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

D2.17 EGTN smart contracts and associated PI motivated workflows in the context of SLA management 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
PI	Physical Internet
BC	Blockchain System
PoD	Proof of Delivery
ETA	Expected Time of Arrival
PoV	Port of Valencia
ALICE	Alliance for Logistics Innovation through Collaboration in Europe
COSSP	COSCO Spain
SP	Service Provider
SLA	Service Level Agreement
T&L	Transport & Logistics
LL	Living Lab
PoR	Port of Rotterdam

1 Executive Summary

This deliverable presents the design and structure of the Blockchain-enabled smart contracts which are called to facilitate, verify, or enforce the negotiation or performance of a contract or an aspect of the SLA. Smart contracts are employed in the context of Blockchain interoperability, which aims at unifying multiple proprietary Blockchain systems of different T&L stakeholders. In this manner, actors across the entire T&L supply chain shall be able to collaborate and exchange information 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 by replacing existing paper-based contracts.

The EGTN smart contracts focus on the contract structure and associated PI motivated workflows in the context of SLA management. Blockchain-enabled smart contracts are exploited as computer programs stored in the EGTN Blockchain. Consequently, they can be triggered to execute automatically when predetermined terms and conditions are met by encoding "if-then" rules that depend on other actions that occur across the supply chain and are recorded in the distributed ledger through the IoT and the connectivity infrastructure. Correspondingly, when the right conditions are satisfied, the smart contract also executes and records its outcome in the EGTN Blockchain component.

The EGTN smart contracts, which are presented in this report, aspire to highlight the value smart contracts and Blockchain technologies bring to the T&L sector and especially to the PI paradigm. Smart contracts guarantee a trustworthy, seamless, and distributed process of contract negotiation and execution that significantly reduces time, administrative overheads, and costs which are currently typically spent on manual interorganisational processes. In this manner, the T&L sector can employ distributed and community driven approaches, instead of centralised, proprietary technological solutions.

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			
D2.17 EGTN smart contracts and associated PI motivated workflows in the context of SLA management v1	Initial design and implementation of initial prototypes of Blockchain-enabled smart contracts to facilitate, verify, or enforce the negotiation or performance of a contract or an aspect of the SLA.	Chapters 4, 5	Section 4.2 describes the workflow requirements that enable T&L actors to interact using smart contracts. Section 5.1 presents the design of the structure of smart contracts in terms of data and rules.
TASKS			
ST2.5.2 EGTN Smart Contracts focuses on the contracts' structure and associated PI motivated workflows in the context of SLA management	Blockchain enabled smart contracts will be exploited as computer programs stored in the Blockchain to facilitate, verify, or enforce the negotiation or performance of a contract or an aspect of the SLA in the Blockchain.	Sections 3.1, 4.1, 5.1	Section 3.1 presents interrelationship between smart contracts and SLAs. Section 4.1 focuses on the description of the workflows that illustrate the flow of smart contract negotiation and verification between all relevant stakeholders. Section 5.1 presents in detail the smart contracts employed in the Blockchain interoperability use cases.
	Consequently, Smart contracts can be triggered to execute automatically when predetermined terms and conditions are met by encoding 'if then' rules that depend on other actions that occur in	Sections 5.2, 5.3	Section 5.2 presents the connection between smart contracts and the IoT connectivity infrastructure of PLANET. Section 5.3 describes the AI-enabled smart contracts.

	the supply chain and are recorded through the IoT and the connectivity infrastructure in the Blockchain. Correspondingly, when the right conditions are satisfied, the smart contract also executes and records its outcome/transaction.		

2.2 Deliverable Overview and Report Structure

This deliverable consists of the following chapters:

- **Chapter 3** offers an insight into smart contracts, their correlation with Service Level Agreements, and their contribution to the Physical Internet. More details on the overall value of Blockchain on the PI can be found within D2.15 *Integration and Interoperability of proprietary Blockchain Systems for Seamless Global Trade Workflows v1* (submitted alongside this deliverable in month 18).
- **Chapter 4** presents the PI workflows that are involved in the Living Lab use cases, in which smart contracts will be employed. The workflow requirements as well as the involved stakeholders are also identified.
- **Chapter 5** is devoted to the EGTN smart contracts; the terms and conditions as well as the involved data structures are described. The chapter presents the interconnection between smart contracts and other EGTN components such as the PLANET IoT infrastructure, as well as the AI-enabled smart contracts.
- **Chapter 6** describes the deployment process of the EGTN smart contracts.
- Finally, **Chapter 7** concludes this report by presenting the current findings at the time of writing this report as well as the next steps that will be included in the final version of this deliverable (D2.18 due in month 30).

3 About Smart Contracts

Smart contracts were initially introduced in Ethereum[2] which extended the Bitcoin baseline technology, thus creating the first programmable Blockchain and featured scripting language that could automate tasks and allow applications to be built on top of them. Custom business rules could be enforced by special software programs called smart contracts and executed by a distributed computing environment, hence extending the reach of the system well beyond finance.

A smart contract may contain values, similarly to any program, which are stored in the Blockchain, while the smart contract provides the way to interact with these values (add, delete, or change any value). The actors of the Blockchain network should agree upon the following:

- how transactions and their data are represented on the Blockchain,
- the "if/when…then…" rules that govern these transactions.

Finally, they should also explore all possible exceptions and define a framework for resolving disputes.

3.1 Smart Contracts and SLA Management

A Service Level Agreement (SLA) is a commitment between a Service Provider (SP) and a client that includes a list of objectives, services, and responsibilities that the client expects from the service provider to provide. SLAs also include metrics that measure the accuracy and extent to which SPs provide those services as well as potential penalties, contingency plans or simply alarms, if the levels of service specified by the agreement are not maintained. SLA management is the ongoing process of ensuring that all provided services and processes—including the underlying contracts— are in alignment with the agreed-upon service level targets stipulated by the contract. At present, third parties are mainly employed for the management of SLAs in various industry domains to ensure effectiveness and efficiency of the business services. Nevertheless, there is no effective supervision mechanism to monitor the third party and no efficient punishment mechanism on SLA violation.

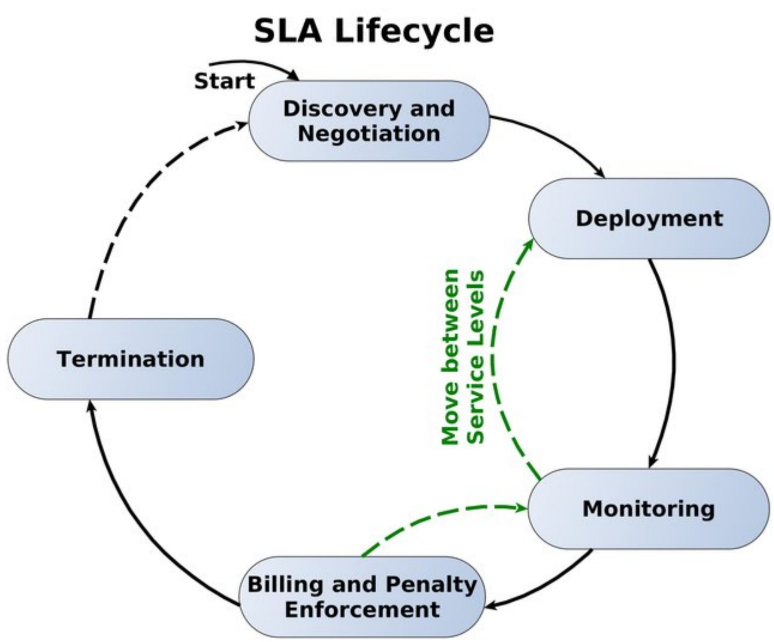

Figure 1: SLA lifecycle, taken from [1]

[2] Ethereum, https://ethereum.org/en/

The lifecycle of smart contracts correlates highly with the lifecycle of SLAs as depicted in Figure 1. They have been recently proposed to address the challenge of efficiently and securely monitoring agreements and to introduce a distributed, fair and transparent decision-making process for SLA management in the cloud domain [2], [3], [4]. Similarly, the inherent characteristics of smart contracts can guarantee a trustworthy, distributed process that reduces time and costs spent on manual interorganisational processes in the Physical Internet paradigm. The decentralised nature of smart contracts ensures the engagement of all T&L stakeholders in the negotiation and monitoring of a contract paving the way towards a transparent and global logistics system. The following section offers a more detailed account on this matter.

3.2 Smart Contracts and their contribution to the PI

The emergence of smart contracts alongside Blockchain technologies have disrupted the operational flow and contract negotiation in a plethora of fields, including transport and logistics. Through smart contracts the rules and conditions of an agreement are defined and agreed in advance between all parties involved. Once a smart contract has been established, these cannot be altered without the consent of all the parties.

As described in the previous section, smart contracts execute automatically upon event trigger (e.g., empty truck of freight forwarder arrives at a logistics warehouse shall trigger a new booking) and guarantee the consignor the acceptance and execution of the pre-agreed offer, but also enforce them to fulfill their own contractual obligations (e.g., fulfill a payment). These are powerful benefits that can contribute greatly and bring T&L a step closer to the realisation of the Physical Internet (PI).

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* [5]. 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 [6]. Despite the advantages the PI may offer, it cannot continue relying on centralised networks nor on the existence of a leading authority [7]. In this way, the PI will be able to proliferate only if it is a distributed and community driven concept and approach.

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. The business value that Blockchain technologies offer to the PI is presented thoroughly in D2.15 *Integration and Interoperability of proprietary Blockchain Systems for Seamless Global Trade Workflows v1* (submitted alongside this deliverable in month 18).

Smart contracts, in particular, play an instrumental role in the roadmap towards the PI. The *Alliance for Logistics Innovation through Collaboration in Europe* (ALICE) has proclaimed that they can achieve this in two ways:

- Logistics nodes shall interact with each other in an automated manner creating seamless booking systems backed by smart contracts, which will in turn increase response time significantly.
- Supply chains shall become proactive in the smart use of resources and capabilities by employing fully autonomous services and operations with predefined smart contracts [8].

Alongside the PI, the concept of synchromodality, another emerging topic in T&L is heavily affected by Blockchain and smart contracts. Synchromodality can be defined as *the provision of efficient, reliable, flexible, and sustainable services through the coordination and cooperation of stakeholders and the synchronisation of operations within one or more supply chains driven by information and communication technologies (ICT) and intelligent transportation system (ITS) technologies* [9]. Blockchain and smart contracts foster collaboration by making stakeholders feel safe doing business on IT platform. Smart contracts have also the potential to contribute to a legal and political framework, by encouraging the definition of stakeholders' liabilities in a clear and transparent manner [9].

The advantages of smart contracts are also evident 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). Blockchain enables new smart contracts to be issued (e.g., Bill of Lading) in a distributed manner, and in this way reducing the previously manual administrative overheads and avoiding delays. In addition to this, any interested party, such as customs officials, that has the required permissions can access the updated information, facilitated by Blockchain and the Blockchain interoperability. This is of crucial importance, as it enables cross-organisation information flow, which means that decisions are data-driven and, therefore, can be changed at any step of the supply chain e.g., in case of damage to the cargo during transport, reroute the cargo from the distribution centre to a repair centre; all this happening in real time [10].

To sum up, the entire T&L chain can be sped up using smart contracts that are executed based on shipping steps. For instance, the following steps can be optimised:

- Real-time access to all the relevant information by all involved stakeholders of international trade processes can reduce administrative costs.
- Increased transparency through asset tracking, which can also help avoid shipment delays.
- Optimised load capacity can minimize the shipping costs of T&L companies [11].

Following this manner, IoT data and AI models can make the step towards the realisation 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. Their interplay with Blockchain within the PLANET project is described in detail in sections 5.2 and 5.2.

4 Conceptualisation and PI Workflows

Blockchain Interoperability is a multidimensional challenge that can be approached from different angles, as described in D2.15, providing solutions that fit a variety of different concepts. In the context of PLANET and at the time of writing this deliverable, two scenarios have been identified that showcase the business value of interconnecting distributed ledgers hosted by different T&L stakeholders to support critical interorganisational trade workflows.

Firstly, a scenario within LL1 that involves Port of Valencia (FV), COSCO SHIPPING LINES SPAIN (COSSP) and DHL EXEL SUPPLY CHAIN SPAIN (DHL) demonstrates the need to exchange information between maritime ports, shipping lines, warehouse providers and last mile delivery services in order to increase efficiency in the supply chain. Secondly, an inter-LL scenario between LL1 and LL2 that involves FV, COSSP, DHL and BLOCKCHAIN FIELDLAB BV (BlockLab) shows the requirement for Blockchain interoperability between maritime ports to exchange information related to cargo dispatching, cargo reception and terrestrial transportation and, in this manner, promote collaboration and transparency. It is worth highlighting that both scenarios were identified and developed in close collaboration with the partners from the Living Labs.

4.1 Workflow description

In this section the workflow of each scenario is described in detail. The focus of the description is on the information exchanged between the involved actors in each interaction.

4.1.1 Exchange of Transport Order

The first scenario refers to the interactions and the exchange of data - included in a Transport Order - between Blockchain systems of different T&L stakeholders. This use case simulates a transport scenario in which COSSP manages shipments from Asia to Spain (Port of Valencia) while the inland transport is managed by DHL Spain and CityLogin. Figure 2 illustrates the entire operational overview of the scenario workflow. At the top of the diagram all stakeholders involved in the scenario are displayed: from COSSP and Port of Valencia to DHL and CityLogin. The key takeaway of the diagram is, however, the flow of information exchanged between all these stakeholders.

A non-exhaustive list of information to be exchanged between the stakeholders of this scenario can be found in Table 2, while a detailed description can be found in the section 6.1.2 of D2.15. The stakeholders are defined in section 4.3.

T&L Stakeholder	Information
Maritime port and Shipping lines	Weight, number of containers and Twenty-foot Equivalent Units (TEUs)
	Fixed cost for merchant transport
	Cargo destination (Port of Delivery, final destination, etc.)
	Container availability at the port terminal
Freight Forwarders and logistic	Truck arrival at port terminal according to instructions agreed
	Container pick up

operators	Any incidents/events during the transport
	Container release at final destination
	Empty container devolution

Table 2: Information exchanged between maritime and terrestrial stakeholders

As Figure 2 illustrates, the information flow is triggered by COSSP – or any shipping community- once a container arrives at the port. All relevant information, such as cargo details etc., needs to be shared with the Port Community Blockchain either directly or through the shipper's Blockchain if there is one. The Port Authority is expected to confirm that they have received the container; this information needs to be fed back to the shipping community. At the same time the freight forwarder Blockchain receives the information that the container is at the terminal.

Once the freight forwarder, namely DHL, picks up the container, they send to the Blockchain of the port community the pick-up confirmation, they send the container to their warehouse and send to the freight forwarder Blockchain the proof of delivery.

The final step of the workflow is the inland shipment, sending the container from the DHL warehouse through CityLogin for the last-mile delivery to Madrid.

The idea behind this Blockchain workflow is that information is shared in a transparent and trustful manner between all stakeholders involved. This is a rather important point, since a critical element of the Physical Internet (PI) is the sharing of information between multiple actors in an open and trustful manner. For instance, information such as Expected Time of Arrival (ETA), or information regarding a potentially empty DHL truck ready to be filled with cargo should be visible to all stakeholders throughout the network.

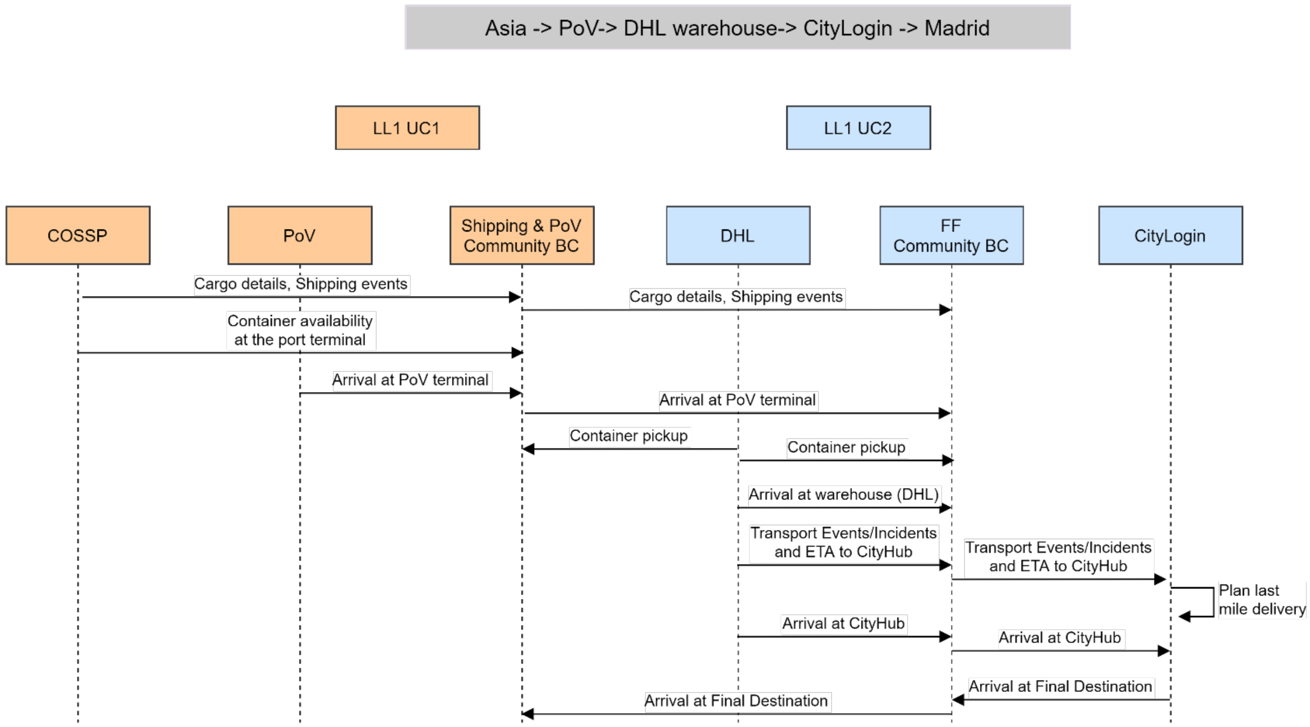

Figure 2: Exchange of Transport Order Blockchain Interoperability Workflow

4.1.2 Integration and Synchronisation of Maritime Ports

The second use case showcases the application of Blockchain interoperability between maritime ports to exchange information related to cargo dispatching, cargo reception and terrestrial transportation. In this manner, Blockchain interoperability fosters cross-organisational and cross-country collaboration and transparency.

As Figure 3 illustrates when a cargo from the US arrives to the Port of Rotterdam all the relevant data (cargo details, shipping events) are stored in the port's Blockchain system, including the availability of containers at the port terminal. This information is also shared with the other Blockchain systems that are involved in the process, the freight forwarder BC and the Port of Valencia BC. 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.

Once the freight forwarder, namely DHL, picks up the container, they send to the Blockchain of the port community and the freight forwarder Blockchain the pick-up confirmation as well as the Estimated Time of Arrival (ETA) to the Port of Valencia.

Upon terrestrial arrival to the Port of Valencia, all involved Blockchain systems are updated accordingly to ensure that every party is aware that the cargo has reached its destination and is ready to be transported to Africa.

The ports involved 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 these electronic documents, 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. 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 shared through the EGTN Platform and retrieved only by trusted actors.

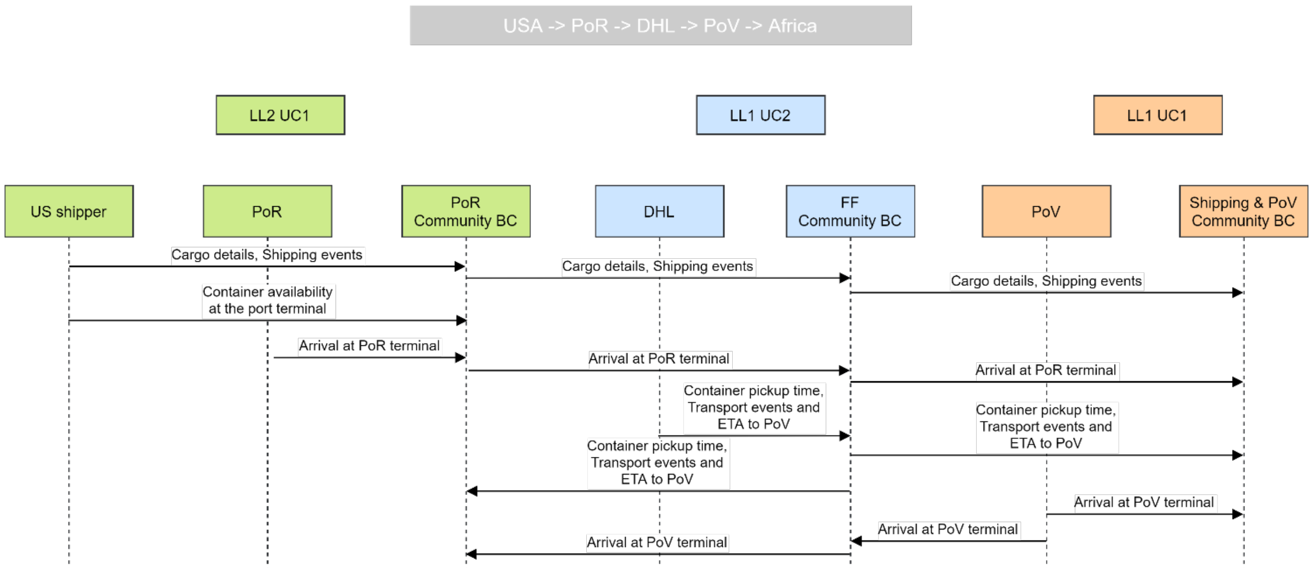

Figure 3: Exchange of Road Transport Document Blockchain Interoperability Workflow

A non-exhaustive list of information to be exchanged between the stakeholders of this scenario can be found in Table 3, while a detailed description can be found in the section 6.1.2 of D2.15. The stakeholders are defined in section 4.3.

Table 3: Information exchanged between different maritime stakeholders

T&L Stakeholder	Information
Maritime port and Shipping lines	Weight, number of containers and Twenty-foot Equivalent Units (TEUs)
	Fixed cost for merchant transport
	Cargo destination (Port of Delivery (PoD), final destination etc.)
	Container availability at the port terminal
Freight Forwarders and warehouse providers	Truck arrival at port terminal according to instructions agreed
	Container pick up
	Any incidences/events during the transport
	Container release at final destination
	Empty container devolution

4.2 Workflow requirements

As described in 3.2, Blockchain and smart contracts have the potential to meet PI implementation requirements as well as to overcome key PI barriers and deficiencies. The interoperability workflows described in the previous section have specific requirements in order to enable logistics nodes to interact with each other in an automated manner and reduce time and costs as well as to optimise allocation of resources. In terms of Blockchain infrastructure, the requirements are presented in D2.15. Similarly, most of the smart contract's requirements are included in the corresponding section of D2.15 (for consistency), omitting the requirements for IoT data that are described below.

In terms of data, the EGTN smart contracts require logistics and transport events as well as the consumption of IoT data to automatically trigger actions upon the occurrence of these events. The EGTN Blockchain service takes advantage of the IoT and the Connectivity layer and accesses data to inform smart contracts decisions. The IoT infrastructure makes available smart T&L assets that generate IoT measurements which are either pushed to the EGTN platform as raw data or as precomputed events e.g., bump, threshold exceedance, reach of Point of Interest (POI). The smart T&L assets available are:

- Smart Pallet
- Smart Container
- Smart Means of Transport
- Smart Warehouse

A more detailed description of the data generated by the smart T&L assets and consumed by the EGTN smart contracts is provided in section 5.2.

4.3 Stakeholders and actors

The different types of actors considered in the EGTN scenarios are:

ID	Actor	Description
RE	**Requestors**	Parties that will request and order the transportation of cargo and transport units to the carriers, establishing contractual agreements with them. The transport requestor role could be played by: (i) the cargo owners (buyers, sellers, or intermediaries), the freight forwarders or cargo agents, the customs agents or officers, the shipping agents and the shippers, as well as the terrestrial carriers that act as requestors with respect to other carriers
CA	**Carriers**	Parties that will execute the transportation of cargo and transport units under a contractual agreement established with the transport requestors. The carrier role could be played by road, railway, and maritime transport companies as well as by their transport agencies. The freight forwarders and cargo agents can also play the role of carriers with respect to the cargo owners
SH	**Shippers**	Parties that will deliver the cargo or transport units to the carriers for its transportation under contractual agreements established between the requestors and the carriers. Shippers can deliver the cargo immediately or can order to depots the delivery of cargo to the carrier. The shipper role could be played by: (i) the cargo owners (sellers or intermediaries), the freight forwarders or cargo agents, the customs agents or officers, the shipping agents, and shippers, as well as the terrestrial carriers that act as shippers with respect to other carriers

CO	**Consignees**	Parties that will receive the cargo or transport units from carriers at the destinations agreed at the contractual agreements established between requestors and carriers. The consignees could either receive the cargo directly or they could order to a depot its reception and entry to the depot. The consignee role could be played by the cargo owners (buyers or intermediaries), the freight forwarders or cargo agents, the customs agents or officers, the shipping agents and shipper, as well as terrestrial carriers that play the role of recipients with respect to other carriers
DEO	**Depositors**	Parties that will order to the depositary (depot operator or port terminal) the entry of cargo or transport units that will be delivered by carriers for its storage, manipulation, and safe keeping under a depot contractual agreement. The depositor role could be played by the cargo owner (buyers or intermediaries), the freight-forwarders or shipping agents, the customs agents or officers, the shipping agents, and the shippers, as well as the terrestrial carriers that play the role of depositors with respect to depositaries
DEA	**Depositaries**	Parties that will carry out the reception and entry of cargo and transport units at the depot, performing the storage, manipulation, and safe keeping of the cargo as well as the delivery and exit from their facilities. Depositaries agree specific obligations with depositors under depot contractual agreements. The depositary role could be played by depot operators, terminals inside and outside the port facilities, having surveillance and safe-keeping obligations with respect to customs and other border control institutions
SR	**Service Requestors**	Parties that will request a logistic service on cargo or transport units under a service contractual agreement. An example of service requestors could be the companies that request the weighting of cargo to scale operators
SP	**Service Providers**	Parties that will provide a service over the cargo or transport units under a service contractual agreement. An example of logistics service provider could be the scale operator that weights the cargo
LSP	**Logistics Service Provider**	Parties that will conceive and implement logistics solutions for the service requestor in terms of transport and warehousing/depot needs

Table 4: EGTN Blockchain actors

5 EGTN Smart Contracts Specification

The EGTN platform Blockchain component – presented in D2.15 - employs smart contracts in order to guarantee the integrity of the data entering the ledger and to automate procedures in the logistics chain that are currently handled using paper-based documents. The goal of data integrity is achieved through the concurrent execution of the smart contracts by all the network participants (or most of them).

5.1 Smart Contracts Structure

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. The automatic execution of the actions by all the involved actors ensures the integrity of the data pushed to the Blockchain and ties them in secure and transparent agreements. EGTN Smart Contracts take advantage of the diverse data and knowledge residing within the EGTN Platform (output from backend Blockchain systems, IoT data, Big Data analytics) to enable reliable generation of metadata and trusted contract execution (see Figure 4). The terms and conditions, the data structures as well as the description of each of the smart contracts use cases are explained in the following subsections.

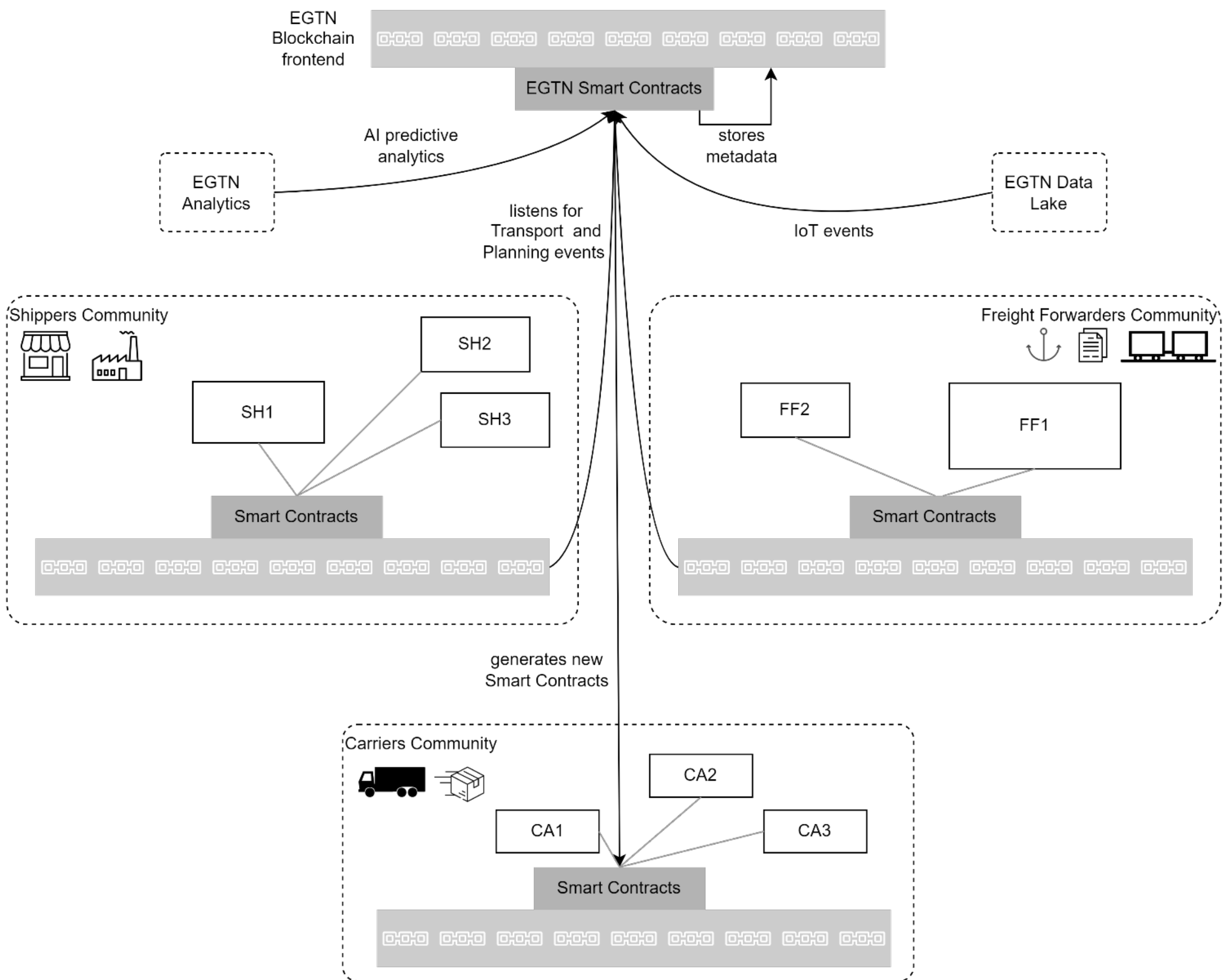

Figure 4: EGTN Smart Contracts ecosystem

5.1.1 Terms and conditions

In the following table, the "if-then" rules (ITXX) that are followed in the EGTN Blockchain components are presented, which aim to standardise and streamline interorganisational T&L workflows.

ID	Indicative Business Actors	Data Source(s)	Data	If condition	Then (type)	Then Description
IT01	SH, CA, FF	Legacy Systems	Cargo Departure (from Origin) event as reported and logged from both Shipper and Carrier	Data from diverse sources match	Metadata	Enhanced-trust Departure
IT02	CA, FF, CO		Proof of Delivery as reported from both Carrier and Consignee	Data from diverse sources match		Enhanced-trust PoD
IT03	FF, CA	Legacy System(s) and IoT	Delivery point/time vs Unloading IoT coordinates/time	Legacy system data match IoT measurements	Metadata, contract status	Contract fulfilled
IT04	SH, FF, CA, CO		System defined vibration/temperature tolerance vs IoT sensors measurements	Legacy system data contradict IoT measurements		Contract violated
IT05	SH, FF, CO		System events (e.g., cargo Customs cleared, number of items delivered) vs IoT evidence (e.g. cargo moved in Customs-cleared area, RFID-based cargo validation)	Legacy system data match or contradict IoT measurements		Contract violated or Enhanced-trust event
IT06	SH, FF, Warehouse manager	Legacy System(s)	System events/data (e.g. transport demand, incoming transport orders)	Own transport/storage capacity insufficient to cover demand	Automatic Smart Contract generation	Contract establishment for outsourcing excess demand, embedding special conditions (QoS, Security, etc.)

IT07	SH, FF, Warehouse manager	Legacy System(s)	System data, historic data, and forecasts (e.g., number of pallets forecast as generated by big data analytics)	Own transport/storage capacity insufficient to cover demand		Contract establishment for temporary increase of WH resources

Table 5: Smart Contracts if-then rules in the EGTN scenarios

5.1.2 Data Structures in the ledger

The aforementioned "if-then" statements are written into code and require a network of computers along with a Blockchain infrastructure to run. The output of their parallel execution in each of the network computers is represented by a new record on the Blockchain. The EGTN smart contracts produce both static (master) and transactional data that are stored on-chain following T&L standards, such as the GS1 EPCIS[3] and the Blockchain in Transport Alliance (BiTA)[4]. Common - between the backend Blockchain systems - semantic models of the data stored in the ledger have been designed and are presented in detail in D2.15.

5.1.3 Smart Contracts Description

IT01

The first type of smart contracts aims to enhance the legitimacy of Dispatch claims from the SH and the CA. The EGTN Blockchain service monitors both the backend systems of the SH and the CA and registers for events that prove the dispatch of cargo from the SH and the cargo pick-up from the CA/FF, e.g., cargo left the Port of Valencia & cargo picked up by DHL. Upon the collection of the corresponding events from both the actors, EGTN Smart Contracts emit a Cargo Dispatched event.

IT02

Similarly, in IT02, the EGTN Blockchain service monitors the backend blockchain systems of the CA/FF and the CO towards providing trusted Cargo Delivered events. Upon the collection of the events/reports from the CA/FF and the CO, the EGTN Smart Contracts emit a trusted Cargo Delivered event.

IT03

IT03 focuses on the transportation of cargo and the interactions between CAs and the FFs. Smart contracts employ events from legacy systems (backend blockchain systems) and compare them with IoT data coming from smart T&L assets (see 4.2 and 5.2) to guarantee the trusted execution of the smart contracts between them, e.g. CA/FF/CO emit events while smart pallets send "Reach a POI" record.

IT04

The IT04 smart contracts compare system defined thresholds with IoT data from smart T&L assets to drive their decisions, e.g., if the vibration measurement in a smart pallet exceeds a predefined threshold, then break the contract.

IT05

The IT05 smart contracts employ diverse data sources to enable trust between SHs, FFs and COs by comparing system events with IoT evidence, e.g., customs cleared vs RFID-based cargo tracking, number of items expected

[3] GS1, EPCIS standard, https://www.gs1.org/standards/epcis
[4] BiTA, https://www.bita.studio

vs number of items delivered. In case all data sources agree on the same output, then the smart contracts emit a trusted event or fulfil the contract.

IT06

In IT06, data is separated from business logic and maintained in two separate smart contracts. The frame contract stores and exposes the basic frame agreement which generates data contracts between SHs, FFs and Warehouse providers to automate and streamline their interactions, e.g., if incoming transport orders in a warehouse exceed a limit, then outsource the excess demand.

IT07

In IT07, SHs, FFs and Warehouse providers take advantage of system data, historic data and forecasts from the EGTN Analytics components to streamline internal processes, e.g., hire more personnel when the forecasted incoming number of pallets exceeds a limit.

5.2 Connection to the IoT infrastructure of the EGTN platform

The connection to the EGTN Data Aggregator and the Connectivity layer is of vital importance, as it enables data-driven decision making through the execution of smart contracts. The connection of the Blockchain infrastructure with the Kafka service, as described in D2.15, will enable smart contracts to consume IoT data and other T&L related data. The EGTN smart contracts employ the T&L Data Connector of the EGTN Blockchain service to listen to logistics and transport events, which in turn trigger smart contracts and inform automated and trustful decisions.

IoT actuators placed in pallets, containers, means of transport and warehouses will feed the EGTN Platform with data in real time. The IoT data are described as follows:

Raw data

- Temperature
- Humidity
- Position & time
- Luminosity
- Acceleration
- Signal Strength (RSSI values for the connectivity of the Smart Pallet beacon)

Events computed based on the raw data

- Threshold exceedance (Temperature/Humidity)
- Bump (Acceleration)
- Open/close door
- Pass border
- Reach a POI

5.3 AI-enabled Smart Contracts

Within the capabilities of the decision support system of PLANET the enablement of smart contracts applications was considered, also known as self-executing contracts. The smart contracts applicability requires several technologies aligned with each other's functionality. These technologies consist of a data aggregation and data connectivity infrastructure which includes the Blockchain and the machine learning based AI forecasting models, from the big data analytics work presented in D2.9 *EGTN Support Services based on Big Data analytics models*.

This section aims partly to determine a preliminary back-end implementation and integration of the predictive models with the Blockchain, for potential future deployments of smart contracts, and their inclusion within the EGTN Platform. The smart contract applications aim to impact and bring further technology integration value to the transport and logistics software components considered and created within PLANET.

At its core this integration currently includes the capability to forecast warehouse pallet flow integrated with the Blockchain, as depicted in Figure 5, which in turn provides enhanced transparency and therefore integrity to the data shared through the Blockchain ledger. In addition to this, the automated trigger of smart contracts based on AI outputs leads to efficient contract negotiation without time delays and overheads.

The pallet flow forecasting models were preliminary evaluated in D2.9 to determine the incoming and outgoing load of pallets in a warehouse for the coming days or weeks. The forecasted information is provided by the predictive models in advance within a suitable timeframe. In this manner, it can enable warehouse operators or decision makers to take timely and accurate decisions to optimise resources regarding the allocation of trucks or additional personnel to handle the pallets more efficiently. Such an improved allocation of resources in hiring additional trucks or personnel can impact the services in several aspects, for instance decreasing time and costs, and increasing efficiency when automating further procedures such as the signing of contracts required for the allocation of such resources.

The work presented in this section in the context of smart contracts is currently in progress. The first step consists of identifying the specific manner the required and available data resources and software components - mainly for the AI based predictive models and Blockchain – will come together followed by their suitable integration. Other requirements that would be expected to be specified in more detail include the required forecasted time frames. Such requirements as well as other unforeseen considerations from the PLANET partners, based on their expertise, will be determined when the scenarios of the Living Labs are fully set and will be included in the final version of this deliverable (D2.19 due month 30).

Figure 5 illustrates the first approach that was considered between the involved partners for the development of the smart contract application. As the Figure shows the forecasting module output functions will act as input to the Hyperledger Fabric Blockchain application. A REST API will be required to be exposed by the Blockchain application (Hyperledger Fabric client) to implement the connection between the two components. Within the client application an analysis of the forecasting algorithm will be carried out either in a manual way or perhaps in a more automated way. The analysis of the predicted information with the client application would depend directly on the specifics of the forecasted time series data provided and how ready this is for a user to be interpreted. It could be the case that additional statistics or additional time resolution adjustments might be required, for instance to adjust different levels of information abstractions and granularity. Such additional analysis could vary based on the different use cases scenarios. These will be determined in collaboration with the involved project partners and will be presented in the final deliverable.

The information gathered and interpreted further within the client application is produced in a quantified form in a compatible format to trigger the smart contract application. Although the data that is used within a smart contract application is usually obtained from within the Blockchain where the contract is deployed, in this project it is proposed to consider additional external data, as required, from the big data analytics forecasting models and related support services, provided in a secure and trusted form.

From this perspective smart contracts are activated based on data from the client application as depicted in Figure 5. The data would most likely be provided in the form of data instances in such a way that enables the evaluation of each of the *if-then* based rules that a smart contract is comprised, which could vary depending on the use cases or scenarios considered.

Depending on the complexity or the amount of the *if-then* based rules to be considered in the smart contracts, further rule or tree-based machine learning models could be enabled. These types of models would be able to comprise and summarise the rules considered for a particular contract aiming to acquire additional resources required. The "if-then" rule-based models would particularly be useful in the following cases:

- Further automation is required for scalability purposes of the smart contracts.
- Handling a possible increase of the needed data to evaluate the "if-then" rules.
- In case the rules considered in a contract or a set of contracts for a particular application grow exponentially. In this case a self-adaptive approach such as using a *rule-based* (or tree based) model could synthetise and prune off automatically the number of rules in case these are redundant and not relevant.

In this manner, a mechanism in which the contracts automatically react and accommodate information variations within particular use case would be enabled.

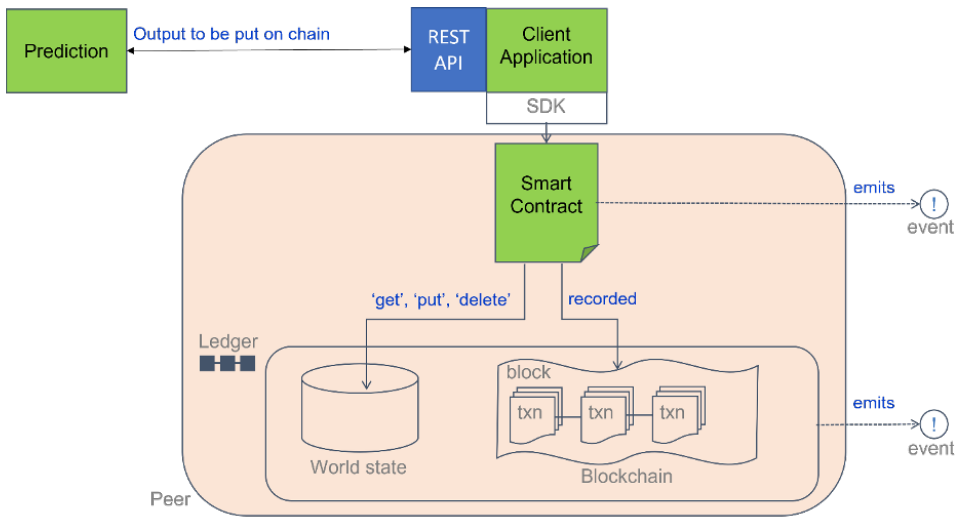

Figure 5: Blockchain and Big Data analytics models integration for Smart Contract services

Following the evaluation of the "*if-then"* based rules within the smart contracts, the application would output a state type regarding the contract itself. These outputs or set of outputs are recorded in the Blockchain ledger and database as depicted in Figure 5. Blockchain technologies are an obvious solution to handle information within smart contracts, since they provide transparency and safeguard against data tampering, which is required for the collaboration between different stakeholders, especially as it provides decentralised services over the shared data.

The generation of smart contracts and their execution once tested will aim at quantifying usability of the specific solutions within the Living Labs, considering that one of the main characteristics of smart contracts is their ease of use. Evaluations will aim also to include testing of novel approaches in applying machine learning based models, and their predictive outputs to handle information more effectively, focusing also on trust and privacy preservation and encoding the functionality needed accordingly to provide higher automated services in the EGTN Platform.

Taking all the above-mentioned into account, it is worth highlighting that the combination of smart contracts with other technological advancements such as IoT data and AI predictive models can make the step towards the realisation of the PI even smaller, by decreasing reaction time to special events (especially the use of real-time IoT data) and increasing efficiency in smart contract negotiations (through AI predictive models).

6 EGTN Smart Contracts Deployment

In the context of EGTN, smart contracts will be deployed to support critical interorganisational trade workflows and enable the exchange of T&L data between different proprietary backend Blockchain systems. Smart contracts will be deployed on permissioned Blockchain networks as well as on public Blockchains in the case of LL2. In this way, the EGTN Blockchain will combine the benefits of private permissioned Blockchains (scalability and identity verification) with those of public Blockchains (trust and decentralisation) as well as will also achieve interoperability between diverse types of Blockchain systems. The different backend systems that are connected through the EGTN blockchain front-end are presented in Figure 6.

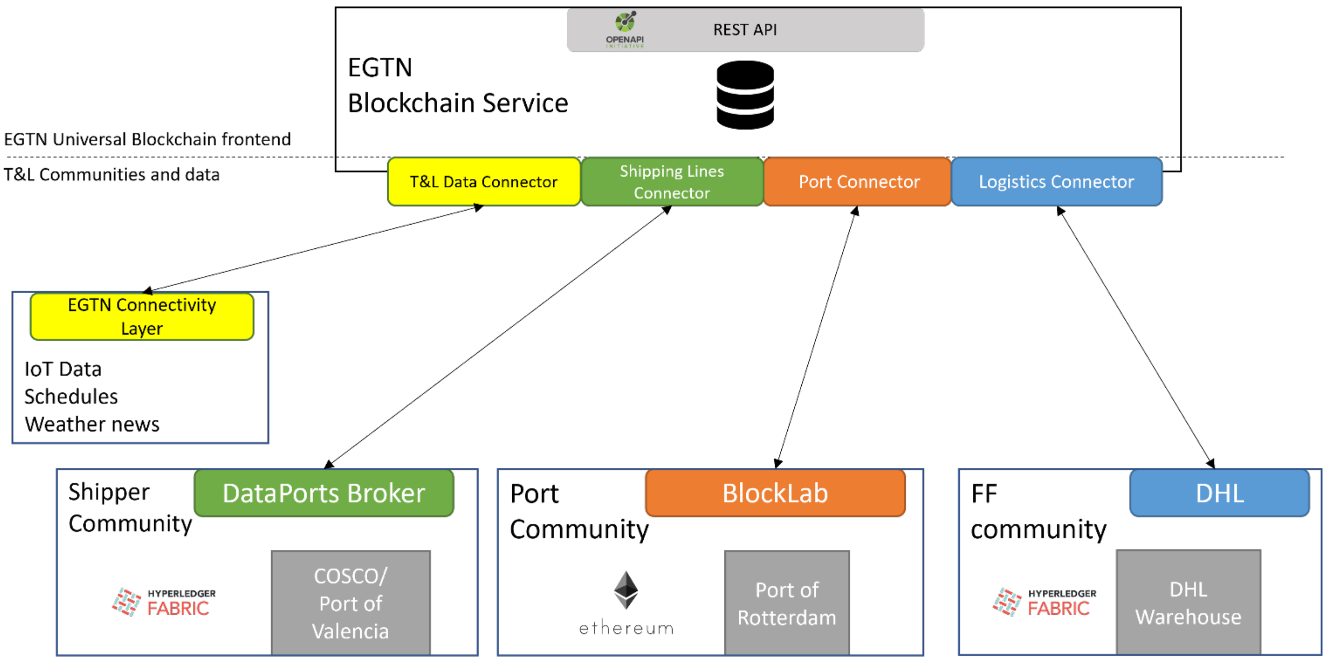

Figure 6: EGTN Blockchain Service Architecture

As described in D2.15, an initial version of the EGTN Blockchain service has been deployed in an experimental environment and the Blockchain interoperability infrastructure is assessed in terms of scalability, security, and performance. Initial versions of smart contracts have been deployed (link to GitLab[5]), which enable the interaction between the backend Blockchain systems, the EGTN Blockchain component, the IoT and Connectivity layers and the Analytics tools of the EGTN Platform, as shown before in Figure 4. The final version of the smart contracts, the final specifications and the details on the technical implementation will be described in the final version of this deliverable (D2.18 due in month 30).

6.1 Security and privacy considerations

Most of the backend Blockchain systems are private permissioned networks where data is exchanged among trusted and identifiable participants. This is the case for the Port of Valencia and DHL, as they both use Hyperledger Fabric networks. However, the Port of Rotterdam uses a public Ethereum testnet to upload anonymised but realistic shipping data.

Regarding the data exchanged between the private blockchain systems, the EGTN Blockchain service connects to each of them through the Connectors using credentials and cryptographic keys that are natively used by the

[5] EGTN Smart Contracts, https://gitlab.com/planet-h2020/egtn-smart-contracts

employed Blockchain framework (Hyperledger Fabric). This gives them read-only permissions on the ledger of the backend system. The EGTN Blockchain component acts as another typical node of the Hyperledger Fabric network taking advantage of the secure protocols employed for the communication between the nodes using Transport Layer Security (TLS).

On the other hand, typical Ethereum clients are used to connect to the public Ethereum testnet to listen to events generated by the Port of Rotterdam system. The events include only hashes of anonymised data accompanied by metadata useful for identification and filtering.

7 Conclusions

This report aims to inform the reader on the progress performed in *ST2.5.2 EGTN Smart Contracts*, which focuses on the structure of the smart contracts and associated PI motivated workflows in the context of SLA management.

The deliverable describes in detail the PI workflows that have been identified and developed until the time of its submission, along with the respective requirements as well as the involved actors and stakeholders. It then moves on to present the structure of the EGTN smart contracts, which will be stored on the EGTN Blockchain component, including the terms and conditions, as well as the data structures that will be exchanged between the different Blockchain systems.

The interconnection between the EGTN smart contracts and the IoT connectivity layer was presented aiming at the development of automatically triggered smart contracts. In the same context, the preliminary approach towards the integration of AI forecasting models with the EGTN smart contracts was presented. Both solutions hope to bring further technological value to the PLANET project.

The EGTN smart contracts, deployed in the context of the EGTN Blockchain component, offer tremendous benefits to the entire T&L sector, by fostering collaboration between all the different actors involved. These technological solutions offer integrity and immutability of the data throughout the entire supply chain, automated and safe contract execution, reduction of overheads and time delays, and a distributed and community-driven approach.

The final version of this deliverable (D2.18 due month 30) will report on the development process of the EGTN smart contracts, including the overall findings and outcomes of the deployment of the solution on the PLANET Living Labs. The deployment process will also be included in the form of a blueprint so that any interested parties can easily use or extend the entire EGTN Blockchain component.

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