire T&L supply chain to collaborate seamlessly by enabling the interconnection of different Blockchain networks belonging to different stakeholders, based on different Blockchain frameworks and standards, and enabling data interoperability by developing a shared Data Model.

The report presents the design, architecture, interfaces, and implementation of the Blockchain 'front end' that is an integral component of the open cloud based *EGTN Platform*. This includes the presentation of the APIs between the different backend Blockchain networks, as well as the APIs towards the other EGTN components. The *EGTN Interledger Service* acts as a proxy between backend Blockchain systems and redirects traffic from one to another by translating heterogeneous events to a commonly agreed Data Model.

The design of the Blockchain solution was primarily influenced by the business requirements that were developed during close and frequent interactions with the partners from the Living Labs. These were presented in the initial version of this report (D2.15) and they are revisited in this final version.

The EGTN Interledger Service highlights the benefits of Blockchain technologies 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 PI.

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			
D2.16 Integration and Interoperability of proprietary Blockchain Systems for Seamless Global Trade Workflows final version		Chapters 5 and 6	Chapter 5 presents the EGTN Interledger Service that achieves interoperability between different Blockchain systems. Chapter 6 describes the information exchanged seamlessly between different Blockchain systems.
TASKS			
ST2.5.1 Interfaces to multiple Proprietary Blockchain Systems for Seamless Global Trade: PLANET acknowledges that large T&L and SC organizations have invested Blockchain applications to support their respective business needs. This task focuses on the need for EGTN actors to share data and functionality in order to operate in unified and consistent ways. 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.		Chapter 3 and 5	Chapter 3 presents the business objectives addressed by the Living Labs within PLANET. Chapter 5 presents the EGTN Interledger Service that achieves interoperability between different Blockchain systems.
The initial approach will be to specify several types of data, both static (master) and transactional for redirection of the common EGTN Blockchain, in line with T1.2.:		section 6.1, section 6.2, section 6.2.1	Section 6.1 describes the static and transactional data exchanged seamlessly between different Blockchain systems. Section 6.2 focuses on the common Data Model developed

• Shared master data serving as a single, jointly agreed and undisputed source of reference as to the types of key data shared and accessed by the EGTN participants • Events of key business milestones (such as the shipping of a product or the arrival of a vessel) and would subsequently trigger smart contracts as explained below. • Blockchain in Transport Alliance (BiTA) (https://www.bita.studio/) standards development for Blockchain application in transport (BiTAS Tracking Data Framework Profile and BiTAS Std 120-2019).			that enables data interoperability between the different systems. Section 6.2.1 presents the compliance of the EGTN solution with standards.

2.2 Deliverable Overview and Report Structure

The deliverable is organised in separate chapters as follows:

- Chapter 3 presents the business objectives addressed by the Living Labs within PLANET.
- Chapter 4 provides a brief description of the EGTN Platform and how the EGTN Blockchain Interoperability Service is an integral component of it. More details on the EGTN Platform can be found in D2.1 *Open EGTN Platform Architecture v1* and the upcoming D2.2 *Open EGTN Platform Architecture final* (due December 2022).
- Chapter 5 is a technical chapter. It lays out the architecture of the developed solution, it presents the APIs between different backend Blockchain networks, as well as the APIs towards different EGTN components.
- In the previous version of this deliverable (D2.15 *Integration and Interoperability of proprietary Blockchain Systems for Seamless Global Trade Workflows v1*) the static master data (e.g., Transport Orders) as well as transactional data of key business milestones were presented. Chapter 6 completes the work undertaken to define the data to be exchanged by presenting the events exchanged between the different Blockchain systems along with the common Data Model that assists in making data interoperable.
- Chapter 7 describes how the Blockchain Interoperability solution developed in PLANET can be tested in the project's Living Labs.
- Chapter 8 focuses on the benefits the EGTN Interledger service may offer towards the realisation of the PI, while it revisits the business objectives set out by the Living Labs (chapter 3) and how these were addressed in the project.
- Finally, Chapter 9 concludes this report by summarising the key outcomes of the EGTN Interledger service within the scope of PLANET.

3 Business Objectives of Blockchain Interoperability

Blockchain offers tremendous value to the T&L community as an innovative solution that has the potential to overcome traditional Transport & Logistics (T&L) challenges, such as the complexity of trade and customs processes, traceability of shipments, transparency, trust, and confidentiality between different stakeholders and so on. Transport & Logistics 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. Blockchain empowers all stakeholders by digitalising the entire T&L process and safeguarding all transactions through its security characteristics (e.g., data immutability).

In PLANET Blockchain takes one step further by unifying separate Blockchain systems, owned by different stakeholders and developed using different platforms and technologies, by employing a solution that enables Blockchain Interoperability. In this context two different Use Cases have been identified and are presented in the following sections. These focus on the exchange of transport documents in digital form in compliance with all characteristics set out by public authorities and according to regulations that recognise these as valid transport documents.

3.1 Business Objectives in PLANET

The following subsections present in detail the main business scenarios identified within the PLANET project.

3.1.1 Exchange of Transport Order

The main stakeholders behind the first use case are Fundación Valenciaport, Konnecta Systems, COSCO and DHL. As noted in the previous version of this deliverable, the main objective behind the use of this technology is to develop a Blockchain network capable of managing multiple interactions and transactions performed during import procedures, involving many different stakeholders, both public and private, such as port and maritime authorities, customs and other inspection bodies, transport companies, port terminals and rail terminals, freight forwarders, importers, and exporters, etc. Our work goes one step further by exploring how different, and often proprietary, Blockchain systems can become interoperable.

The main business objective focuses on secure data sharing starting from the port terminal to the hinterland, thereby allowing for more efficient and faster interconnectivity. Following this path, a further analysis of the environment has been carried out to detect possible new opportunities where Blockchain functionalities and interoperability can be applied to generate an added value to the different actors involved along the supply chain.

In the first use case Blockchain is employed to exchange shipping and logistics documents between different stakeholders, namely COSCO and DHL as it has proved to be an efficient and trustworthy solution thanks to its traceability and immutability capabilities. These interoperability tests have also allowed for the exploration of new potential lines of future business collaboration between different T&L stakeholders. The EGTN Blockchain Interoperability service connects and monitors events and transactions across all stakeholders within the supply chain, enabling transparent, immutable, reliable, and efficient information sharing.

Based on these points, Blockchain Interoperability within PLANET aims to meet the following objectives:

Process digitisation, thereby guaranteeing paperless transactions and reduction of operational time, avoiding the costs of paper-based processes and human error
Increase supply chain visibility by enabling access, exchange, and traceability of data in real-time conditions among multiple actors
Increase process efficiency/automation thanks to the use of smart contracts

Enhancement of customer experiences by bringing trust, transparency, and collaboration
Enhancement of operational productivity, leading to T&L cost reductions and revenue increase
Ease the scalability process for deploying different Blockchain solutions
Strengthen collaboration between different supply chain ecosystems
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
Promote stakeholder engagement

In this use case, two separate Blockchain networks are interconnected with each other. The first belongs to the Port Community, it is developed in Hyperledger Fabric, and it focuses on the Transport Order that is issued once cargo arrives by sea to Spain. The second Blockchain belongs to the Freight Forwarder, it is also developed using Hyperledger Fabric, and it traces the cargo for its mainland transportation until its last-mile delivery. The data flow and the associated smart contracts of this Use Case are described in detail in Deliverable D2.18 EGTN smart contracts and associated PI motivated workflows in the context of SLA management final version.

3.1.2 Integration and Synchronisation of Maritime ports

This is the second use case, in which the Port of Rotterdam employs a Blockchain-based platform for the digitalisation of documents required for logistics transaction across the trade corridors that are connected via the port. All shipments are exposed through the platform and all associated information and events become efficiently accessible, distributed, and secured in real time. In the context of PLANET, the platform facilitates the digitisation of the (Electronic) Road Transport Document ("e-RTD", or "e-CMR"), a document necessary for all road freight transport within the European Union.

This use case that has been under investigation within PLANET focuses on the synchronisation of maritime ports across the European peninsula. The main objective behind the Blockchain Interoperability within the PLANET project is to achieve a holistic single view of the real-time state of logistics across the EU. A single real-time view is crucial for the analysis and optimisation of T&L flows on a European level, as well as for the increase of automation towards a Physical Internet for autonomous operating transport vehicles. Several different stakeholders are involved across the supply chain (ports in different cities or countries, freight forwarders, last-mile delivery providers and so on) and each of them may have their own Blockchain network. PLANET aims at overcoming the silos of separate Blockchain systems that do not communicate with each other.

The real-time EU-level T&L view is achieved by aggregating the logistics events captured in regional proprietary Blockchain systems. Logistics events are notarised in immutable timestamped blocks of data that need to be shared with other Blockchain systems of different technologies. On top of that, the overarching EGTN platform should be able to aggregate all events into a single holistic view.

The first business objective that can be achieved by interoperable Blockchain systems is the optimisation of planning and warehouse operations, enabled through the real-time sharing of logistics events between regional systems, which in turn allows for anticipation of inbound and out-bound cargo and modalities.

The second business objective focuses on improving the quality and speed of transport document preparation to reduce delays in T&L. This is achieved with the digitalisation and tokenisation of previously paper-based transport documents – e.g., CMR, Bill of Lading, warehouse receipts etc.– that are owned and distributed between separate interoperable Blockchain systems.

4 The EGTN Platform

The PLANET project aims at changing the way T&L actors interact, share information, and optimise operational performance under the principles of the PI paradigm. The EGTN Platform is a key-enabling element towards the realisation of this vision.

Modern T&L networks face several challenges, such as traceability of shipments, trust, and transparency between different stakeholders, and complex trade and customs processes that are difficult to manage. Lately, several solutions have been introduced aiming at the digitisation of the supply chain process - Tilkal, Transparency-One, IBM Food Trust, Trust Your Supplier. In a similar context, the PLANET project and the EGTN Platform aims to empower T&L stakeholders by offering them tools, services and guidelines for shipping, routing, and PI node optimisation as well as to collaborate with other actors in the supply chain, within and across borders in a self-determined and secure way. Through this lens, the PLANET project does not aspire to develop just another "platform". Instead, its ambition is to develop an original blueprint accompanied with best practices that support T&L actors in the definition and implementation of clear digital strategies and to offer support in their physical operations.

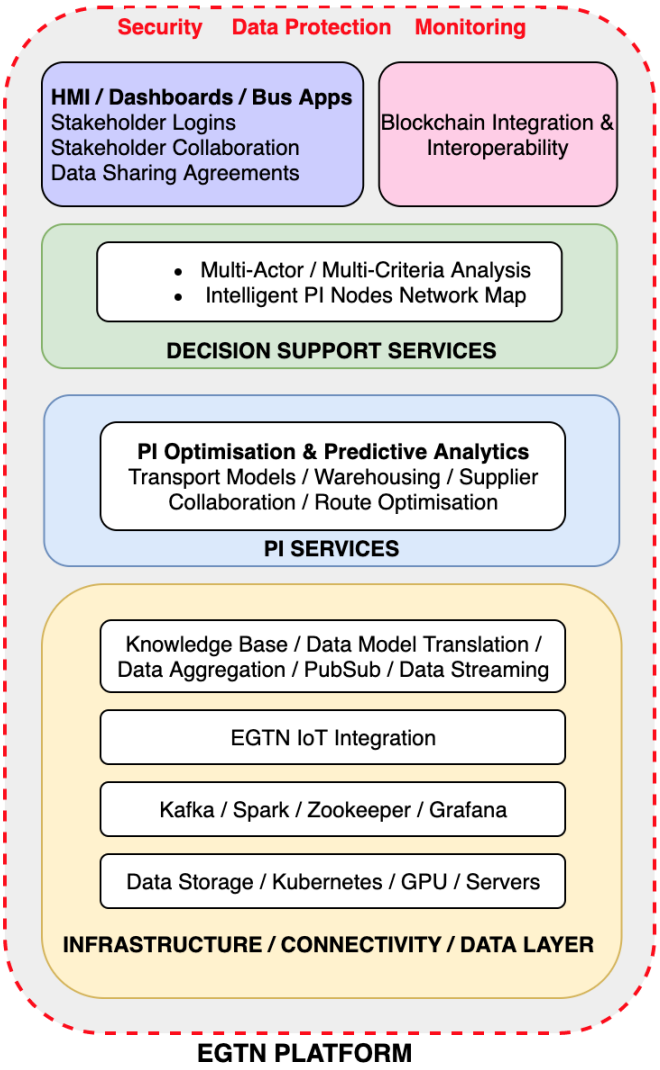

Figure 1: The EGTN Platform

The open cloud-based infrastructure that is developed is the cornerstone of the PLANET project, as it offers the foundation on top of which the EGTN Platform and the EGTN services are developed, as shown in Figure 1. The

unique combination of technologies and models includes among others: Blockchain services for interoperability of backend systems and intelligent forecasting algorithms for predictive analytics. More, specifically, the EGTN Platform Blockchain interoperability service aims to breakdown the silos of the different Blockchain systems/partners to support critical interorganisational trade workflow, while the use of smart contracts facilitates automated and paperless negotiations. The EGTN users can take advantage of these cutting-edge technologies along with the unique set of features offered by the platform, as it:

1. Improves customs control through the digitisation of the process
2. Increases trust but also confidentiality between different partners
3. Ensures the authenticity and the integrity of the data shared between partners

One of the key technological enablers for increasing visibility in logistics is the real-time data ingestion pipeline which can accumulate data from a plethora of data sources, ranging from IoT sensors to weather and traffic data. In this way, critical information such as waiting times, order status, or even delays in vessel journeys can be fed into the platform and used for offering T&L actors real-time automated decisions, such as dynamic contract activation. Moreover, the EGTN Platform provides T&L actors data-driven decision support services related to synchromodality, based on optimisation models and predictive analytics. More precisely, these services include corridor route optimisation, forecasting services for warehouses and ports and supplier collaboration analytics. Another key topic that PLANET project aims to address is the alignment of the EGTN platform to the PI roadmap. It addresses key PI challenges by using intelligent forecasting such as predicting the use of resources in a PI node or rerouting cargo in case of congestion in one of the corridor ports.

Other key features of the platform include its modelling and simulation capabilities of analysing T&L and ICT innovations that position emerging technologies (e.g., Blockchain and IoT) as contributors to the Physical Internet, while its Human Machine Interfaces set a new standard for a more open and inclusive ecosystem where logistics partners share infrastructure and data and, in this way, overcome the silos of existing T&L systems and organisations.

The EGTN Platform aspires to be an inclusive and powerful platform, as it can be adopted by any size of T&L actor or company. As such, it is not limited to only large enterprises with expensive IT budgets, therefore taking a step closer to the realisation of the Physical Internet paradigm.

5 EGTN Interledger Service

The EGTN Interledger Service is a Blockchain "front-end" that is available on the EGTN Platform to unify multiple back end Blockchain systems and to support interorganizational and intercommunity trade workflows. It takes advantage of cutting edge microservices provided within the EGTN Platform i.e., Artificial Intelligence (AI) Analytics, Decision Support Systems (DSS). Moreover, it consumes diverse datasets available in the EGTN Data Lake to enable advanced functionality such as forwarding of logistics events between disconnected communities, cross-checking the validity of events through IoT data and automatic generation of smart contracts based on AI predictions, as shown in Figure 2, where three different blockchain communities are connected through the EGTN Interledger Service and Smart Contracts.

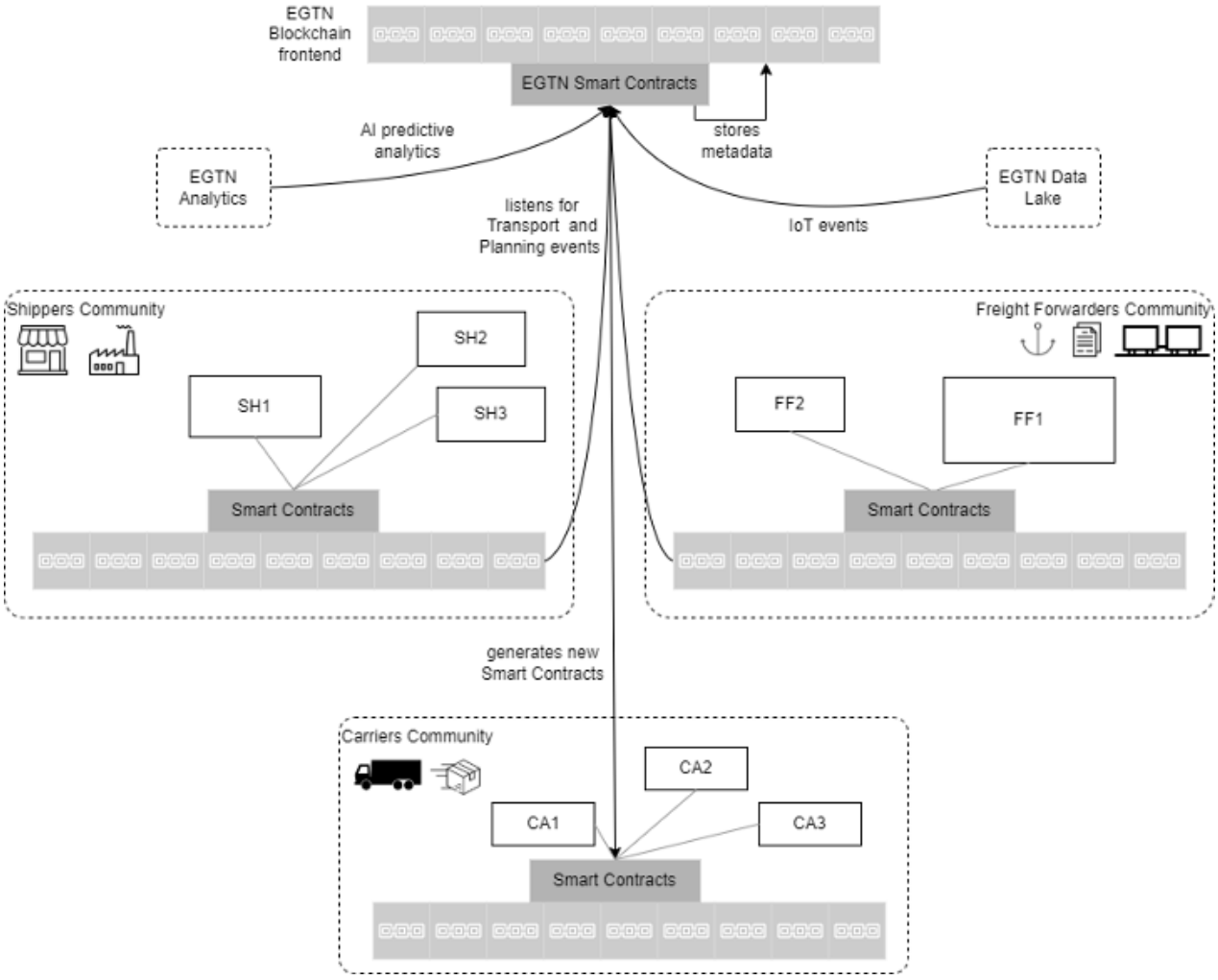

Figure 2: EGTN Interledger Service and Smart Contracts Overview

The rest of the section analyses the final version of the service as deployed in the EGTN Platform together with its internal design, components, and APIs.

5.1 Mapping Interoperability Requirements

Blockchain interoperability requirements have been presented in the previous version of this deliverable, see D2.15 section 5.2, based on a Usage-Actors-Requirements approach. We describe here below, in Table 2 and Table 3, the mapping between each requirement into the corresponding element of the EGTN Interledger Service.

Business Scenario	ID	Functional Requirement	Respective EGTN Interledger Service functionalities
A., B.	A.1, B.1	Provide interfaces to interconnect different Blockchain systems	The EGTN Interledger Service provides standardised interfaces, aka connection profiles (see more in section 5.3), to connect with backend Blockchain systems of different technologies, such as HL Fabric and Ethereum.
	A.2, B.2	Allow redirection of transactions from/to different Blockchain systems	The EGTN Interledger Service handles the redirection of logistic events from one backend Blockchain system to the other Blockchain systems connected with the Interledger service. The service manages the correct forwarding of messages towards avoiding duplication of information while also managing the disapproval/rejection of a transaction from a Blockchain system.
	A.3, B.3	Provide interfaces to the IoT layer to consume events and data that will trigger smart contracts	The EGTN Interledger Service provides connectors to the EGTN Connectivity Layer to consume IoT events coming from smart logistic assets and trigger smart contracts, see more in section 5.4.
	A.4, B.4	Define common data structures to be exchanged	The EGTN Interledger Service translates messages coming from heterogeneous Blockchain systems and following different standards (e.g., GS1), to a common Data Model that is consumed by the different modules of the service and also shared with the rest of the EGTN Services such as the Dashboard, see more in section 6.2.

Table 2: Business Scenario A and B requirements mapping with the EGTN Interledger Service functionalities

Business Scenario	ID	Functional Requirement	Respective EGTN Interledger Service functionalities
C.	C.1	Enable interfaces with the EGTN dashboard	The EGTN Interledger Service enables interfaces with the EGTN Dashboard through the EGTN Event Streaming Service by defining standardised messages that are generated by the Interledger Service and consumed by the Dashboard, see more in Section 5.5.3
	C.2	Forward incoming transactions to the EGTN dashboard	The EGTN Interledger Service outputs logistic events and alarms for agreements violation to the EGTN Event Streaming Service (or to other parts of the EGTN Data Lake such as the MongoDB) which are then consumed by the EGTN Dashboard and shown in the HMIs, see more in Section 5.5.3.

	C.3	Enable interaction of the stakeholders with the backend Blockchain systems	The user enters a certain shipment id/GSIN to retrieve the data/contracts they are interested in. They will be able to download, save or send the retrieved data to other users.

Table 3: Business Scenario C requirements mapping with the EGTN Interledger Service functionalities

5.2 Design, Architecture & Internal Modules

The final version of the EGTN Interledger Service architecture is presented in Figure 3. The design of the service was introduced in the first version of this deliverable (D2.15) and as stated there, the high-level software architecture, the external APIs and the data exchanged are not changed in the final version of this deliverable. However, important additions have been made towards a more comprehensive and secure component.

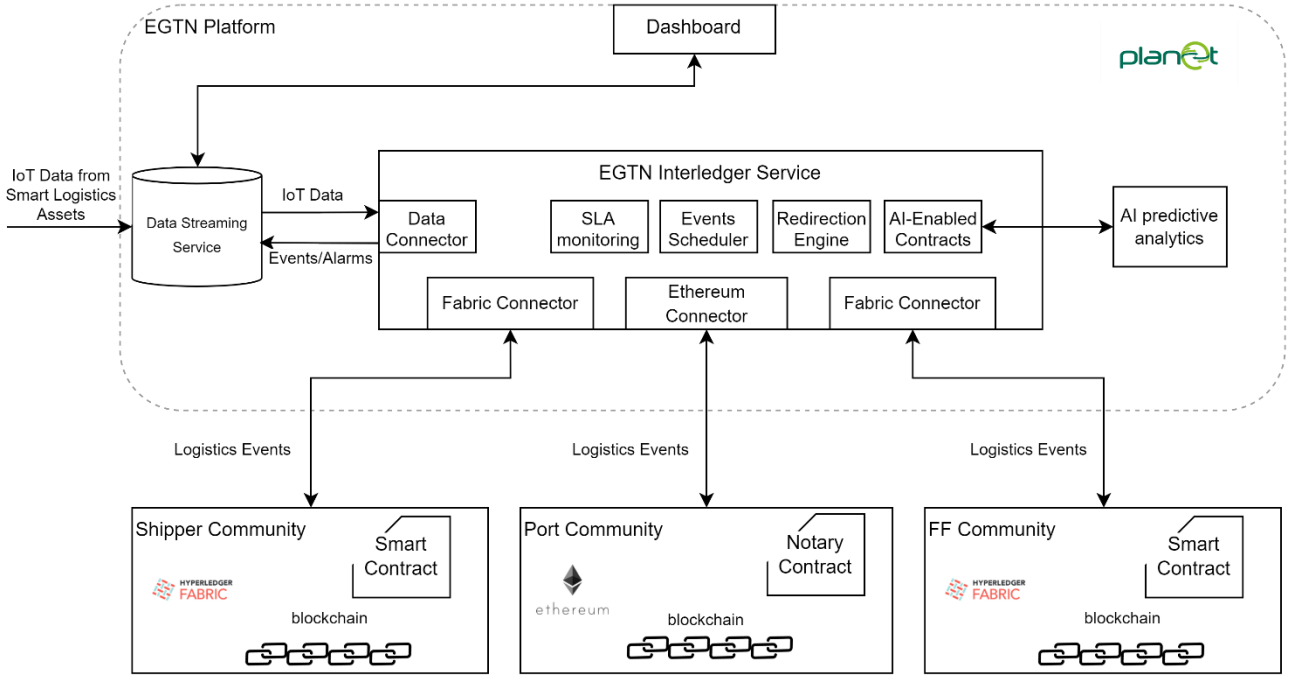

Figure 3: The EGTN Interledger Service Architecture

The latest developments on the EGTN Interledger Service result to a secure, flexible, and lightweight service that plays a fundamental role in the EGTN Architecture, which is to enable interoperability between T&L stakeholders. The internal modules of the final architecture are listed below:

- **SLA monitoring:** This module handles the monitoring of predefined SLA agreements between T&L actors using smart contracts and IoT data. The IoT data triggers the smart contracts to emit alarms and events upon a contract violation or contract fulfilment, while the events are forwarded to all the connected Blockchain systems to increase the visibility in the entire supply chain. More details on the smart contracts can be found in the other deliverable of T2.5, the D2.18 *"EGTN Smart Contracts and associated PI motivated workflows in the context of SLA management final version"*.
- **Events scheduler:** This module schedules the events to be forwarded by confirming the correct order and by deciding if an event needs to be forwarded or not.

- **Redirection Engine**: This module is responsible for relaying data between two Blockchain connectors according to the events scheduler output. It checks for duplicate events and ensures atomic event receiving from the Blockchain connectors.
- **Data connector**: This is a connector to the EGTN Event Streaming Service, aka an Apache Kafka deployment, to i) consume IoT data from sensors deployed in the smart logistic assets and ii) push events generated by the redirection engine or/and the events scheduler. More specifically, the Event Streaming Connector acts both as a consumer and a producer for specific Kafka topics, which are declared via a configuration file and will be later explained in the deployment section (see 5.6). Moreover, the Data connector allows the connection with a MongoDB to enable the storage and management of data more suitable to this context, such as information about the SLA agreements.
- **Blockchain connectors**: Connectors to backend Blockchain systems supporting multiple Blockchain technologies, including HL Fabric, Ethereum and HL Indy. The connectors receive transfer requests either from the core modules or from an Initiator Blockchain and are responsible for relaying the transfer to the Responder Blockchain by executing smart contract functions.
- **AI-enabled smart contracts**: This module takes advantage of the output of AI predictive analytics services deployed in the EGTN Platform and delivers a state-of-the-art meta-service for improved management of warehouses in the PI. More details on the D2.18.

5.2.1 Achieving Blockchain Interoperability through the SOFIE component

The service is based on one of the outputs of the SOFIE H2020 project[2] i.e., the Interledger component which is a framework for achieving Blockchain interoperability. The EGTN Interledger Service integrates the open-source codebase of the SOFIE component, as can be found on GitHub[3]. While it takes advantage of the powerful yet lightweight functionalities of the SOFIE component, the EGTN Interledger Service fixes bugs, improves its performance and further enhances the codebase with new features, such as the cross-checking of logistics events against IoT data. More specifically the changes/improvements done in the Interledger component of the SOFIE project are:

1. Ethereum connector code refactoring towards more stable functionality when connected with an Ethereum network
2. Upgrade of the Fabric event listener to register to the chaincode events[4] instead of the block events to improve the throughput performance of the service. This modification enables the Interledger component to listen for every event within a block committed to the connected ledger, which consists of multiple transactions (a transactions might or might not contain an event). The previously used block listener mechanism constrained the throughput of the component by allowing listening only for the first event match of a block added in the HL Fabric ledger.
3. Enhancement with a connector to an Apache Kafka deployment to consume IoT events, produce trusted meta-events and monitor SLA agreements between shippers, carriers, and freight forwarders
4. Definition and integration of a common Data Model, specifically focused on the T&L domain, to enable easier data redirection between backend Blockchain systems
5. Enhancement with a connector to a MongoDB to manage agreements between T&L actors and allow the Dashboard to visualise them.

[2] Horizon 2020 SOFIE - Secure Open Federation for Internet Everywhere, https://cordis.europa.eu/project/id/779984
[3] SOFIE Interledger component, https://github.com/SOFIE-project/Interledger
[4] HL Fabric chaincode events, https://hyperledger-fabric.readthedocs.io/en/latest/peer_event_services.html

5.3 APIs to multiple Blockchain Systems

The EGTN Interledger Service uses connectors as the interfaces to multiple backend Blockchain systems. The Connectors provide a standardised and at the same time straightforward way to connect with heterogeneous Blockchain frameworks using configuration files. The Interledger Service supports connection with HL Fabric, Ethereum and Indy networks, which covers most of the use cases that can be met in the T&L domain.

The HL Fabric Connector uses a HL Fabric SDK (the Python one[5]), acting as a client that interacts with Fabric networks, by invoking specific chaincode functions. For this to happen, there are specific requirements from the SDK side.

First, a path to a connection profile is needed. The connection profile (in json format) describes the HL Fabric network's components to which the Interledger Service is going to send its requests, along with the client's credentials that are going to be used and includes information about the HL Fabric network topology (peers, orderers, CAs etc) providing a starting point for network discovery. Moreover, the connection profile contains the paths of the credentials of the user that is going to invoke the necessary chaincode functions.

In addition to the connection profile, the HL Fabric Blockchain Connector needs additional information i.e., the channel name on which the chaincode is deployed along with the actual chaincode's name and the chaincode's version. Figure 4 presents a configuration file that contains the paths to every necessary file needed by the EGTN Interledger Service to interact with a HL Fabric network.

```
type = fabric
network_profile =
/home/fotis/go/src/gitlab.com/inlecom/planet/dhlLedgerPlatform/scripts/output/netwo
rk-1.json
channel_name = mychannel
cc_name = dhl
cc_version = v1.0
org_name = org1.example.com
user_name = Admin
peer_name = peer0.org1.example.com
ledger_name = FF
```

Figure 4: Configuration File for a HL Fabric network

In case of an Ethereum network, the requirements differ. First, the EGTN Interledger service requires a Web3 provider to create the necessary RPC calls and forward them to the Ethereum node. Either Geth[6] or Infura[7] could be used as the Web3 provider of an Ethereum Connector, while an an Ethereum account is needed to interact with a specific smart contract. The Ethereum account should have a sufficient balance of gas to be able to interact with the smart contract. Gas refers to the unit that measures the amount of computational effort required to execute specific operations on the Ethereum network. In addition to this, a private key is needed for the specific account to sign each transaction. Moreover, the smart contract's address is needed as well as the path to the ABI (Application Binary Interface) file of the smart contract. The ABI file consists of a json representation of the smart contract's functions signatures and variable declarations, defining the methods and the structures that the caller can use to interact with the binary contract. All the above are presented in the configuration file example found in Figure 5.

[5] Hyperledger Fabric SDK Python, https://github.com/hyperledger/fabric-sdk-py
[6] Go Ethereum (Geth), https://geth.ethereum.org/
[7] Infura, https://www.infura.io/

```
type = ethereum
url = https://goerli.infura.io/v3/07fd7ece9d554b8a83c982263a3688e7
private_key = 0x1a8c738734d996d48acb8afa8a8d68c417e919789607c19b0fc59df22e967393
minter = 0x0da6c548c084a3d7ee2cd12e1e4068bfd68f2e91
contract = 0x108Cec996C8e6cd96EAD92ecFe250eB447279216
contract_abi = /home/fotis/truffle/build/contracts/Cargos_simulation.json
ledger_name = PoR
```

Figure 5: Configuration File for an Ethereum Network

5.4 APIs to the EGTN Event Streaming Service

The EGTN Interledger Service takes advantage of the heterogeneous datasets within the EGTN Platform to trigger smart contracts and inform decisions. To this end, it uses a Data Connector module, which acts both as a producer and consumer of the EGTN Data Streaming Service, namely the Kafka deployment in the EGTN Platform.

As per the consumer role, the Service subscribes to a Kafka topic and reads IoT data from sensors, while it keeps track of every cargo asset that is added to the EGTN Interledger throughout its lifecycle. In addition, the consumer part of the Data Connector features advanced mechanisms for the efficient management and filtering of the IoT messages according to their type, such as measurements, arriving events and departing events etc. This enables searching the data in a parallel way minimising unnecessary access to the messages in the Kafka topic. It is worth mentioning that the consumer assumes that every message in the topic is in a JSON format to be valid. The producer's part of the Data Connector consists of either pushing a trusted meta-event or an alarm event to the specified Kafka topic.

Finally, the Data Connector is configurable through the general configuration file of the EGNT Interledger Service. The URL of the Kafka broker to be connected to, together with the topic used by the Data Connector, are exposed in this file, see more details in 5.6. Moreover, the communication between the Data Connector and the Kafka service is protected using SASL/PLAIN authentication, which is a username/password authentication mechanism to allow secure client requests.

5.5 Relation with other EGTN Services

The EGTN Interledger Service lies at the centre of the EGTN Architecture and contributes towards allowing the interoperability of T&L backend systems by enabling trustful exchange of data between them. As described in this section, the Service interfaces with all the layers of the architecture, from the connectivity layer to the PI Services, the Decision Support Services, and the HMI layer, namely the Dashboard.

5.5.1 Connectivity Layer

As explained in 5.4, the EGTN Interledger Service communicates with the Connectivity Layer of the EGTN Platform, which includes the Data Lake and the Events Streaming Service. The Data Lake is employed to store data such as the agreements that are being monitored by the EGTN smart contracts. A screenshot of the MongoDB database can be found in Annex I.

The Events Streaming Service includes an Apache Kafka deployment with topics for each data source, including but not limited to last mile deliveries, IoT data from sensors deployed in smart logistics assets and IoT events following the EPCIS standard[8]. The security and privacy of the data shared through the Kafka topics is guaranteed using access control lists that allow permissioned access only by specific actors. The EGTN Interledger Service has "read" access to the bc-events and the ll1-iot (sensor readings from LL1) topics, while it has "write" access only to the bc-events topic as it needs to share Blockchain events.

[8] EPCIS standard, https://www.gs1.org/standards/epcis

5.5.2 PI Predictive Analytics & Decision Support Services

The PI Predictive Analytics layer includes route optimisation services, warehouse predictive analytics and other AI models to enable smart connectivity in the PI Hubs. The EGTN Interledger Service connects with the Demand Forecast service and the Booking Capacity DSS and creates a meta-service for generating AI-enabled smart contracts to streamline warehouse management. More details about each of the EGTN Services can be found in D2.2 and the respective deliverables of each WP2 task.

The Demand Forecast Service forecasts incoming pallets in a warehouse based on historical datasets. The prediction is not just a single number (i.e., the number of pallets) but instead it outputs a time series prediction with confidence intervals for a certain period e.g., for a 10-day prediction there is a higher degree of uncertainty in the first days while the uncertainty decreases as we move towards the last day.

This time series prediction is consumed by the Booking Capacity DSS service (see more in D2.2 and the D2.12) which determines how much trucking capacity to book 10 days and 3days ahead based on booking and cancellation fees.

Finally, the AI-enabled Smart Contracts Service of the EGTN Platform automatically generates and installs new smart contracts between the involved actors from the FF and the Carrier communities which minimises both costs and time, compared to paper-based, non-automatic processes. More details are found in D2.18.

5.5.3 EGTN Dashboard

The Human Machine Interfaces (HMIs) provide a unified integration of the EGTN Platform components and offer visualisation of T&L data from different sources, which in turn shall assist the decision-making process of T&L stakeholders.

The HMIs go beyond a mere presentation of numbers and analytics. Instead, they are based on the work undertaken in the PLANET work packages to draw requirements and anticipated support to the Supply Chain actors. Supply chain visibility to the evolving networks has been key to the design considerations. Technological advancements, solutions, and concepts such as the Physical Internet and Blockchain have also been pivotal to the final HMI development.

The HMIs include data collection and analytics and a secured dashboard that offers the users with visualisations in a user-friendly environment, including different access roles, customisable templates, and value-driven insights. Simplicity, adaptability, and security have been key requirements during the design of the module and reflect the need for intuitive human and machine to machine interfaces.

The dashboard toolkit contains alert notifications and the ability for the user to set thresholds in selected data categories, enables the creation of new user roles and/or adjustments on existing ones, a wealth of information and graphical representations of performance indicators and metrics and a robust filtering capability for a fast and accurate analysis of figures.

Dashboard features

The EGTN Interledger Service consumes data and logistics events by connecting to different Blockchain networks. In this process, it generates metadata and triggers/validates/invalidates smart contracts, which effectively monitor Service Level Agreements (SLAs) between logistics entities. In this manner, processes become automated and paper-based documentation is avoided.

As Figure 6 shows, the HMIs present the output of the Blockchain service in the ‘View documents’ function. The user enters the shipment id/GSIN code (following the latest GS1 standards) and they are presented with the

smart contract for that particular shipment, Figure 7. The user is also presented with the associated logistics events i.e., a series of information on the shipment coming from the involved Blockchain systems, as the figures below illustrate. Based on the incoming IoT data the user may view whether the cargo has been received/unloaded to a certain location as per the agreed transaction.

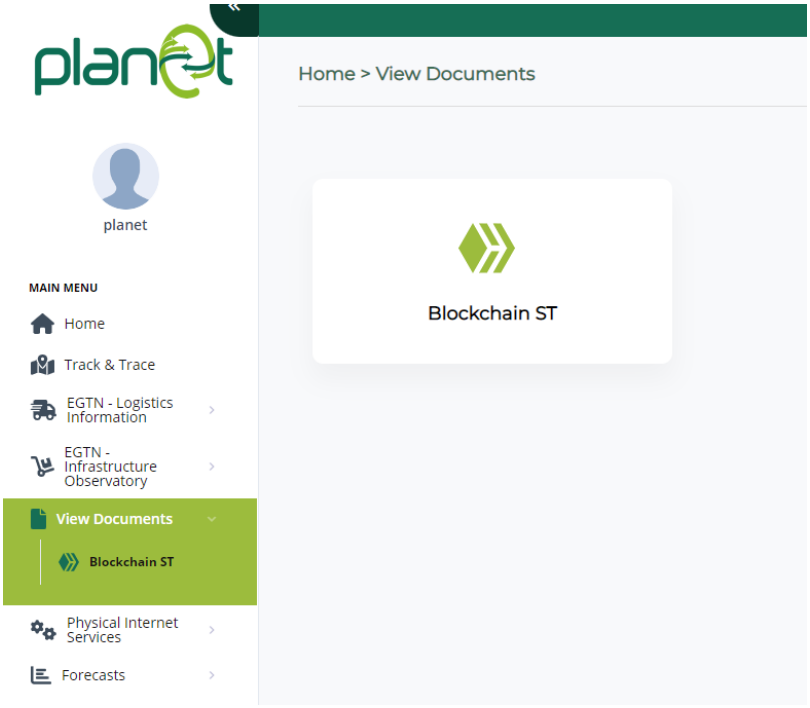

Figure 6. Blockchain-dedicated page in the PLANET HMIs.

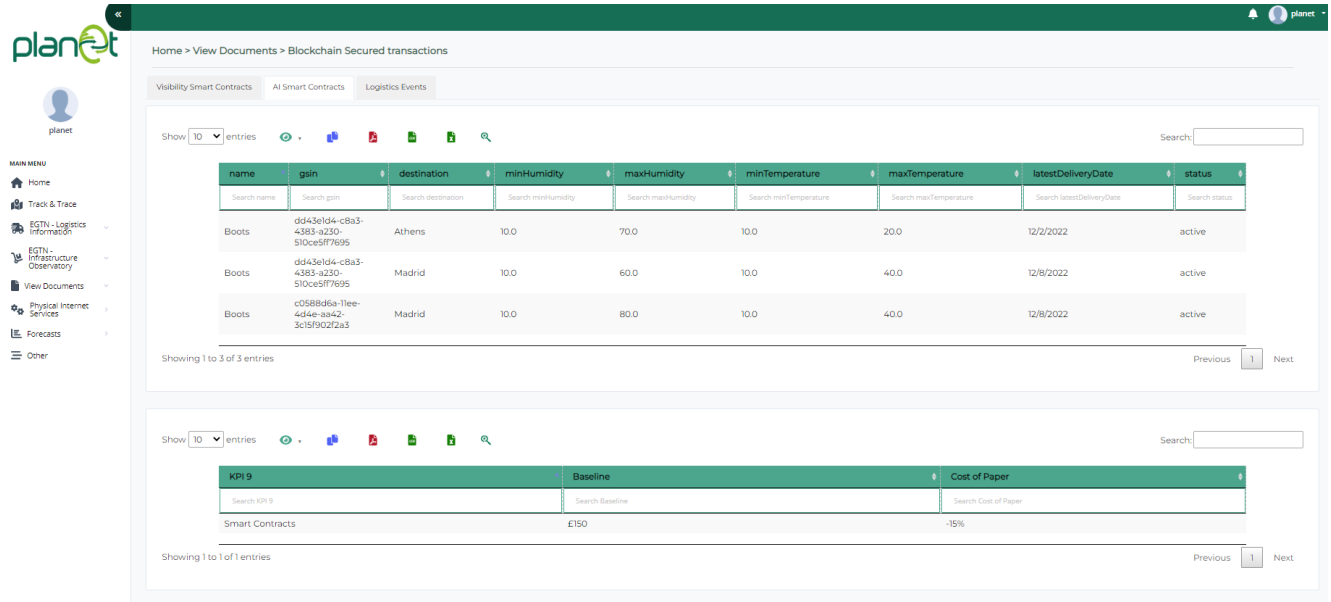

Figure 7: Tab for AI-enabled Smart Contracts in the EGTN Dashboard

5.6 Deployment

The EGTN Interledger Service has been uploaded on the PLANET's GitLab account[9]. The src/interledger directory contains the code implementing the software modules of the EGTN Interledger service and the connectors to Blockchain and the Kafka service. The Interledger service has been packaged in a Docker container to enable its easy deployment and configuration using an environment variables file.

The EGTN Interledger service Docker container takes as input a configuration file (.env file), which contains all the information needed to instantiate the service and connect to the backend Blockchain networks and the Kafka service. An example of the configuration file together with a brief description of each section can be found below, where two HL Fabric networks are connected and the "left" and "right" terminology is used to identify the two backend Blockchain systems.

```
# environment for interledger configuration
COMPOSE_PROJECT_NAME="notifications"
KAFKA_BROKER="kafka:9092"
TOPIC_CONSUMER="ll1-iot"
TOPIC_PRODUCER="bc-events"
POV_LATITUDE="43.7127089"
POV_LONGITUDE="10.4189768"
DHL_WAREHOUSE_LATITUDE="40.4603691"
DHL_WAREHOUSE_LONGITUDE="-3.8305261"
CITY_LOGIN_LATITUDE="40.3946417"
CITY_LOGIN_LONGITUDE="3.9195721"

### RIGHT NETWORK CONFIG

# for Ethereum network
# general for right network
RIGHT_NETWORK_WEB3_URL=https://goerli.infura.io/v3/07fd7ece9d554b8a83c982263a3688e7
RIGHT_NETWORK_PRIV_KEY=0x1a8c738734d996d48acb8afa8a8d68c417e919789607c19b0fc59df22e
967393
RIGHT_NETWORK_MINTER=0x0da6c548c084a3d7ee2cd12e1e4068bfd68f2e91
RIGHT_NETWORK_CONTRACT_ADDRESS=0x108Cec996C8e6cd96EAD92ecFe250eB447279216
# right network file paths
RIGHT_ABI_PATH=/home/fotis/...


### LEFT NETWORK CONFIG

# for Fabric network
# general for left network
RIGHT_NETWORK_PATH=/home/fotis/go/src/gitlab.com/inlecom/planet/dhlLedgerPlatform/s
cripts/fabric-samples/first-network
RIGHT_ORDERER_PORT=7050
RIGHT_P0O1_PORT=7051
RIGHT_CAO1_PORT=7054
RIGHT_ORDERER_NAME="orderer.example.com"
RIGHT_ORDERER_URL="localhost"
RIGHT_CA_NAME="ca.org1.example.com"
RIGHT_CA_URL="localhost"
RIGHT_PEER0_NAME="peer0.org1.example.com"
RIGHT_PEER1_NAME="peer1.org1.example.com"
RIGHT_PEER_URL="localhost"
RIGHT_ORG_MSPID="Org1MSP"
# left network file paths
```

[9] EGTN Interledger Service open-source repository, https://gitlab.com/planet-h2020/egtn-bc-interoperability

```
RIGHT_NETWORK_USER_TLS_PATH=/home/fotis/go/src/gitlab.com/inlecom/planet/dhlLedgerP
latform/scripts/fabric-samples/first-network/crypto-
config/peerOrganizations/org1.example.com/users/Admin@org1.example.com/msp/signcert
s/Admin@org1.example.com-cert.pem
RIGHT_NETWORK_USER_PK=/home/fotis/go/src/gitlab.com/inlecom/planet/dhlLedgerPlatfor
m/scripts/fabric-samples/first-network/crypto-
config/peerOrganizations/org1.example.com/users/Admin@org1.example.com/msp/keystore
/7679db80765ec9b93ac54c628444a576cebb1c13f5ccf001fcdd85c176935925_sk
RIGHT_NETWORK_ORDERER_TLS_PATH=/home/fotis/go/src/gitlab.com/inlecom/planet/dhlLedg
erPlatform/scripts/fabric-samples/first-network/crypto-
config/ordererOrganizations/example.com/tlsca/tlsca.example.com-cert.pem
RIGHT_NETWORK_PEER_TLS_PATH=/home/fotis/go/src/gitlab.com/inlecom/planet/dhlLedgerP
latform/scripts/fabric-samples/first-network/crypto-
config/peerOrganizations/org1.example.com/peers/peer0.org1.example.com/msp/tlscacer
ts/tlsca.org1.example.com-cert.pem
RIGHT_NETWORK_CA_TLS_PATH=/home/fotis/go/src/gitlab.com/inlecom/planet/dhlLedgerPla
tform/scripts/fabric-samples/first-network/crypto-
config/peerOrganizations/org1.example.com/ca/ca.org1.example.com-cert.pem
# other for left network
RIGHT_CHANNEL_NAME="mychannel"
RIGHT_CC_NAME="dhl"
RIGHT_CC_VERSION="v1.0"
RIGHT_ORG_NAME="Org1"
RIGHT_USER_NAME="Admin"
RIGHT_PEER_NAME="peer0.org1.example.com"
```

Figure 8: EGTN Interledger configuration file

As shown in Figure 8, the .env file first requires general configuration information about the Kafka installation that will be connected to consume and ingest events i.e., the Kafka URL and topic. Then it requires specific variables for each of the networks (left and right) to be connected to:

1. General network topology details, such as connection URLs and the path for the connection profiles of the network (*"general for left/right network"*)
2. Paths to the certificate files (*"left/right network file paths"*)
3. Other connection details (only for HL Fabric networks) such as contract address, name, and version (*"other for left network"*)

More technical details on the installation and usage of the EGTN Interledger Service can be found in the Readme file of its GitLab repository[10].

[10] EGTN Interledger Service open-source repository, https://gitlab.com/planet-h2020/egtn-bc-interoperability

6 Data for Redirection between Blockchain Systems

In the first version of this deliverable (D2.15), different types of data were specified for redirection through the EGTN Interledger Service, such as static master data serving as a single, jointly agreed and undisputed source of reference (e.g., Transport Orders) as well as transactional data of key business milestones (e.g., the shipping of a product or the arrival of a vessel) that subsequently trigger smart contracts as described in D2.18.

In this section, we present the logistics events exchanged through the EGTN Interledger Service, which carry information to increase the visibility of the supply chain and streamline inter-organisational processes. The information carried by the events follow a common Data Model which is also described in the following subsections.

6.1 EGTN Events

The EGTN Interledger Service redirects transactional data of key business milestones, aka logistics events, both to the connected Blockchain systems and to the rest of the services within the EGTN Platform. It also uses various data sources such as i) sensor readings from the EGTN Data Streaming Service or ii) data from other legacy systems to cross-check the logistics events reported by the individual Blockchain systems and emit trusted meta-events. For example, if a "container arrived at the port" event agrees with the GPS coordinates from the sensor attached on the container itself, then a trusted meta-event is emitted from the EGTN Interledger Service.

In addition, it monitors SLA agreements using smart contracts that emit events upon contract violation, contract fulfillment or any other aspect of the agreement lifecycle (see more details on D2.18). The smart contracts are fed with IoT data coming from the sensors deployed on the logistics assets and compare these measurements with thresholds defined by the agreements. In case the measurements exceed a threshold, the smart contract emits an alarm event that includes all the relevant information to enable the involved actors to act. Table 4 lists all the events supported by the EGTN Interledger Service.

ID	EVENT NAME	Emitted by	Type
1	ContainerArrivalPort	Port/Shippers Blockchain community	Logistics event
2	ContainerReadyForTransport	Port/Shippers Blockchain community	Logistics event
3	EGTNContainerReadyForTransport	EGTN Interledger Service	Trusted meta-event
4	ContainerDeparted	Port/Shippers Blockchain community	Logistics event
5	ContainerPickup	FF/Carrier Blockchain community	Logistics event
6	EGTNContainerDeparted	EGTN Interledger Service	Trusted meta-event
7	EGTNContractViolation	EGTN Interledger Service	Alarm event
8	ContainerArrivalWarehouse	FF/Carrier Blockchain community	Logistics event
9	EGTNContainerArrivalWarehouse	EGTN Interledger Service	Trusted meta-event
10	ContainerUnload	FF/Carrier Blockchain community	Logistics event

11	EGTNContainerUnload	EGTN Interledger Service	Trusted meta-event

Table 4: EGTN Interledger Service Events

The events of type "Logistics event" are emitted from one of the connected Blockchain communities, i.e. the Shippers or the FF or the Port community in the PLANET context. These events are pulled by the EGTN Interledger Service and compared with other data trust anchors such as IoT data and/or legacy systems. This results in five trusted meta-events emitted by the service, following the naming convention EGTNContainerXXX with the XXX being various logistics business milestones.

All the trusted meta-events listed in Table 4 are pushed to a specific topic of the EGTN Events Streaming Service (the Kafka Service) so that any interested party within the EGTN Platform can access them by registering to this same topic. For example, the EGTN Dashboard registers to the Kafka topic, namely the bc-events, it consumes the events and shows the events' payload in a dedicated tab of the EGTN Platform Dashboard, see more details in 5.5.3.

An example of an EGTN event in JSON format can be found in section 6.2 together with the description of each field of the Data Model of its payload.

6.1.1 Events description

This subsection lists each event that is managed by the EGTN, either consumed by or generated. All events can be found in the Kafka topic *bc-events* of the EGTN Events Streaming Service.

- **ContainerArrivalPort**

  Description: This is an event that is received from a connected Blockchain system of a port, upon the arrival of a container at a port e.g., container arrived at the PoV.

  From: backend Blockchain system connected with the EGTN Interledger Service

  Verification: N/A

  Type: logistics event

- **ContainerReadyForTransport**

  Description: This is an event that is received from a connected Blockchain system of a port, upon the container clearance within the port e.g., Container passed all checks within the PoV and is ready to depart.

  From: backend Blockchain system connected with the EGTN Interledger Service

  Verification: N/A

  Type: logistics event

- **EGTNContainerReadyForTransport**

  Description: This is an event emitted by the EGTN Interledger Service as a proof of clearance of a container in the port e.g., PoV emits ContainerReadyForTransport and a sensor attached to the container sends readings with the correct GPS coordinates of the port gate.

  From: emitted by the EGTN Interledger Service

  Verification: cross-checked with IoT data

  Type: trusted meta-event

- **ContainerDeparted**

Description: This is an event that is received from a connected Port or Shippers Blockchain community, upon the departure of a container from a port e.g., Container departed from PoV.

From: backend Blockchain system connected with the EGTN Interledger Service

Verification: N/A

Type: logistics event

- **ContainerPickup**

Description: This is an event that is received from a connected FF Blockchain community, upon the pickup of a container in a port e.g., DHL picked up a container in the PoV.

From: backend Blockchain system connected with the EGTN Interledger Service

Verification: N/A

Type: logistics event

- **EGTNContainerDeparted**

Description: This is an event emitted by the EGTN Interledger Service as a proof of departure of a container from a port e.g., PoV emitted ContainerDeparted AND DHL emitted ContainerPickup => EGTN emits EGTNContainerDeparted.

From: emitted by the EGTN Interledger Service

Verification: cross-checked with other logistics events

Type: trusted meta-event

- **EGTNContractViolation**

Description: This is an event that is emitted by the EGTN Interledger Service upon the violation of a rule of a contract. The EGTN Interledger Service consumes the sensors measurements and compares them with the thresholds defined in contracts e.g., temperature reading is 30 while the contract threshold is 28.

From: emitted by the EGTN Interledger Service

Verification: cross-checked with IoT data

Type: Alarm event

- **ContainerArrivalWarehouse**

Description: This is an event that is received from a connected Blockchain system upon the arrival of a container at a port e.g., Container arrived at the port of Valencia.

From: backend Blockchain system connected with the EGTN Interledger Service

Verification: N/A

Type: logistics event

- **EGTNContainerArrivalWarehouse**

Description: This is an event that is emitted by the EGTN Interledger Service upon the arrival of a container at a port e.g., Container arrived at the DHL warehouse AND IoT sensor readings agree.

From: emitted by the EGTN Interledger Service

Verification: cross-checked with IoT data

Type: trusted meta-event

- **ContainerUnload**

  Description: This is an event that is received from a connected FF Blockchain community upon the unload of a container at a warehouse e.g., container unloaded at the DHL warehouse.

  From: backend Blockchain system connected with the EGTN Interledger Service

  Verification: N/A

  Type: logistics event

- **EGTNContainerUnload**

  Description: This is an event that is emitted by the EGTN Interledger Service as a proof of unload of a container at a warehouse e.g., container unloaded at the DHL warehouse AND IoT sensor readings agree.

  From: emitted by the EGTN Interledger Service

  Verification: cross-checked with IoT data

  Type: trusted meta-event

6.2 Data Model for redirection

The events described in the previous section include, within their payload, information for redirection among the connected Blockchain systems. The EGTN Interledger Service acts as a proxy between backend Blockchain systems and redirects traffic from one to another by translating heterogeneous events to a commonly agreed Data Model. The common Data Model for all the events has been defined by the T&L stakeholders of the project to accommodate the different data structures and standards used by the backend Blockchain systems and enable their interoperability. Since T&L backend systems use their own processes, APIs, and data structures to describe their assets, the definition of a common Data Model or a common "language of standards" is a step towards making the Blockchain systems interoperable. It also tries to accommodate diverse transport documents so that it leaves no one outside, as per the EGTN Platform requirements defined in WP1.

In the context of PLANET, Port of Valencia (PoV) uses Unified Transport Documents[11] (UTDs or DUTs) and PoR uses electronic CMRs[12] (eCMRs), which are different documents but for the same purpose, of accompanying a cargo through its journey in the supply chain. These documents incorporate information that is publicly shareable but also private information that shouldn't be shared publicly through the Blockchain. Table 5 summarises the information in each document as well as the privacy level of each field to define the commonly agreed shareable information that will be included in the common Data Model.

Document	(Mandatory) Information on document	Privacy level
Transport Order (DUT)	Name and address of customer	Private
	Name and address of LSP	**Public**
	Place of loading	**Public**
	Date of loading	**Public**
	Place of discharging	**Public**

[11] Unified Transport Documents, https://www.valenciaportpcs.com/media/1221/pcs11-trans003__messaging-user-guide-dut-xml.pdf

[12] http://www.fairlog.de/downloads/CMR_help_blanko.pdf

	Date of discharge	**Public**
	Description of cargo	Semi-private
	Number of packages	**Public**
	Gross weight and volume	**Public**
	Freight terms	Private
	Issue date	**Public**
	Name of issuer	Private
	Signature of issuer	Private
	Transport order reference number	**Public**
eCMR	Name and address of sender/consignor	Private
	Name and address of consignee	Private
	Place of delivery	**Public**
	Place and date of loading the goods	**Public**
	Annexed documents	**Public**
	Marks and numbers	**Public**
	Type and number of packages	**Public**
	Packing type	**Public**
	Description of goods	Semi-private
	Gross weight of goods	**Public**
	Volume of goods in m3	**Public**
	Freight payment	Private
	Name and address of the haulier	**Public**
	Name and address of subsequent transporter	**Public**
	Comments of sender and haulier	Private
	Freight terms	Private
	Signature and date of sender	Semi-private
	Signature and date of haulier	Semi-private
	Signature, date, and place of delivery for consignee	Semi-private

Table 5: PLANET Transport Documents Data

The consolidation of the publicly shareable data of the two documents is the common Data Model of the EGTN Interledger Service Events and is defined after extensive discussions among the involved actors to respect the privacy and confidentiality of the data to be exchanged.

Common Data Model	Example	Description
Document_ID	'553457742912760168394916480320181556669'	ID
Document_type	'eCMR'	type of document, e.g., transport order or eCMR

Document_hash	'127e6fbfe24a750e72930c220a8e138275656b8e5d8f48a98c3c92df2caba935'	Arbitrary string of characters (reference and integrity check for docs in the backend systems)
Transport_order_reference_number	'b80b9699-8521-4553-8312-f5d2d5e38f8d'	Arbitrary string of characters specified by LSP
City_of_loading	'Rotterdam'	City (we don't want to share precise locations)
Date_of_loading	'08-11-2021'	Date
Time_of_loading	'11:00'	Time
City_of_discharge	'Valencia'	City (we don't want to share precise locations)
Date_of_discharge	'10-11-2021'	Date
Time_of_discharge	'10:00'	Time
Type_of_package	'container'	euro pallet, container
Number_of_packages	'3'	# of packages
Weight	'20kg'	Weight
Volume	'4m^3'	Volume
Issue_date	'06-11-2021'	confirmation of the transport order and valid signature
State	'Active'	State of the cargo (for PoV)
Ledger_name	'PoR'	Ledger that emitted the event
TSN_ID	'708e4077-e355-4340-a3aa-db8988374b31'	ID of
Event	'ContainerReadyForTransport'	Event Name (see Table 4)

Figure 9: EGTN Event Payload Example

Finally, an example of a contract violation event is shown below in json format:

Contract Violation Event

```
{
      'Event': 'EGTNContractViolation',
      'Agreement_ID': 'c6b4a00c-bd82-4c37-aee0-ed27f96c925a',
      'Transport_Order_reference_number': 'b80b9699-8521-4553-8312-f5d2d5e38f8d',
      'Code': '18',
```

```
        'Reason': 'temperatureViolation',
        'Value': '12',
        'TSN_ID': '4574893547-4538954396-48385943'
}
```

A realistic business scenario that involves stakeholders from the PLANET LLs, who take advantage of the EGTN Interledger Service and by extension the events and the common Data Model, is presented in section 7.

6.2.1 Compliance with standards

In terms of standards, the Port of Valencia uses the Blockchain in Transport Alliance (BiTA)[13], DHL uses GS1 EPCIS and the Port of Rotterdam uses GS1 standards[14]. As shown in the previous section, the EGTN Blockchain Service adopts a combination of the above standards to define a common Data Model and accommodate the different structures. The EGTN Smart Contracts are the ones to map the common Data Model to the data structure of each Blockchain system. More details on this matter can be found in D2.18 “EGTN smart contracts and associated PI motivated workflows in the context of SLA management final version”.

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

7 Application in the Living Labs

The EGTN Interledger Service acts as a proxy between backend Blockchain systems, which exchange pointers (hashes) to 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.

An example Use Case is the scenario that involves the Shippers community, represented by the Port of Valencia (PoV) and COSCO, the Freight Forwarder community, represented by DHL and the Port community, represented by the Port of Rotterdam (PoR), in which shipments arrive in PoR and travel through road transport to a DHL warehouse in Madrid and finally to PoV. Transport Documents need to be exchanged through the EGTN Platform to speed up the processes and increase the transparency of business milestones (e.g., container arrived at port, container pickup from FF). As can be seen in Figure 10, logistics events from the PoR as well as a contract violation event are shown in the EGTN Dashboard, captured through the EGTN Interledger Service.

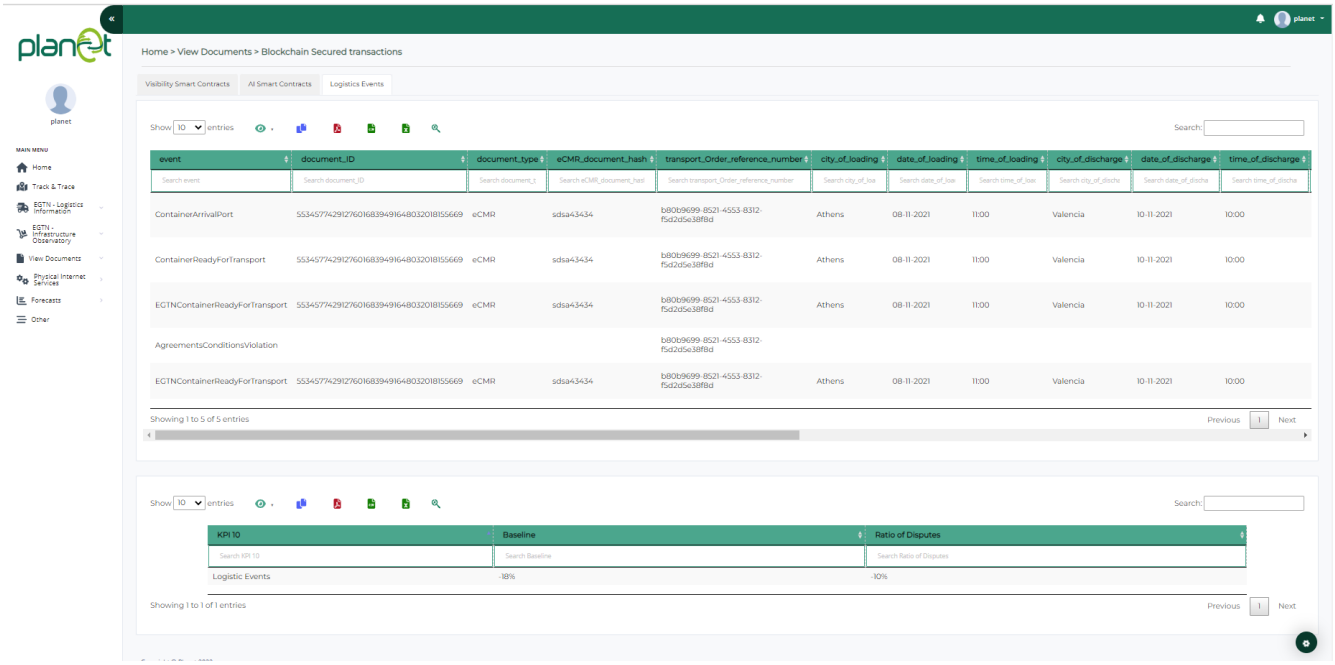

Figure 10: Logistics events from different Blockchain Communities in the EGTN Dashboard

The following two user stories represent examples of what could be tested during the LLs evaluation in the upcoming months:

1. A user creates a shipment in PoR system, enters main shipment information and attaches a transport document i.e., an eCMR
2. A root hash of the document is notarized as reference to the shipment and stored in the Blockchain of PoR.
3. The local Blockchain emits an event including the hash of the document as well as other metadata, namely the information of the EGTN Data Model.
4. The Blockchain connector of the EGTN Interledger Service listens to the PoR smart contract and pickups the event that contains only publicly shareable information.
5. The event is stored in the EGTN Platform and is shown to users through the EGTN Dashboard.

A user needs to retrieve the actual transport document:

1. A user logs in the EGTN Platform and explores the logistic events coming from multiple backend Blockchain systems and appeared in a table.

2. He/she sees an event and decides that he/she needs more information about it, so he/she requests for the actual document.
3. The EGTN Dashboard makes a request to the API of the PoR's system using the user's token and the hash of the document to retrieve, found in the logistics event.
4. The PoR system validates the request by checking the permissions of the user to access the document.
5. The document is sent to the Dashboard and shown to the user.

8 Living Labs & EGTN Interledger Service

This chapter focuses on the business benefits Blockchain and especially Blockchain Interoperability offer to the T&L domain through the research and development undertaken in the PLANET project. The application of the EGTN Interledger Service in the project Living Labs displays a practical example of how this emerging research topic can play an instrumental role in the roadmap towards the PI.

8.1 Benefits of Blockchain Interoperability in T&L: The PLANET Use Case

A key enabler for the PI is *digital interoperability* as it enables separate T&L networks to conduct business with each other seamlessly [1]. More specifically, digital interoperability is defined as "the ability to achieve quick, seamless, secure, and reliable data and information exchange between computing devices (devices capable of transferring data), between information systems (of different organisations, logistics networks), or between devices and systems, for the aim of enhancing cooperation or coopetition of independent logistics parties or networks" [1]. As the PI aims at interconnecting T&L networks, i.e., moving from offline collaboration to interconnection of the involved actors, in a similar manner, Blockchain solutions need to take a step towards the interconnection of the different Blockchain solutions that are currently employed by separate T&L stakeholders. Blockchain interoperability is a growing research topic, and it has been the focus of the work undertaken in Task 2.5 of PLANET.

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. In the PLANET project, the EGTN platform interconnects existing backend Blockchain systems belonging to different stakeholders in the supply chain and exposes universal, standardised interfaces to all involved actors of the supply chain.

As previously mentioned in section , Blockchain solutions offer enormous business benefits to T&L. They are digitised solutions; hence they are a sustainable solution that leads to a decrease of paper usage and reduction of shipping documents between T&L stakeholders. This also implies that manual tasks are heavily reduced allowing actors to commit to tasks of higher value [2]. It is also worth pointing out that Blockchain offers significant benefits in terms of security. These are presented in detail in *D2.18 EGTN smart contracts and associated PI motivated workflows in the context of SLA management final version*.

All of the aforementioned benefits are showcased in PLANET by developing Blockchain solutions in two different Use Cases of the Living Labs.

8.2 Addressing the Business Objectives

This section is devoted to the Use Cases that the Blockchain Interoperability solution developed in PLANET has been applied to. The business objectives that were laid out in section defined the goals that the EGTN Blockchain Service was to address.

8.2.1 Exchange of Transport Order

The first Use Case connects a Blockchain network belonging to a Port Authority with a Blockchain network belonging to a Freight Forwarder. The scenario revolves around the exchange of a Transport Order between one with the other. This is issued by the Port Authority once a container arrives to Spain by sea. The Freight Forwarder takes over the container associated with the specific Transport Order to ship it within mainland Spain. Table 6

revisits the business objectives that were presented in section 3.1.1 and explores how these were incorporated in the EGTN Interledger Service.

Business Objectives	EGTN Interledger Service
Process digitisation, thereby guaranteeing paperless transactions and reduction of operational time, avoiding the costs of paper-based processes and human error.	As presented in Figure 3, the architecture of the solution replaces paper-based solutions with smart contracts that are generated automatically, thus preventing human error.
Increase supply chain visibility by enabling access, exchange, and traceability of data in real-time conditions among multiple actors.	As Figure 2 illustrates all actors involved in the PLANET Use Cases have access and can view all relevant information through the EGTN Dashboard, thereby increasing trust and transparency among all involved actors. Using Blockchain, immutability and security of data is also achieved. On top of that, through the application of predefined rules and conditions, smart contracts automatically indicate when a major event along the process chain is occurs (e.g., a contract violation due to temperature increase caught by IoT sensors). All these benefits, enhance stakeholder trust in the entire process and encourage them to collaborate with each other.
Enhancement of customer experiences by bringing trust, transparency, and collaboration.	
Strengthen collaboration between different supply chain ecosystems.	
Promote stakeholder engagement.	
Improve credibility and public trust of data shared.	
Reduce potential public relations risk from supply chain malpractice.	Smart contracts run when predetermined terms and conditions are met (“if-conditions”) and execute actions or trigger events/alarms (“then-rules”) without an intermediary’s involvement or loss of time. This safeguards the process and significantly decreases the risk of malpractice.
Increase process efficiency/automation thanks to the use of smart contracts.	D2.18 *EGTN Smart Contracts and associated PI motivated workflows in the context of SLA management final version* provides an in-depth view of the smart contracts in PLANET.
Enhancement of operational productivity, leading to T&L cost reductions and revenue increase.	The EGTN events – presented in section 6.1- that are safely exchanged between all involved Blockchain networks along with the EGTN Interledger Service acting as intermediary succeed in interconnecting previously disconnected systems, thereby increasing collaboration, improving operations, and decreasing human labour.
Ease the scalability process of deploying different Blockchain solutions.	The EGTN Interledger Service is an open-source solution that interconnects separate Blockchain networks belonging to different stakeholders. New Blockchain networks can easily be added to the existing solution.

Strengthen corporate reputation through providing transparency of information and processes.	As Blockchain safeguards data thanks to its immutability characteristic [3], all involved stakeholders can trust the data within the EGTN Service.

Table 6: Addressing the Business Objectives of Use Case I

8.2.2 Integration and Synchronisation of Maritime Ports

The second Use Case focuses on the synchronisation of different European maritime ports for cargo that arrives to Europe by sea to one port and is shipped by road to the other port. In this manner, on top of the two previous Blockchain networks that were included in the previous Use Case a third Blockchain network is added in the EGTN Interledger Service. The EGTN solution facilitates the digitisation of the (Electronic) Road Transport Document ("e-RTD", or "e-CMR"), a document necessary for all road freight transport within the European Union. Table 7 revisits the business objectives of this Use Case, as they were laid out in section 3.1.2.

Table 7. Addressing the Business Objectives of Use Case II.

Business Objectives	EGTN Interledger Service
Optimisation of planning and warehouse operations, enabled through the real-time sharing of logistics events between regional systems, which in turn allows for anticipation of in- and out-bound cargo and modalities.	As presented in section 5, different Blockchain networks are interconnected via the EGTN Interledger Service. The Event Streaming Connector consumes IoT data and trusted logistics events in real time.
Quality improvement and increased speed of transport document preparation to reduce delays in T&L. This is achieved with the digitalisation and tokenisation of previously paper-based transport documents – e.g., CMR, Bill of Lading, warehouse receipts etc.– that are owned and distributed between separate interoperable Blockchain systems.	As presented in Figure 3, the architecture of the solution replaces paper-based solutions with smart contracts that are generated automatically, thus preventing human error.

9 Conclusions

This deliverable presents the work undertaken in subtask ST2.5.1 *Interfaces to multiple Proprietary Blockchain Systems for Seamless Global Trade*. More specifically, it provides a detailed account of the methodology, the design and development of the EGTN Interledger Service, including its relationship with the other EGTN technical components.

The EGTN Interledger Service offers a solution that addresses the challenges raised by the lack of collaboration and coordination between different T&L stakeholders, as they all use their own, proprietary Blockchain solutions. It succeeds in unifying multiple backend Blockchain systems and in this manner supports interorganisational and intercommunity trade workflows.

It takes advantage of the cutting edge microservices provided through the EGTN Platform - i.e., AI and DSS - and consumes data from the different datasets available in the EGTN Data Lake to enable advanced functionalities, such as forwarding logistics events between disconnected communities, cross-checking the validity of events through IoT data and automatic generation of smart contracts based on AI predictions.

Since standards make interoperability possible, the EGTN Interledger Data Model provides a common language of standards that creates an ecosystem of platforms, applications, and networks that securely link people, places, and things.

The EGTN Interledger Service is an open-source solution (available on https://gitlab.com/planet-h2020/egtn-bc-interoperability), while it offers best practices and guidelines on how T&L stakeholders of all sizes and budgets can easily adopt and extend the offered solution in their own use cases.

Overall, the developed solution offers data integrity and immutability throughout the entire T&L workflow, automated and safe contract execution using smart contracts (more on this in D2.18), reduction of overheads and time delays; all this using a distributed and community-driven approach. Through this approach, the EGTN Interledger Service becomes a great enabler for the PI paradigm.

10 References

[1] S. a. T. D. a. M. D. a. M. B. a. B. E. a. H. G. Q. Pan, "Digital interoperability in logistics and supply chain management: state-of-the-art and research avenues towards Physical Internet," *Computers in Industry,* vol. 128, 2021.

[2] "Expedite trade with complete visibility and security," 2022. [Online]. Available: https://www.tradelens.com/tradelens-use-cases/trade-document-collection. [Accessed November 2022].

[3] "What is blockchain technology?," IBM, 2022. [Online]. Available: https://www.ibm.com/topics/what-is-blockchain. [Accessed 2022].

11 Annex I

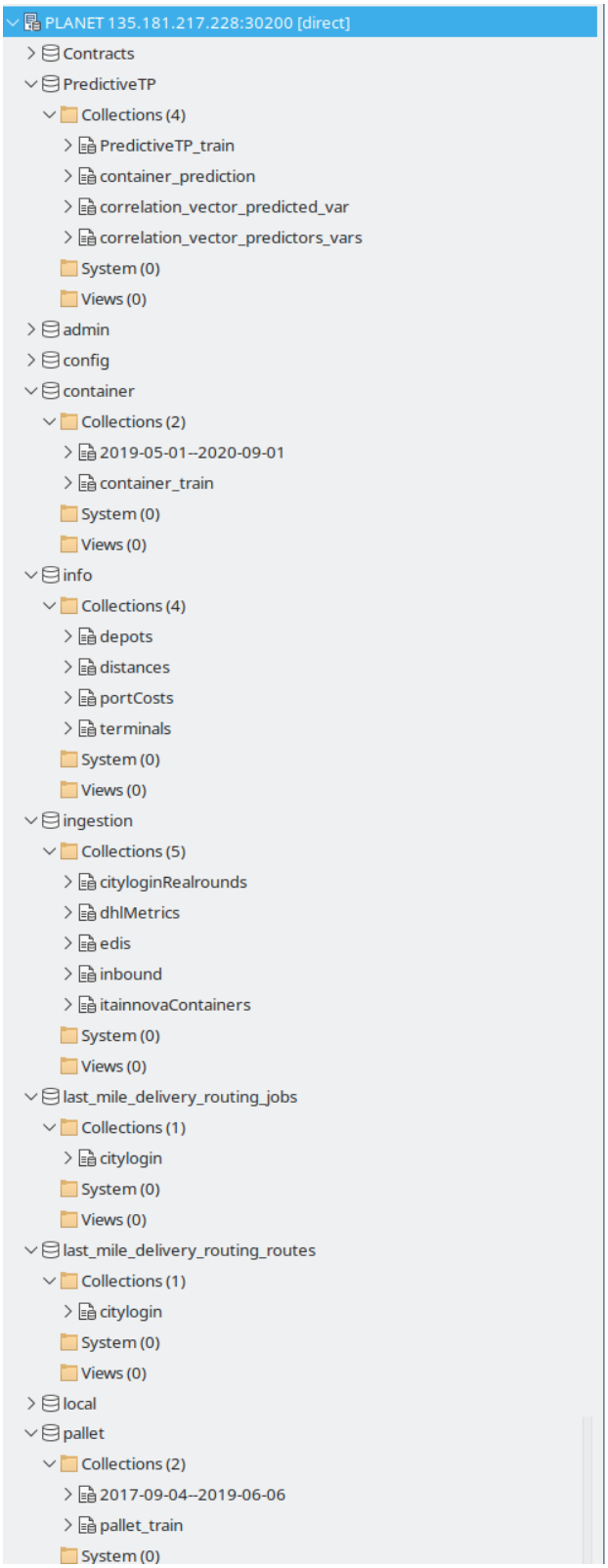

Figure 11: EGTN MongoDB screenshot