



New **ICT** infrastructure and reference architecture to support
Operations in future PI Logistics **NET**works

D2.8 Smart PI Containers – Tracking & Reporting as a Service – Final

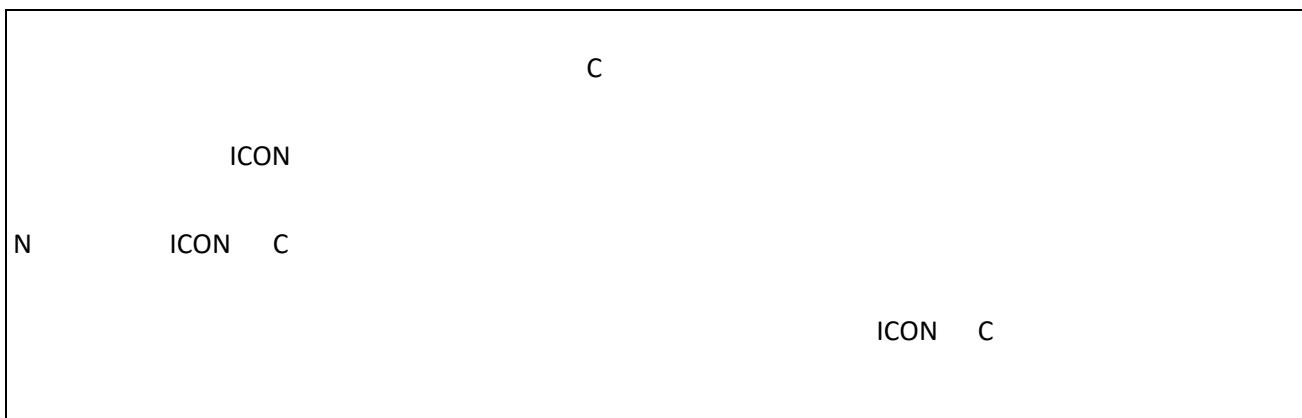
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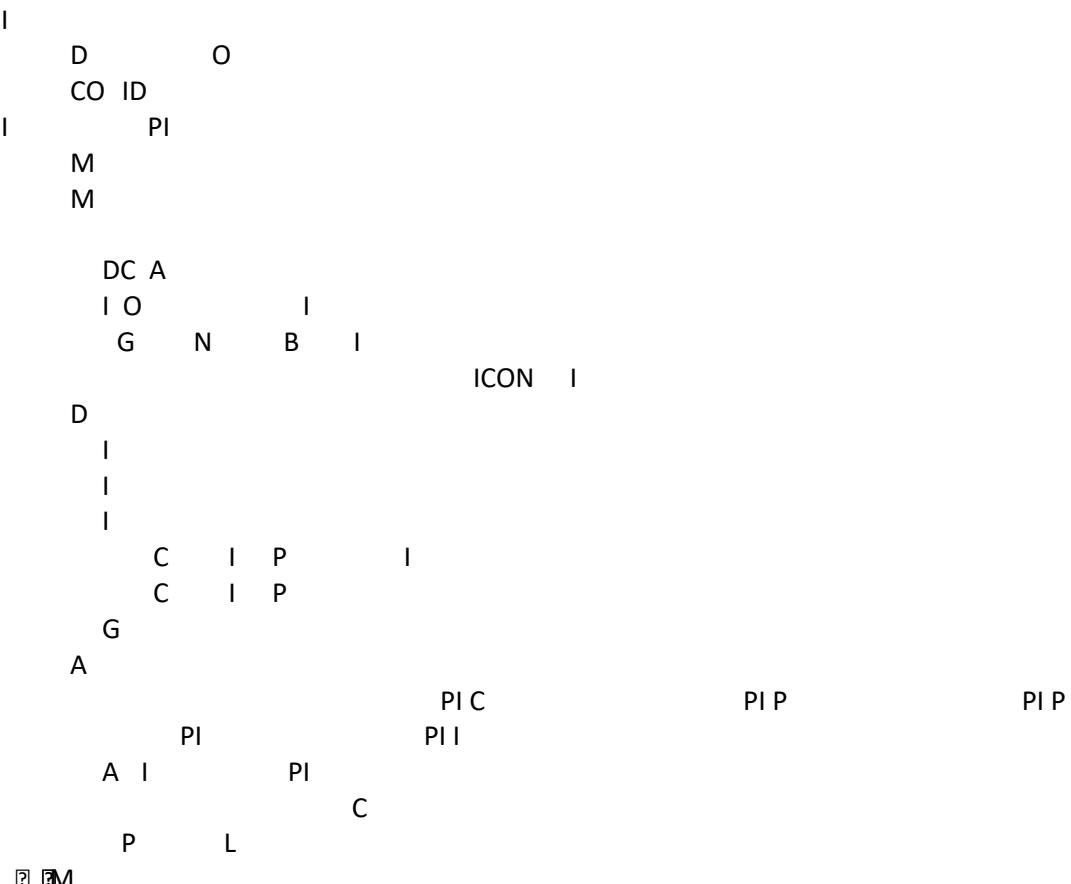
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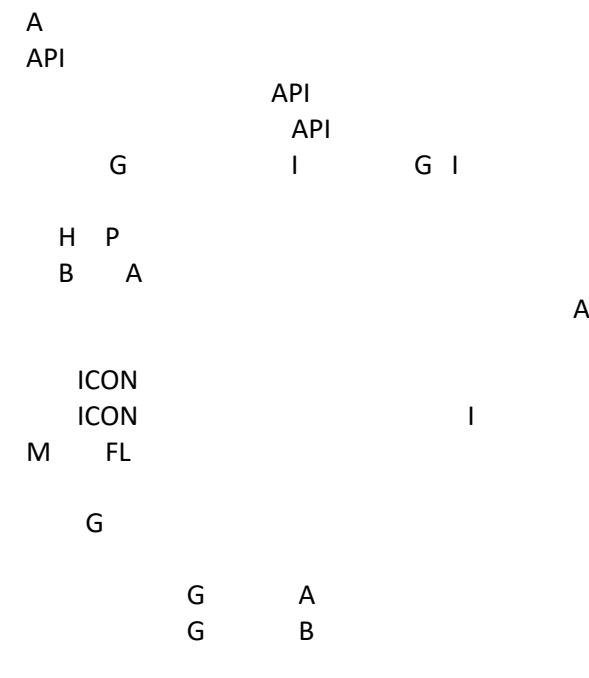


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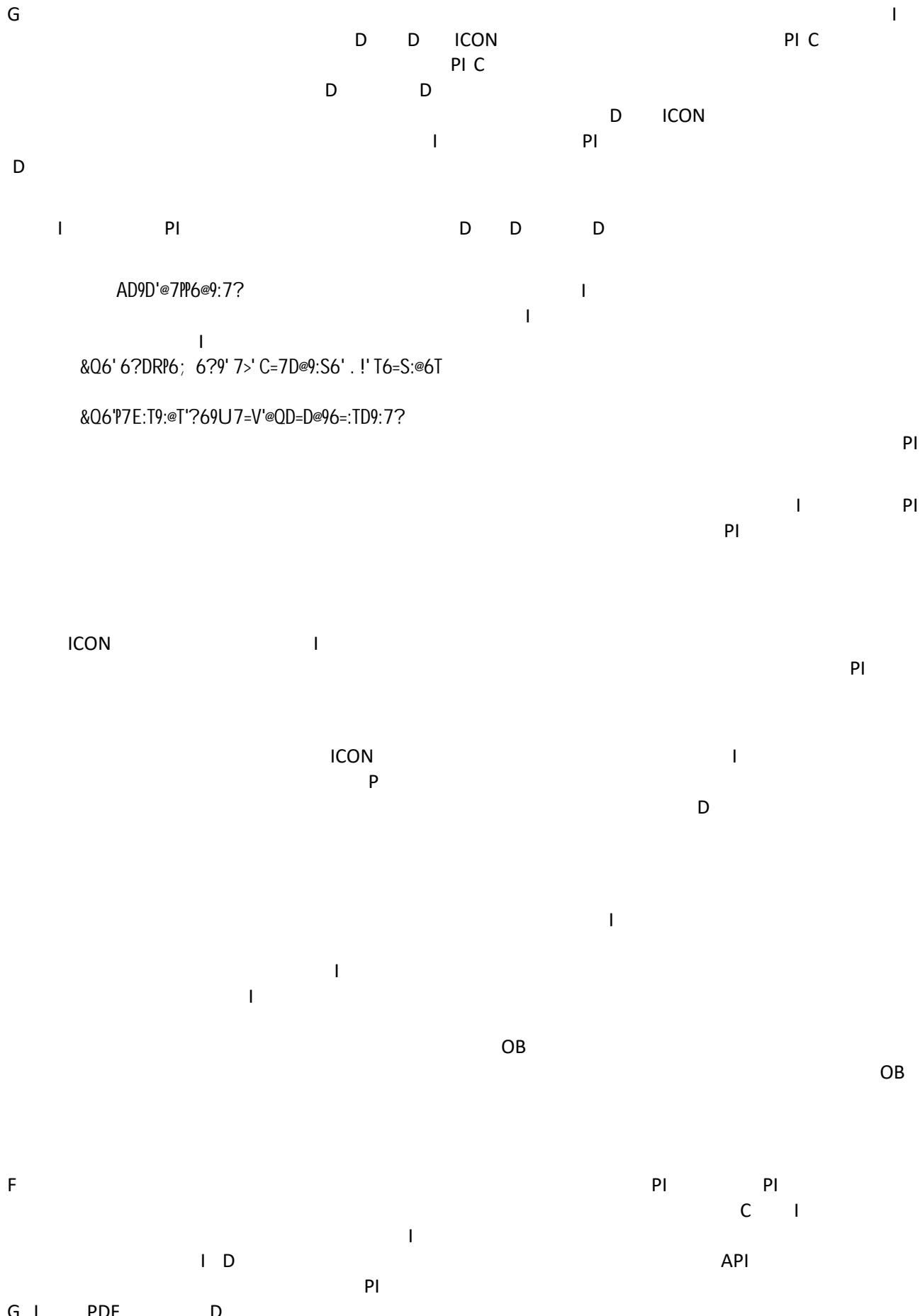
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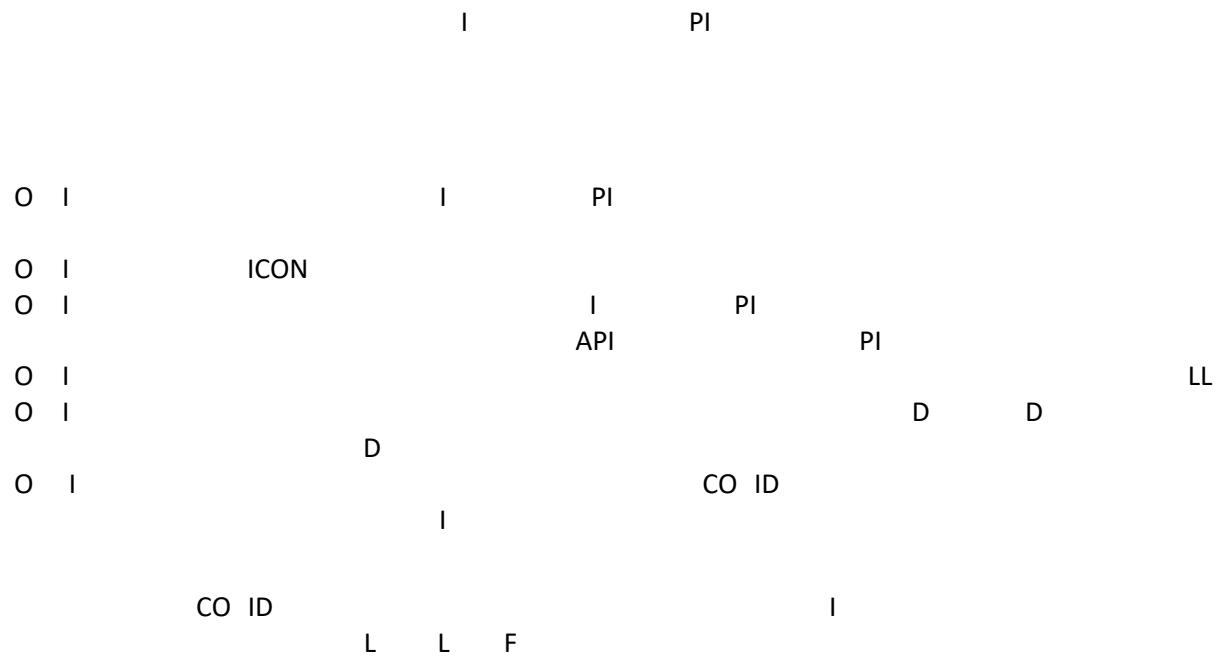
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Glossary of terms and abbreviations used

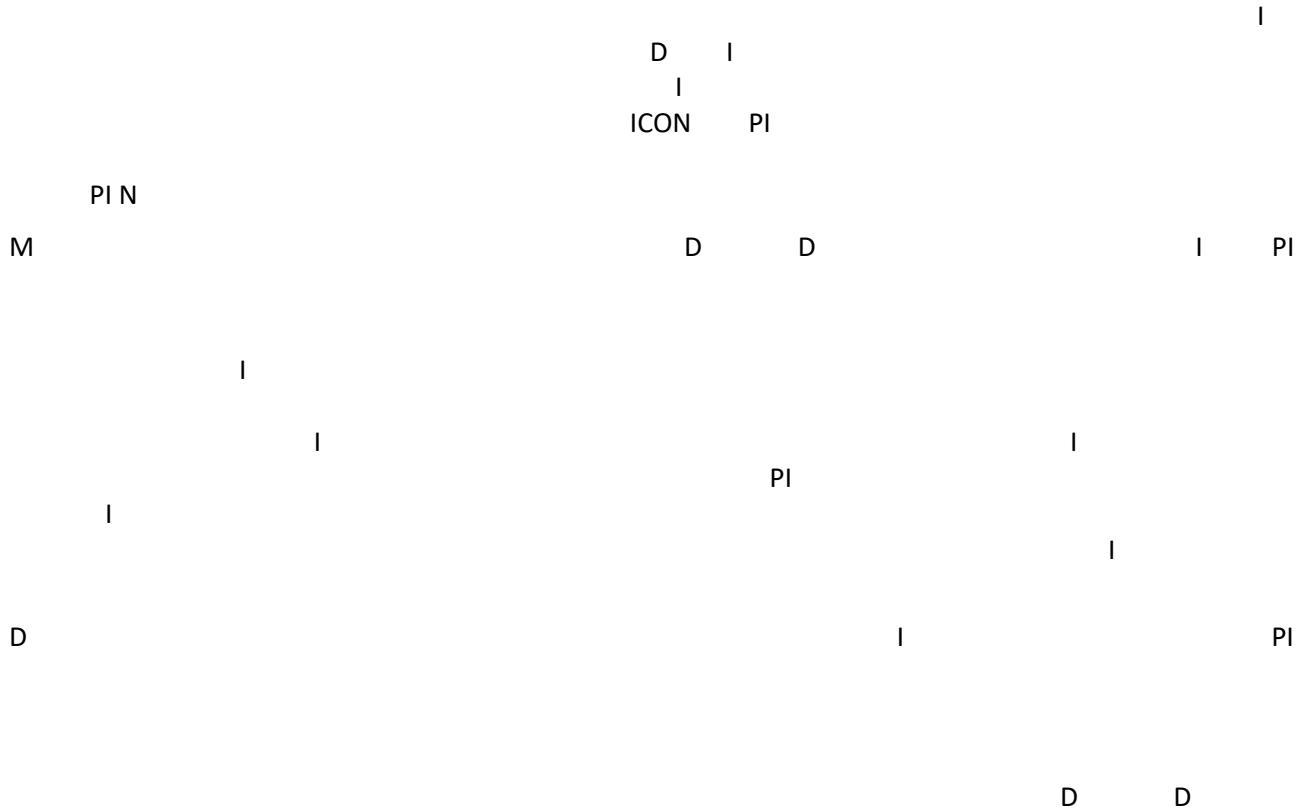
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1. Executive Summary

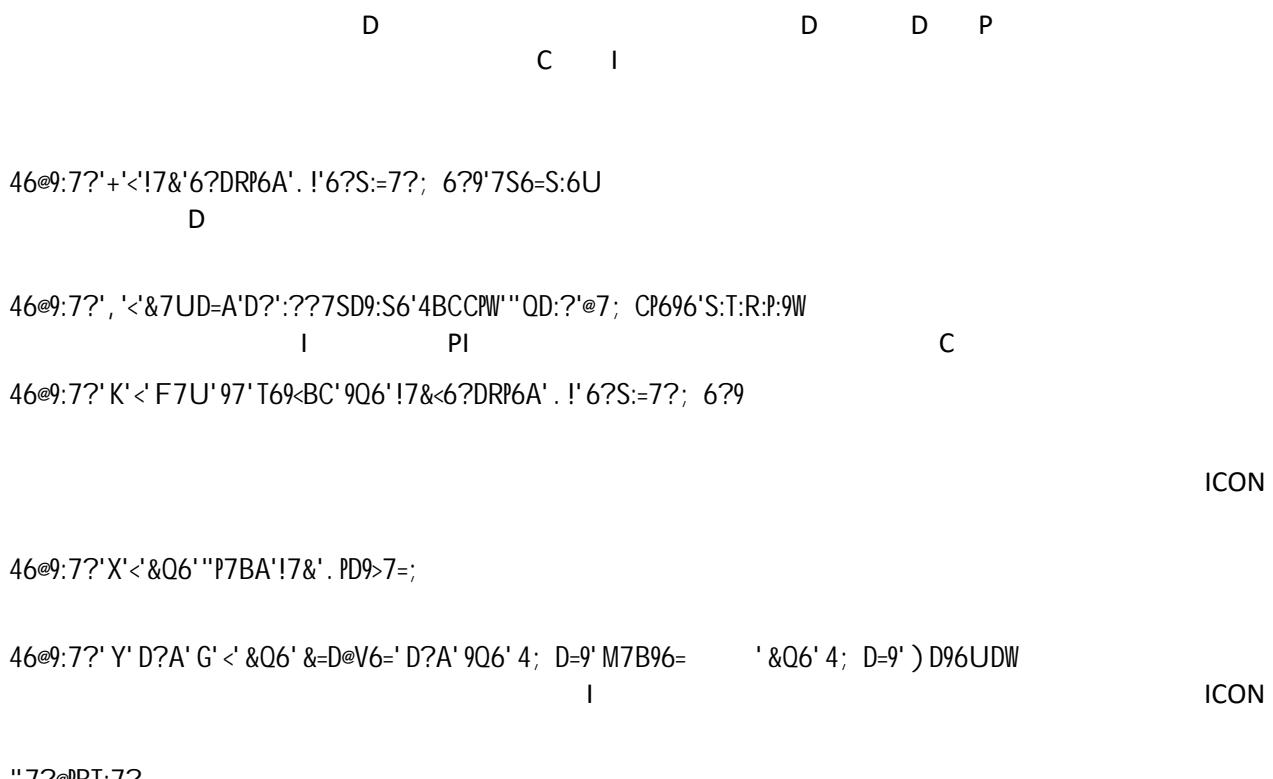




2. Introduction

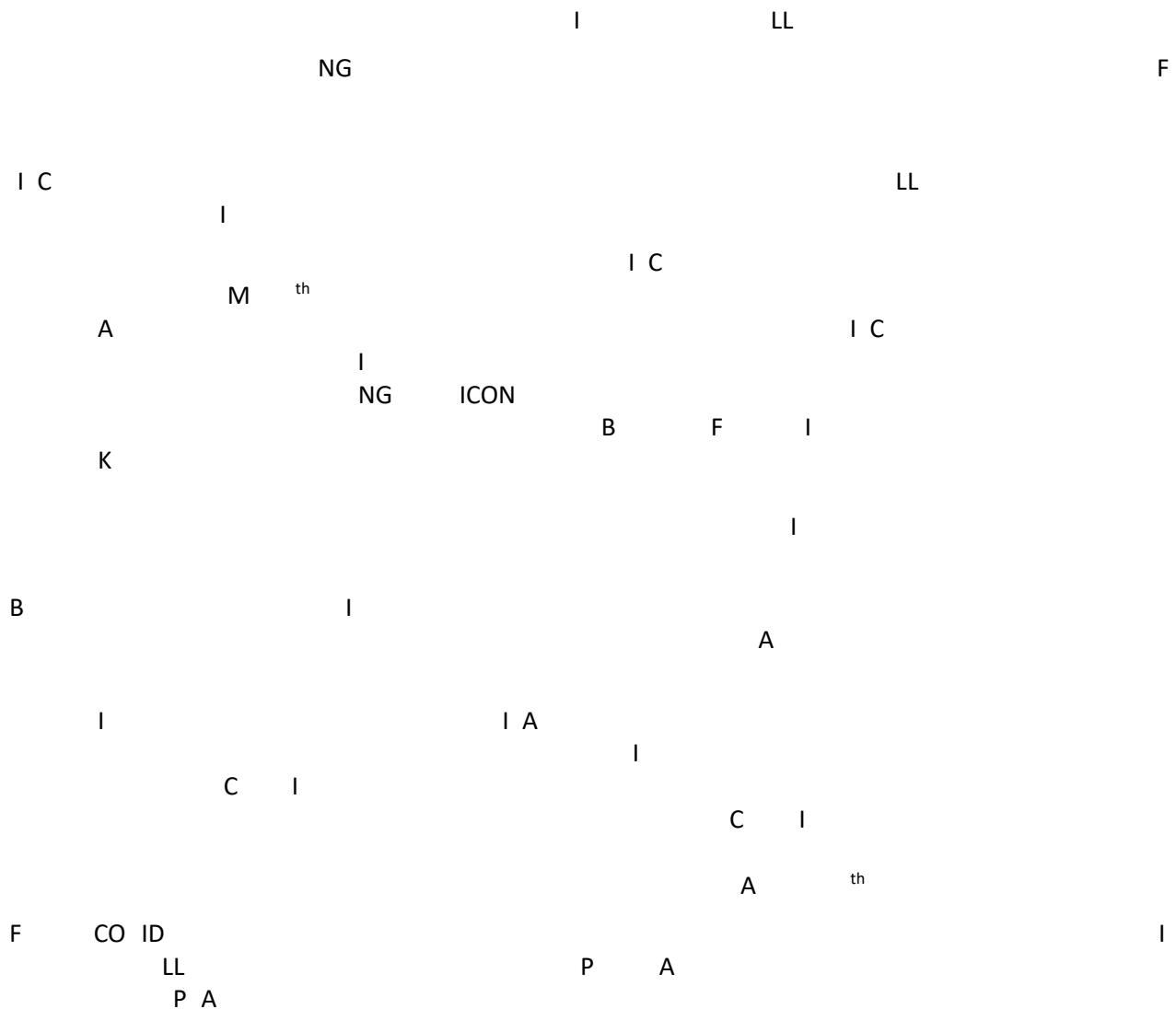


2.1 Deliverable Overview and Report Structure



2.2 COVID-19 pandemic delay and mitigation activities

CO ID



3. IoT enabled PI environment overview

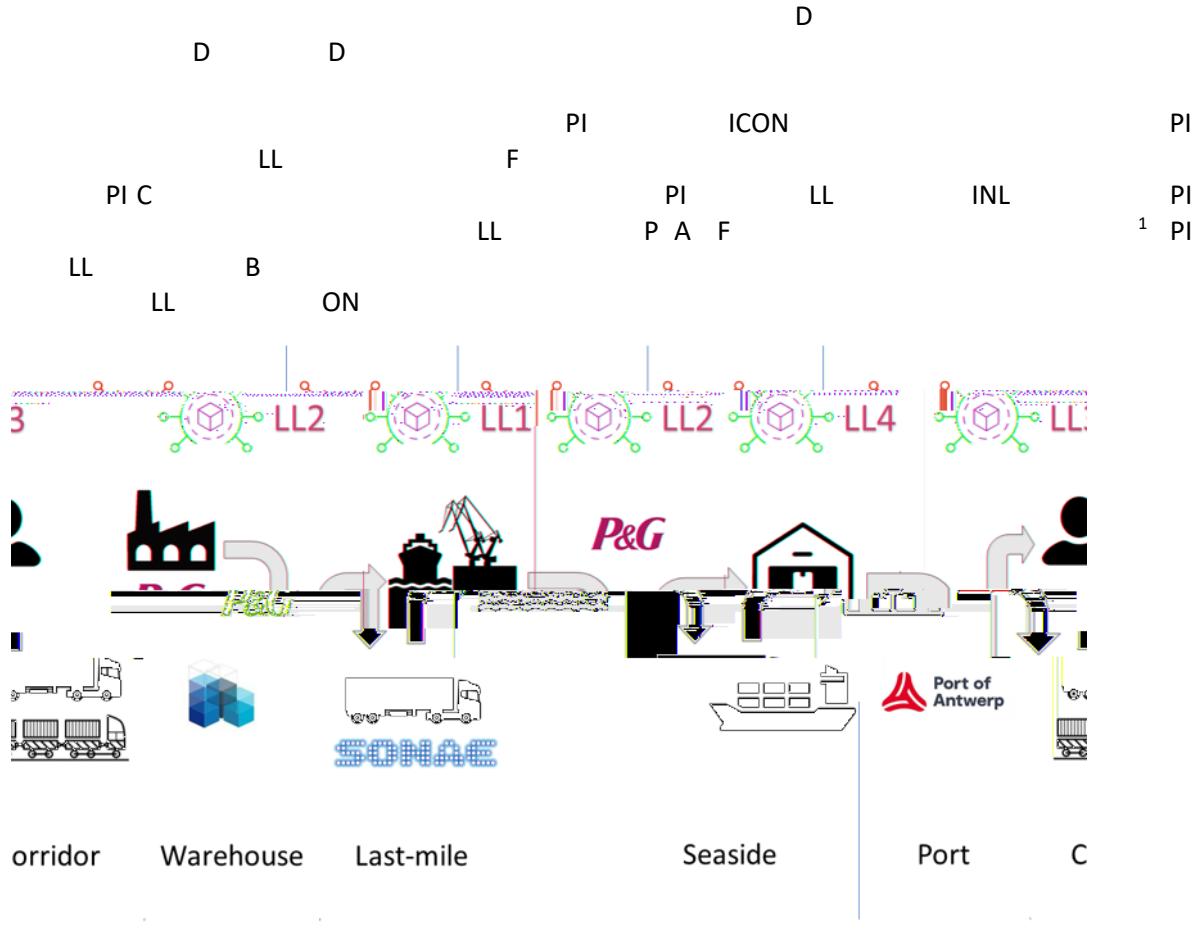
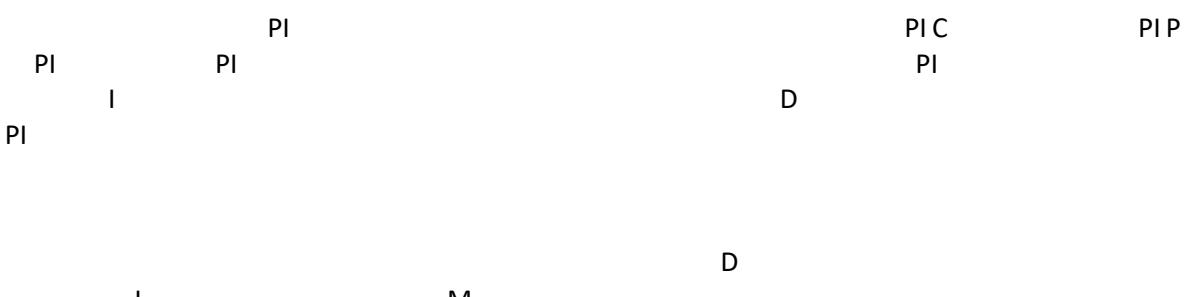


Figure 1 PI seen by the ICONET perspective



3.1 Main business requirements overview

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¹ We use the Digital Internet term of proxy. In DI, a proxy is a server application that behaves as an intermediary for requests from clients seeking resources from other Internet servers that provide those resources. Proxies aims at the simplification and optimisation of the complexity of requests.

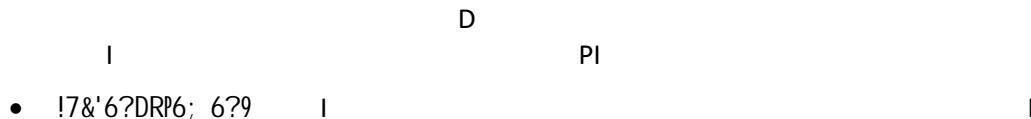
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Table 1 Business requirement summary

R	D
A dab a d	The IoT physical infrastructure has to be affordable for all the users. As a service approach has to be preferred to the device selling. The IoT service must provide interfaces that allows an affordable and secure integration with third parties' software (e.g., Port's RMS, Warehousing, Traffic control, Resources status, TMS etc.), respecting the privacy issues.
Ea a d a a a Ea a	The logistics operators are not expert in technology. The system has to have an easy installation process, in terms of physical deployment, maintenance and configuration.
S c a b a S c a d a	The IoT will provide a reliable, low-cost end-to-end and real-time visibility of the whole supply chain (corridors, warehouses, hubs). The visibility has to be implemented with an improved granularity for all the encapsulation layers (e.g., PI container, pallet, packet). In this scenario, each stakeholder involved in the logistics transaction can access to IoT devices deployed at every level of the encapsulation stack (e.g., PI container, pallet, packet).
L ca a a d d a a a a	The IoT will provide the position of certain goods at a certain time at multiple layers (e.g. PI container, pallet, packet). In this scenario, an advanced track&trace service can be provided, providing real-time encapsulation information up to the goods layer.
L ca a a a a A a	The IoT will be provide the connectivity for monitoring assets connected to the logistics operations (e.g., shelf, pallets, crates, containers ...), thus providing information regarding their position and status. In this scenario, an improved assets' management will support the optimisation of the operational efficiency.
E	The IoT will monitor the status of the goods in terms of integrity or safety (e.g., cold chain monitoring) at multiple layers (e.g., PI container, pallet, packet).
Da a ac ba d b a a d b	Exploiting the data retrieved the IoT environment, Big-data analysis techniques can be implemented to generate knowledge and models to support the decision-making implementing Data-oriented and fact-based business intelligence
Acc a a ETA d	The storage of bigdata generated by the IoT devices, can support the computation of an accurate ETA prediction.
Ma o E c Ca ac R G	Improved efficiency improving the capacity and the efficiency of the intermodal corridors, hubs, and of the warehouses, thus reducing the costs and/or increasing the profits. Examples: (i) Increasing the transport load factor, thus avoid empty trips; (ii) implementing a reliable and up-to-date warehouse management; (iii) Optimised and deterministic scheduling and organisation uploading/downloading/crossdocking operations in PI hubs.
I c a Sa a a a a a c ad a a	Implementing a reliable, secure and less expensive logistics services, and offering an advanced information sharing service capable to provide an accurate end-to-end real-time visibility of the goods along the supply chain and accurate predictions. Moreover, it allows to gain competitive advantage by differentiating against similar supply chain actors
Fa ab	Exploiting the information coming from the IoT, the liability of certain event can bring back to the effective party.

D

3.2 Main technical requirements and architecture overview



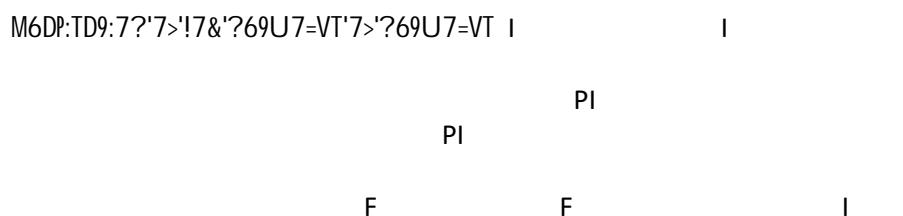
Composability and pervasiveness. IoT must allow the PI-packets encapsulation, implementing the Recursive Gateway-mediated Edge Connectivity and Management pattern, depicted Figure 2. This configuration must allow a hierarchical monitoring of PI-goods, PI-containers and PI means. IoT must allow a pervasive monitoring (e.g., also inside the container, where the wireless/5G connectivity are un-available), thus answering the questions “Where?”, “When?” and “How?” for all the encapsulation levels (see

-
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- %DTW' BT6'; D:96?D?@6'D?A':?96E=D9:7?I'
- "P7BA'RDT6A'CPD9>7=; I'

API

Table 2 “Where?”, “When?” and “How?”

NQ6=6[P
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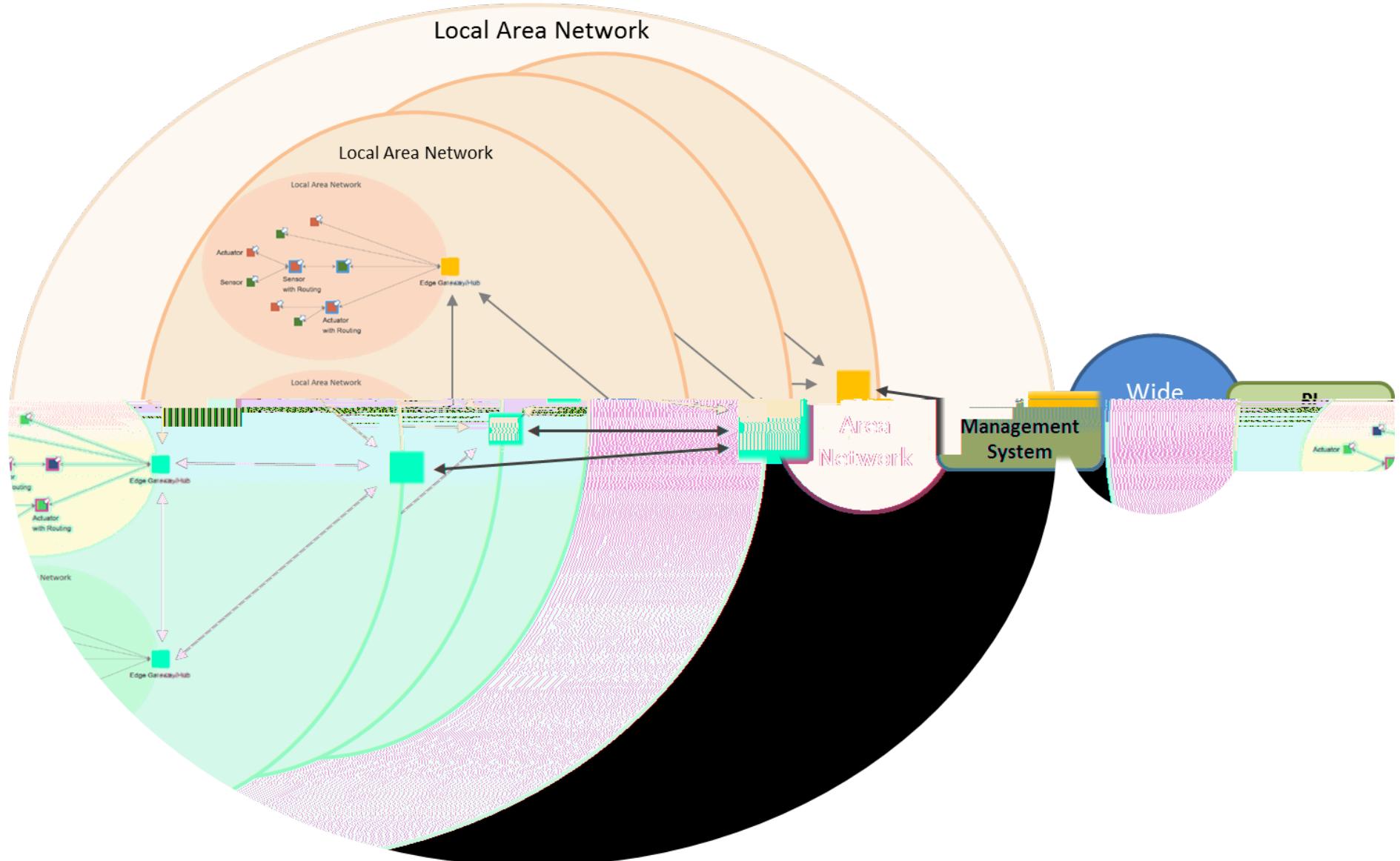


Figure 2 Recursive Gateway-mediated Edge Connectivity and Management pattern

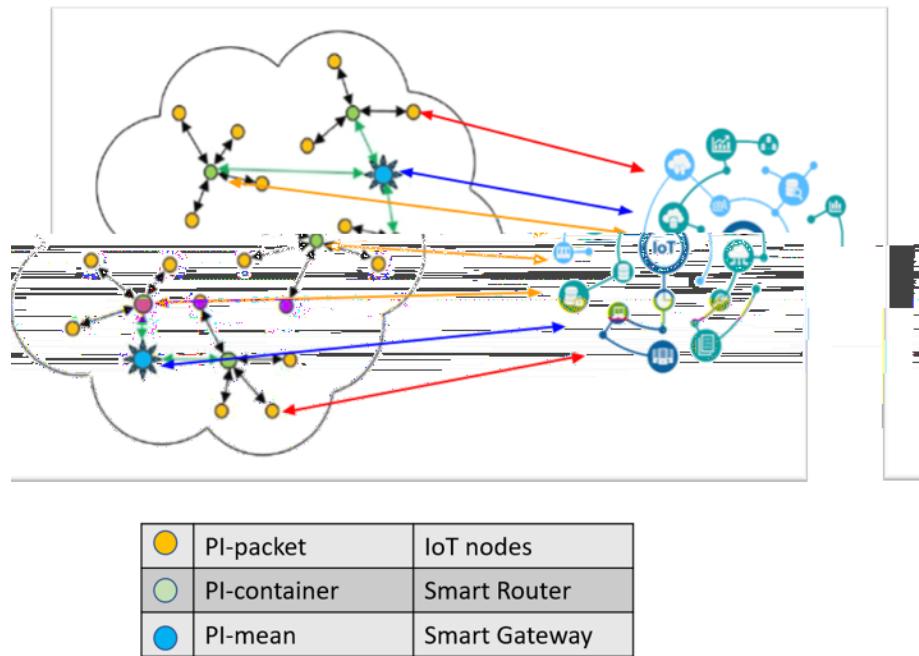


Figure 3 Hierarchical monitoring: a hierarchy of IoT devices

2. An IoT device, equipped of more than one network interfaces, can select between the available ones the most convenient. As matter of example, an IoT devices can select the cheapest or the less power intensive connection, or, inside the container (done in metal, thus behaving as a Faraday cage²), can cooperate with a higher hierarchy level device, capable to implement communication routes toward the Cloud. The exploitation of multiple IoT networks interfaces improve also the ubiquitousness characteristics of the system.

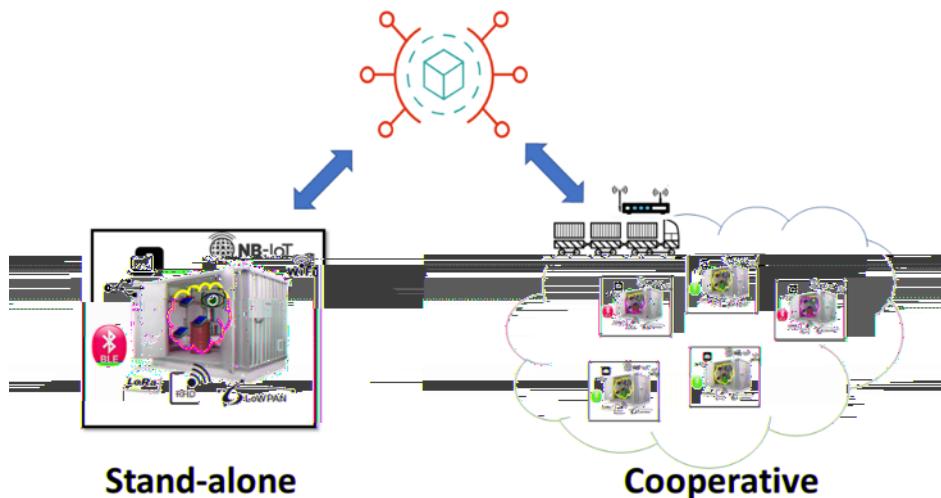


Figure 4 Opportunistic routing

As depicted in Figure 3, each element of the PI-enabled logistics (e.g., PI-packet, PI-container, PI-mean, ...) can communicate exploiting the opportunistic routing, thus participating in the generation of IoT networks of networks. This approach improves the coverage and the pervasiveness of the IoT network allowing the implementation the complete visibility of the supply chain, communicating in real-time added value information regarding the goods and their encapsulation with improved granularity.

² A Faraday cage is an enclosure capable to block electromagnetic fields. Metal enclosure as containers are Faraday cages.

3.3 Standardisation reference framework

In this section, the reference standardisation scenario for the realisation of supply chain complete visibility is described. Particularly, we will consider the standardisation path implemented by DCSA, that has been released in May 2020, regarding the realisation of the IoT connected container, the ISO suite to define the communication stack for Intelligent Transport Systems (ITS), and the 5G. Both these standardisation experience are taken into account in the realisation of the Smart PI Container/Smart PI Pallet/Smart PI Mean (see Sec. 3.5) and the devices for implementing them (see Sec. 7 and 7).

3.3.1 DCSA standard for digital containers

DCSA (Digital Container Shipping Association) is a non-profit organisation established in 2019 by several of the largest container shipping companies with the mission to drive technology standards to enable carriers to bring innovative solutions to market. Their main objective is to define standardised approach to provide information throughout the container journey overtaking the lack of interoperability between different IoT solutions (6). In our point of view, the compliancy with this standard is important since it is released by the industry for the industry, to satisfy a real hot topic in the logistics domain (the complete visibility of the supply chain) toward its optimisation in terms of costs and environmental impact.

The “DCSA Gateway Connectivity Interfaces standard” (7) has been released at the beginning of Q2 2020 and represent the first step towards solving this lack of interoperability. In fact, its scope is to standardise a set of Physical and Media Access Control (PHY+MAC) layer protocols to interconnect containers, allowing the data collection and dispatchment toward remote control rooms. Because the considered environment (the logistics container world, so moving object detached from the infrastructures), the selected protocols will be wireless and low power consumption, allowing the autonomous supply exploiting batteries.

The standardisation document is organised in 3 Use Case (UC) listed below:

- UC_1. Reefer container sensor & other data monitoring, tracking and remote control.
- UC_2. Dry container sensor data monitoring and tracking.
- UC_3. Automatic electronic container registration.

Particularly, UC1 and UC2 are related to the tracking and monitoring of containers as depicted in Figure 5. DCSA envisions the possibility of deploying gateway on vessels, on landside means and on ports/terminals/container yards capable to gather added value information for tracking and monitoring the containers.

The scenario proposed by DCSA suggest how to dimension the static gateways installed on the infrastructure, and, therefore, the IoT devices (for tracking and monitoring) to be installed on the containers. For this reason we can extrapolate that the envisioned devices compliant with the DCSA standard must consider almost one of the protocols described in Figure 6: cellular (2G, 4G, LTE-Cat. M, NB-IoT), LoRaWAN and BLE. Of course, the landside IoT devices equipped with cellular technologies can directly communicate toward the remote-control rooms exploiting the network made available by mobile network providers.

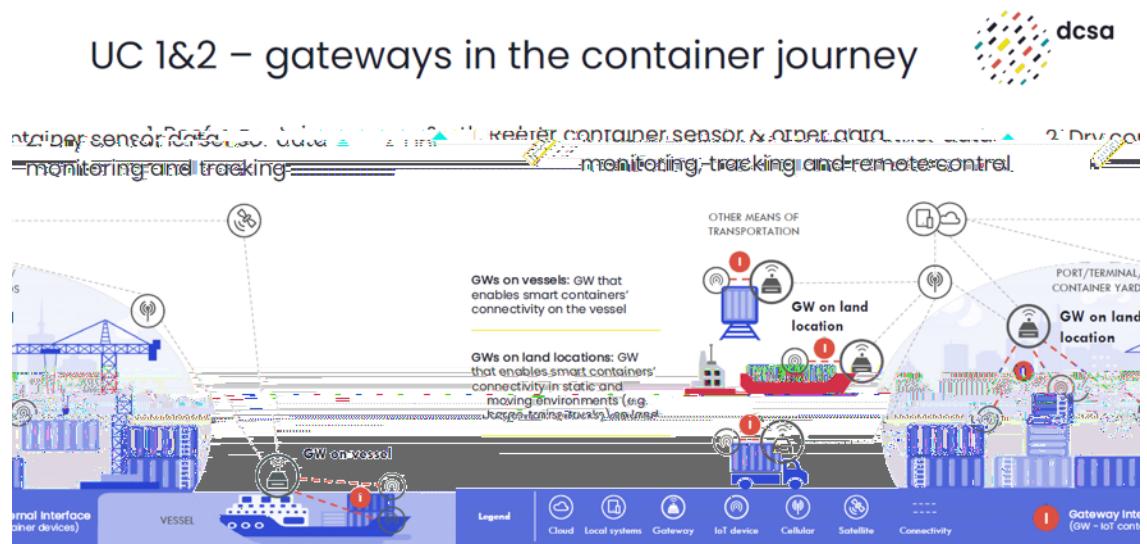


Figure 5 DCSA environment and connections

Use case Groups	Domain	Functionality	Gateways types	Internal radio interface(s)
Group 1 Reefer container sensor & other data monitoring, tracking and remote control	At sea	On vessel connectivity	Gateways on vessels GWs that enables smart containers' connectivity on vessels	<ul style="list-style-type: none"> Cellular (2G, 4G, LTE-M, NB-IoT) LoRaWAN (sub-GHz ISM bands) Bluetooth (2,4 GHz ISM band)
Group 2 Dry container sensor data monitoring and tracking	On land	On land connectivity	Gateways on land locations GWs that enables smart containers' connectivity in static and moving environments on land locations	<ul style="list-style-type: none"> LoRaWAN (sub-GHz ISM bands) Bluetooth (2,4 GHz ISM band)

Figure 6 Considered IoT protocols in UC1 and UC2

3.3.2 ISO standard for ITS station

The ISO TC204 (8) WG16 has defined a standardised ITS communication stack, also known as CALM for C-ITS (Communications in Cooperative Intelligent Transport Systems), depicted in Figure 7 (to see the complete standardisation scenario in ITS check this link (9)). The proposed stack supports several physical communication media, that can be used simultaneously for different types of applications (ITS safety applications, ITS non-safety applications, and all legacy Internet applications). In this scenario, IoT can provide a great benefit in the ITS environment on integrating added value information sources as sensor nodes deployed along the road as well as on the vehicles. For this reason, two standardisation actions were done in 2016 to integrate IoT within the CALM stack: ISO 19079:2016 (10) and ISO 19080:2016 (11). In this view, it is possible to integrate in both Road Side Units (RSU) and On-Board Units (RSU) the 6LoWPAN+CoAP standard on top of IEEE802.15.X MAC and PHY layers (i.e., IEEE802.15.1-BLE and IEEE802.15.4) as depicted in Figure 8. Regarding the logistics and the PI domains, the interoperability with this standard suite is very important since it will be the base of the fully connected vehicle: in this manner the smart container can connect and share information with the OBU and then with the ITS infrastructure, thus using such infrastructure to dispatch the data collected with the remote Cloud IoT Platform, as well as feeding the transport side with added value data (e.g., notifying that the container is encapsulating dangerous compounds).

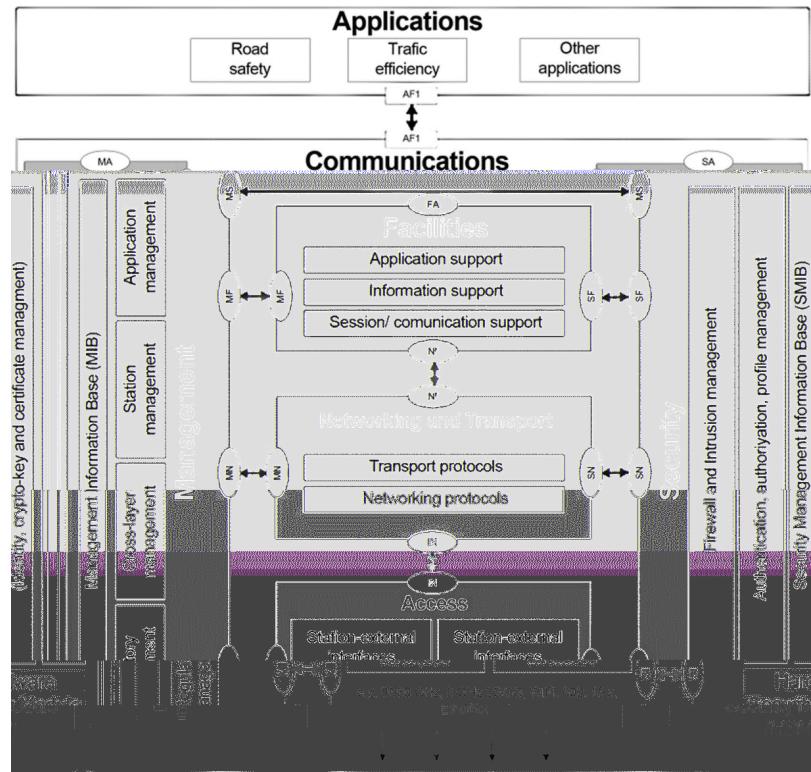


Figure 7 CALM C-ITS stack

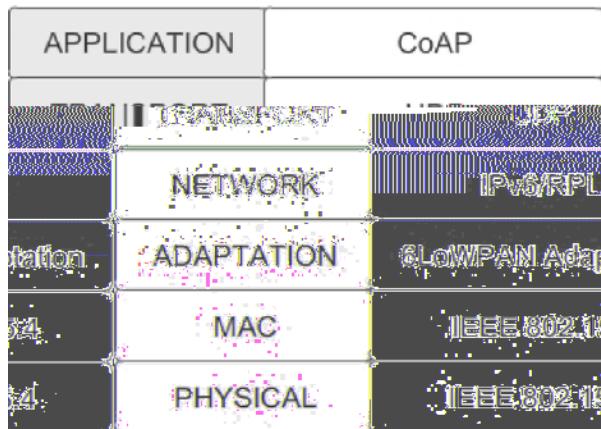


Figure 8 6LoWPAN+CoAP reference stack

3.3.3 5G and NarrowBand-IoT

is the fifth-generation technology standard for cellular networks, thus the planned successor to the 4G networks which is the current connectivity exploited by most of the mobile-phones. Its main improvements compared with the previous protocols are (see also Figure 9):

1. In fact, it aims at providing improved network coverage, long device operational lifetime (implementing improved power saving functionalities) and a high density of connections (improve the scalability managing a huge amount of IoT devices).
2. , implementing high performance, ultra-reliable, low latency industrial IoT and mission critical applications.
3. , implementing improved performance and a more seamless user experience accessing multimedia content for human-centric communications.



Figure 9 5G 3 directions (12)

NarrowBand-Internet of Things (NB-IoT) is a standards-based low power wide area (LPWA) technology developed to enable a wide range of new IoT devices and services. Its specification was frozen in 3GPP Release 13 (LTE Advanced Pro), in June 2016 (13). NB-IoT significantly improves the power consumption of user devices, system capacity and spectrum efficiency, especially in deep coverage. Particularly, the energy saving functionalities are improved with respect to the standard mobile protocols, introducing Power Saving and Extended Discontinuous Reception Mode (14).

In this scenario, considering the guidelines coming from the GSMA white paper of April 2018 (12), NB-IoT can be considered as forerunner protocol toward 5G. In fact, Figure 10 shows the various 5G network components that are built up and deployed over time. It highlights that NB-IoT, already (partially) operational, is considered (together with LTE-M) as the 5G technology capable to enable the , and it will coexist with the other 5G components (i.e., enhanced mobile broadband and critical communications) when these will be deployed.

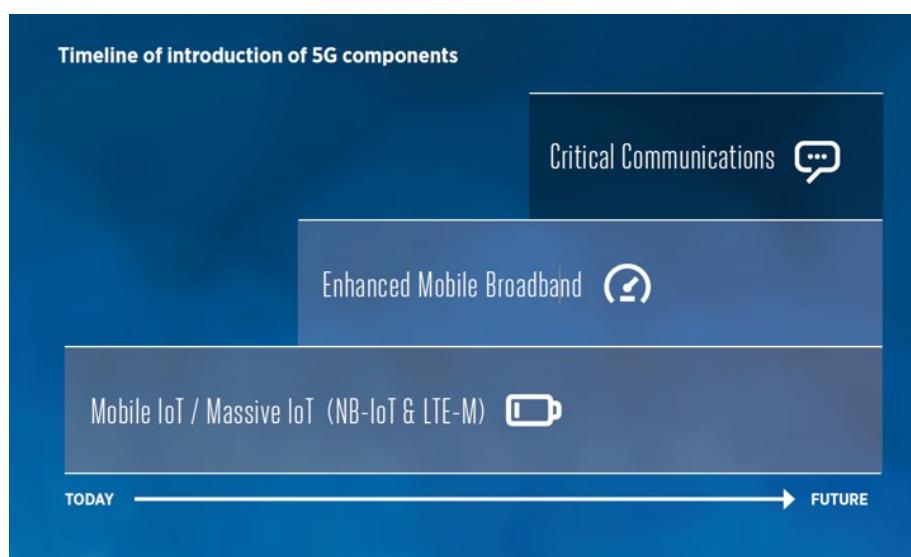


Figure 10 Timeline of introduction of 5G components (GSMA, 2018)

3.3.4 Standardisation framework vs. ICONET IoT architecture

The ICONET IoT architecture complies with the standardisation framework presented in the previous sections.

5G connectivity boosts the proposed architecture realising the natural pervasive communication infrastructure for implementing stand-alone transactions toward the Cloud. In this scenario, the exploitation of NB-IoT and LTE Cat-M allows the devices installed on top of the Smart PI containers to implement transactions toward the remote platforms with a reduced the battery consumption (thus reducing the costs) comparing with the previous cellular standards.

On the other hand, the ICONET IoT Architecture comply with DCSA standardisation scenario. In fact, DCSA standard Release 1 defines the IoT connectors for the realisation of gateways capable to collect data from (Smart/Connected) Gateways, both in the seaside (i.e., deployed in the vessels) and in the landside (i.e., deployed in the tracks, trains, infrastructures). Particularly, it envisions the exploitation of mobile stand-alone communication (considering 2G, 4G, NB-IoT and LTE Cat-M) as well as cooperative communication (i.e., LoRaWAN and BLE). This scenario leaves the possibility to implement multi-protocol devices capable to compose and select network, as suggested in the proposed architecture.

The compliancy with ISO CALM stack, can be seen as a generalisation of the DCSA standard: connected vehicles (in this case, trucks) enables IoT interfaces to cooperate with, allowing an improvement of the performance of both the transport and the logistics systems (as well as smart cities systems).

3.4 Data collection and sharing: interoperability and data usability

The IoT environment proposed in ICONET must implement an interoperable framework where devices of different stakeholder can cooperate in an open and scalable scenario. As highlighted in D2.6 and D2.7, the IoT framework will be one of the contributors of the PI digital infrastructure, thus it will expose interoperable APIs capable to satisfy up to the syntactic interoperability level (see Figure 11).

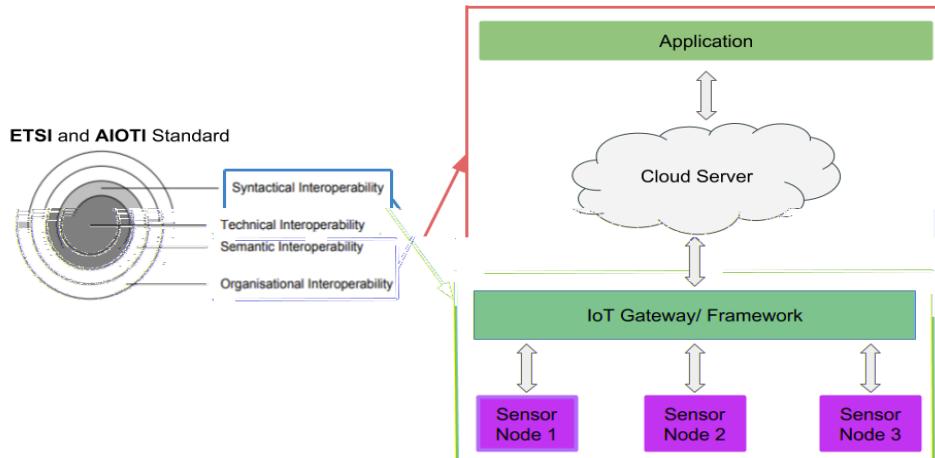


Figure 11 Mapping IoT framework on the ETSI and AIOTI Standard

In this scenario, the Cloud IoT is considered the main interoperability centre, since devices on the premises do not have available enough computational capacity to implement different interoperable APIs. In thi scenario, the Cloud IoT platform oversees:

1. Collecting data from devices of different parties in a secure and ad-hoc manner.
2. Dispatching data toward all the PI stakeholders involved in the PI transaction, in a secure and ad-hoc manner.

In the following sections, the interoperability issues are discussed focusing on:

1. How IoT devices will cooperate with the Cloud IoT platform interoperating up to the semantic level (see Sec. 3.4.1 and 3.4.2) considering a secure and ad-hoc approach (see Sec. 3.4.3).

2. How the Cloud IoT platform makes the data available to the PI world, in terms of interoperability and security (see Sec. 3.4.4), and the considered methodologies for data sharing and usability (see Sec. 3.4.4 and 3.4.5).

3.4.1 IoT devices interoperability – Technical and syntactic interoperability

As discussed in D1.6, while the direct Internet transactions (i.e., using Ethernet and Wi-Fi) implement the cross-platform interoperability design pattern (see Figure 12), while the mobile dispatchments consider the a Platform-to-Platform pattern, having in the middle the mobile network operators platform in charge of dispatching the data coming from the mobile network toward the IP address of the Cloud IoT platform (see Figure 13).

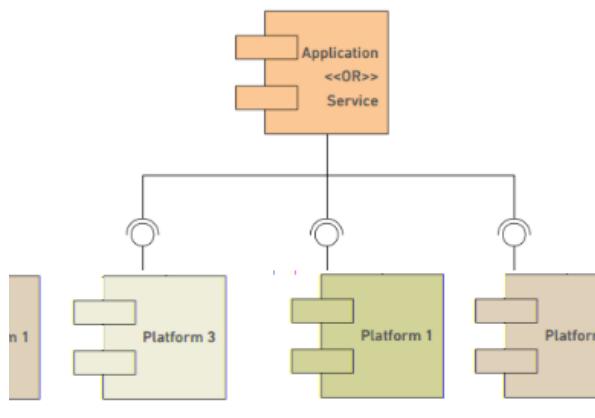


Figure 12 Cross-platform interoperability pattern

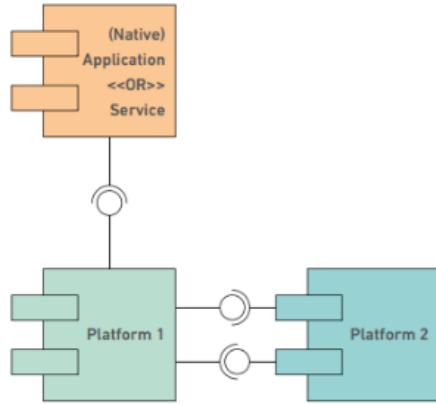


Figure 13 Platform-to-Platform interoperability pattern

The introduction of these approaches derives from the following considerations:

1. The IoT Device can select the best path to dispatch the data to reduce the power consumption, thus reducing its maintenance costs. In fact, usually mobile connectivity is more power consumption intensive with respect to the other IoT protocols considered by DCSA (i.e., BLE and LoRaWAN) or by ISO in the ITS domain (i.e., 6LoWPAN+CoAP over IEEE802.15.4).
2. Selecting a local gateway can also provide added value information regarding the encapsulation of the goods/pallets/containers.

3.4.2 IoT devices interoperability – Semantic interoperability

Following the guidelines of the deliverable D2.1 of the Horizon 2020 project CHARIOT (The CHARIOT project, s.d.), in D2.7 we have considered Sensor Markup Language (SenML) (RFC8428, August 2018) to improve the interoperability features of the proposed IoT environment toward the semantic level.

SenML is an emerging drafted standard from IETF for representing sensor measurements and device parameters. It defines a minimal and self-describing data-model capable to integrate data and meta-data (to describe the data), thus capable to satisfy the IoT efficiency constraints, as well as to realise the semantic interoperability among IoT devices.

On the other side, DCSA is going to publish the Release 2 of its IoT standards program to in depth analyse higher protocols layers than the one proposed in first release, as well as data structure and handling, as depicted in Figure 14 (DCSA, 2020) (planned to release in Q4 of 2020).

Figure 14

3. Analyse the data retrieved by the IoT devices generating (e.g., “how long the container stays at the customs?”). In this manner, raw data will be transformed into more comprehensible and aggregated information.
4. Realising an (), capable to visualise the route and the status of the container.

3.4.6 Generation of event, statistics, and meta-data

For the generation of events, statistics, and metadata, we will follow the following two approaches:

1. , that allows the processing of certain raw data at the edge of the collection layer (e.g., in the IoT nodes) generating asynchronous event driven information. The information generated by the edge computing are called . Of course, events can be computed at the Cloud side, but this type of information regards the punctual processing (only a set of samples related to the same time) of data gathered from the IoT devices.
2. , that allows the comprehension of long duration events, integrating along the time the raw data collected by the IoT devices. To implement such approach a data storage is required, and it will be realised at the Cloud/server level. In this scenario, defines the information that describes (e.g., time of arrival), while define the information derived by aggregating meta-data and/or events (e.g., the average of time of arrival). Particularly, statistics are general parameters independent by the shipment, anonymised and (e.g., average time of arrival). These parameters are computed/updated (metadata/statistics) at the end of each shipment.

In the following table the events, statistics and meta-data

	Meta-data	Cloud	Countries crossed during the shipment
	Meta-data	Cloud	The percentage of time, within the shipment, that a container stay stopped in a selected corridor.
	Statistics	Cloud	Average time to arrive from a certain point to a certain other.
	Statistics	Cloud	Average time that a container stays stopped in a certain area (e.g., customs).
	Statistics	Cloud	Average distance between a point to another.
	Statistics	Cloud	The average of the shipment efficiency in a certain corridor
	Statistics	Cloud	The percentage time that a container is booked in a PI orders with respect to a time period.

The computation and the sharing of these parameters will support all the PI users in the fact-based and data-oriented decision making process, simplifying the understanding how the goods dispatchments are implemented. Particularly:

1. can provide information regarding punctual facts happened during the goods dispatchment. The approach presented in ICONET allows the generation of computed on the stable IoT devices installed on the containers/truck trailers, as the one proposed in Table 3. However, it also enables the integration of , exploiting interoperable “special” IoT devices thought for certain vertical functionalities and services (e.g., monitoring of expensive wines).
2. , providing an ergonomic representation to analyse its performance.
3. , providing a powerful instrument of analysis and comparation, to evaluate the performance of a shipment, as well as of the whole logistics networks.

3.5 Architecture realisation and main components

The proposed architecture depicted in Figure 2 is a general architecture that can be deployed all along the supply chain, thus enabling its complete monitoring and the realisation of the PI-digital-twin. In this, the standardised communication interfaces will be integrated on the goods (PI packets or PI pallets) and will communicate exploiting the available communication channels on the connected PI-means, PI warehouses, and PI container. Particularly, the smart PI container can be considered the cornerstone of the PI, allowing the interoperation (monitoring) with the connected goods in-movement without direct power supply (battery powered) and remote communication considering different possible technologies thought for different environments (e.g., the boat environment in the middle of the sea, the truck environment in the motorway...).

In the following, the realisation of the Smart PI Container is detailed. Moreover, also the definition of the concepts of Smart PI Pallet and Smart PI Packet is provided, improving the goods tracking and monitoring granularity, and enabling the instantiation of scalable set of special functionalities and services, tailored for the specific commodities sector.

3.5.1 The realisation of the Smart PI Container – The Smart PI Pallet and the Smart PI Packets

The Smart PI container is the cornerstone of the ICONET finding. In fact, it is the brick that allows the realisation of the IoT environment capable to answer to the three questions of

Table 2. A solution can be defined as $ec ed PI c a e a ca e ab de a d de ef ca IT e f da a c ec a d ca ab e d a c e e e ga e ed f a$. Such a solution can enable an improved scalability on the amount and types of IoT sensors capable to provide added value information.

In this scenario, the smart PI container will be capable, to monitor the goods encapsulate inside itself, and to be encapsulated in a Smart PI-mean (or another level in the hierarchy shown in Figure 3), as exemplified in Figure 15. It allows the data collection regarding:

1. The , in term of position and time, as well as aggregated data as bump, T/H and light.
- 2.

Added value functionalities can be added to monitor the presence or the punctual status of the goods, or the container itself status (door open/closed, sealed/not sealed). In the following the concepts of Smart PI Pallet and Smart PI packet will be defined.

The smart PI-container must communicate remotely toward the IoT Cloud platform dispatching all the information collected. Following the DCSA guidelines the IoT device can exploit different paths toward the Cloud, selecting the most convenient between the available.

The concepts of Smart PI Pallet and Smart PI Packet introduce a set of functionalities capable to improve the performance of the supply chain and its related assets. In fact, in this manner several business requirements (summarised in Sec. 3.1) are realised, implementing:

1. . In this manner, the tracking and the monitoring services can be done at the level of the pallet or of the packet, supporting more punctual operations of routing and decision making. This service can, for example, support logistics operators that implement groupage policies (e.g., the transport of wine, where punctual temperature and bump is very important), or the improvement of last mile logistics services. Particularly, certain special edge functionalities can be implemented, only introducing a special IoT device though for that sector (no other configuration required).
2. . Having available the big picture of the availability of assets (e.g., container and pallet), the optimisation of their usage can improve their efficiency, thus reducing the costs.
3. . This point is the direct consequence of the previous one. In fact, having the big picture regarding the position and the availability of the assets (in this case the attentions are focused on pallets, kegs, baskets, ...) efficient



Figure 15 Smart PI-container



Figure 16 The Smart PI Pallet

and low cost asset-as-a-service solutions can be implemented. In this scenario, the re-use of assets is encouraged, thus reducing the environmental impact.

In the ICONET project, the enabler of both the Smart PI Container and the Smart PI Pallet is the smart routers (for further technical details, see Sec. 7). This device, implemented in the ICONET project, allows the implementation of all the features previously described:

1. It can be positioned on the top of the container and behaves as tracker (battery powered, GPS and on board sensors, 2G/5G connectivity).
2. It can establish internal connectivity to gather information from Smart PI Pallets as well as from added value IoT devices (e.g., gas sensors, open/close door, ...), considering 2 different short range IoT protocols.
3. It can establish external connectivity, to gather information from external added values IoT devices (e.g., smart seals, ...), as well as cooperate with gateway compliant with DCSA (instead of using 2G/5G, thus reducing the power consumption and the costs) and with ISO CALM stack standards (see Sec. 3.3).

On the other side, for the implementation of the Smart PI Pallet we have considered commercial devices BLE beacons equipped with added values sensors (e.g., temperature and humidity, bumps, reed sensors, ...). Such type of devices is selected since they have a cost comparable with the cost of the monitored assets.

The introduction of such device on the standard PI pallet

, enabling an . In this scenario a unique relation between the Smart PI pallet and the higher level gateway (installed, for example, on the Smart PI container or on a truck trailer) is established, allowing to have un-ambiguous goods-wise tracking. In the last mile logistics domain, it can support to monitor the operativity, e.g. understanding where the pallet is uploaded and downloaded. In the warehouse domain, it supports automatic inventory functionality and on the storage quality monitoring.

Moreover,

related with the goods encapsulated on it. For example, certain (expensive) wines need to monitor the temperature trends (they cannot to stay over a certain temperature for a certain period, to maintain their organoleptic characteristics): in this scenario special IoT devices can be installed in “special” Smart PI Pallets can be thought for these special functions and interoperate with the IoT environments (exploiting standardised approaches), without the need of reconfiguring the other IoT devices.

can be implemented having the position of “empty” pallets. These functionalities can improve the circular economy, reducing the environmental impact and allowing the implementation of “as-a-service” business models. This scenario fits perfectly with the realisation of specialised pallets (as previously mentioned), where the cost of the IoT device amortised, thus reducing the service costs and improving its performance.

Finally, other IoT devices can be added up to the Smart PI Container to implement important monitoring functionalities, as for example:

in reefer engines, to understand the health status of the motors to activate the refrigeration units.

Having information regarding the compounds’ concentration can support decision making (e.g., measuring the ethylene to understand the maturity level of the fruit) and improve the security (e.g., if inside the container a dangerous compound is generated, the operators can be preventively warned). Moreover, pollution smart sensors can provide important information to support a greener logistics.

A smart seal can notify when and where it is open or closed, providing added value information regarding the efficiency of the shipment, as well as detecting tampering actions.

3.5.2 Smart PI means and Smart PI Infrastructure

DCSA standardisation framework (see Sec. 3.3.1) foresees the presence of gateways on the PI means or on the PI infrastructure (i.e., PI hubs and PI warehouses) capable to collect data and information regarding the logistics equipment (i.e., the Smart PI Containers or the Smart PI pallets) as well as added value measurements from IoT sensors (e.g., pollution sensors, tyre pressure sensors in trucks). Particularly, DCSA Standard Release 1 (Digital Container Shipping Association (DCSA), 2020) suggest which IoT protocols must be used to be compliant with it. Figure 17 shows an example on how a train becomes a Smart PI mean considering the IoT technologies.

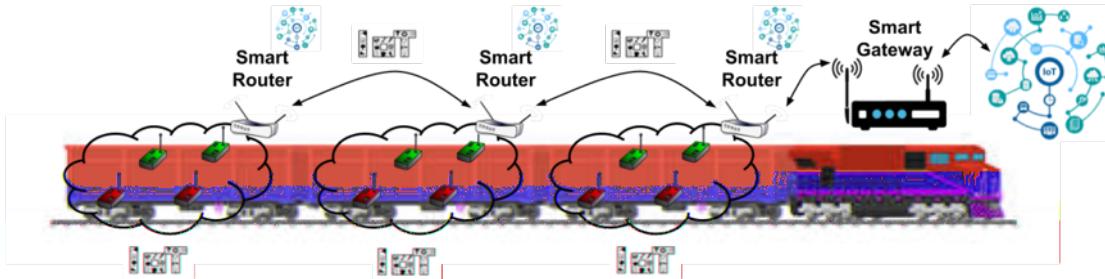


Figure 17 Train as a Smart PI-mean

To realise such solution, within the ICONET project we have implemented the Smart Gateway described in Sec. 8.

3.5.3 An IoT enabled PI environment

All the components described in the previous section allow the realisation of the supply chain complete visibility providing information regarding the goods at different granularity toward the PI users and the involved stakeholders. In fact, the concepts of Smart PI container, Smart PI Pallets, Smart PI Packet, as well as PI mean and PI infrastructure provide an ubiquitous connected environment capable to track and monitor the goods flows along the supply chain, from the sender toward the receiver, as depicted in Figure 1. The collected information will be dispatched exploiting the Cloud IoT platform (see Sec. 6) toward the higher OLI stack level, allowing proactive multimodal routing and fact-based and data-oriented decision making.

4. Toward an innovative Supply Chain complete visibility

In this section, we aim at wrapping up the innovation derived by the innovative approach used to realise the pervasive PI IoT environment. All these innovations come from the realisation of the visionary architecture presented in Sec. 3 (detailed in D1.6) capable to seamlessly interoperate with PI services, as well as with other domains (e.g., smart cities, ITS, smart factory/industry 4.0), providing added value information to support proactive and fact based actions. Having real time such variety of information, a real-time decision-making approach can be implemented toward the service optimisation, cost reduction and pollution reduction.

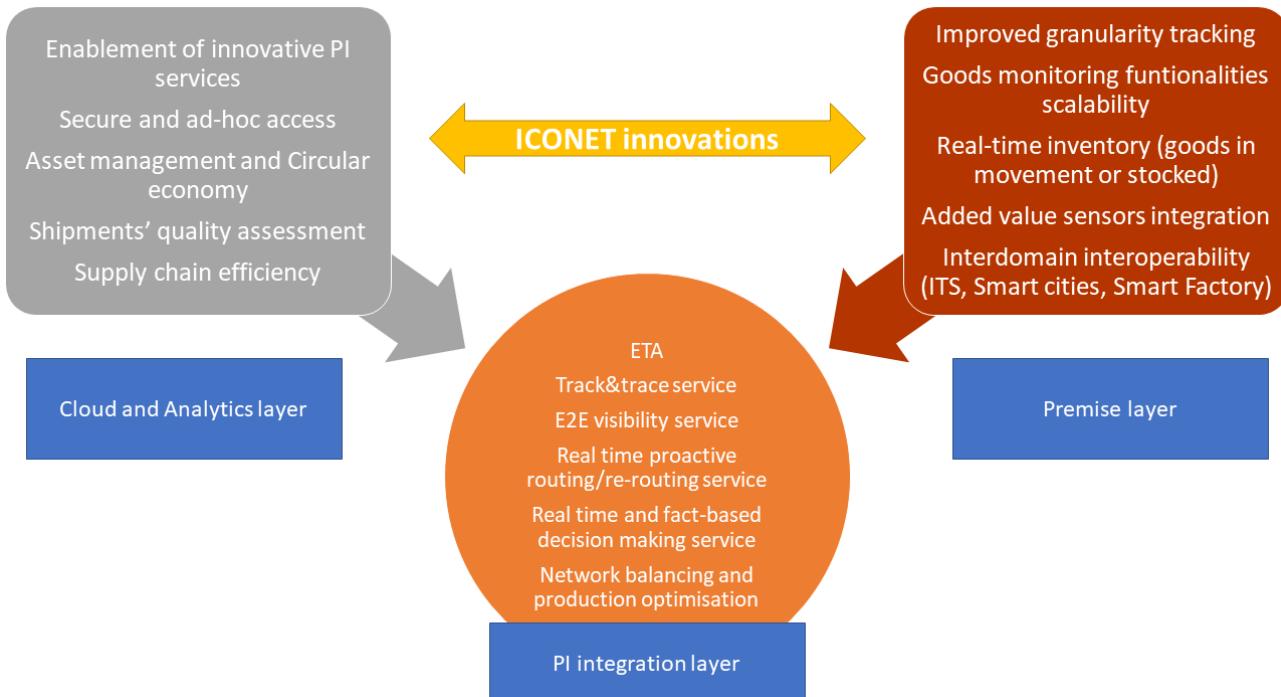


Figure 18 Innovation at different layers

In Figure 18, the direct innovations generated by the proposed approach are classified in 3 categories related with the different level of abstraction of the IoT environment:

1. The “ ” refers to the innovative services directly derived from the realisation of smart sensors deployed on the field.
2. The “ ”, provide aggregated information capable to suggest the logistics network performance, thus supporting decision making and resources optimisation toward the cost reduction and the customers’ satisfaction improvement.
3. The “ ” describes the functionalities and services derived from the realisation of an IoT-enabled PI environment. in fact, IoT is seen as enabling technology, providing raw and processed information supporting proactive actions/reactions, in the direction of resources’ optimisation and cost reduction.

4.1 The Premise Layer

The premise layer examines innovation as relates to the potential value-added data as retrieved from the field. The proposed IoT architecture enables improved scalability, both in terms of quantities (number) and in terms of functionalities. In this context, Table 4 outlines the relevant innovations:

Table 4 The premise layer innovations

Inn. #			
INN_01		This innovation allows the definition of Smart PI Container, Smart PI Pallet, and Smart PI Packet, installing IoT devices on top of these. In this scenario,	Sec. 3.5

	an improved tracking and monitoring of the goods is enabled.	
<i>INN_02</i>	The real time inventory of the whole supply chain is enabled by both the Smart PI Pallet and Smart PI Packet realisation and the pervasiveness of the monitoring service, coming from the results related with INN_01.	Sec. 3.5
<i>INN_03</i>	The results related with INN_01 enable the realisation and the deployment of specialised devices to monitor certain types of goods (e.g., perishable goods, wines).	Sec. 3.5
<i>INN_04</i>	The device deployed on assets allows to track and monitor themselves, supporting .	Sec. 3.5
<i>INN_05</i>	Predictive maintenance for reefer motors, gas monitoring (e.g., ethylene sensors for monitoring fruit, harmful compounds monitoring), pollution monitoring, smart container seal can be seen as exhaustive set of examples capable to support the supply chain improvement toward its optimisation and improvement	Sec. 3.5
<i>INN_06</i>	Easy interoperability with other domains allows seamless exchange of value-adding information facilitating service optimisation and improvement.	Sec. 3.3 and 3.4

4.2 The Cloud and Analytics layer

The development of and meta-data), provisioned the IoT infrastructure. It also allows the accelerated implementation of a Track & Trace Service, and enables the innovations shown below:

Table 5 The Cloud and Analytics layer innovations

<i>Inn. #</i>			
<i>INN_07</i>		All authorized PI users involved in a given transaction will be aware in real-time of all the events related to the shipment, supporting fact-based and data-oriented decision making.	Sec. 3.5
<i>INN_08</i>		Extracting, aggregating and anonymising IoT data and seamless storage and computation over the Cloud IoT platform, introduces better understanding of the Supply Chain behaviour providing deeper performance insights in terms of time, quality and efficiency.	Sec. 3.5
<i>INN_09</i>		Easy to install and integrate IoT devices, engaged for asset monitoring (see INN_04) enable low-cost asset management consequently promoting .	Sec. 3.4 and 3.5

4.3 The PI Interaction Layer

The development of

. This layer enables the implementation of proactive and effective actions within the PI, integrating different information coming from several services (especially the Cloud IoT services) and

influencing the physical logistics world. Table 6 shows the innovative PI services enabled by the integration with the IoT services.

Table 6 Innovative PI service enabled by IoT

<i>Inn. #</i>		
<i>INN_10</i>		IoT sensors track and monitor the goods providing real-time information in regards with their current status facilitating proactive decision making, either through direct human intervention or automatised by the PI itself to effectively optimise the transactions ³ .
<i>INN_11</i>		Real-time notifications regarding the position of the goods, the status of both the goods (i.e., quality rerouting ⁴) and the network (e.g., forming queues) are provided with reduced latency, allowing to the realisation of proactive routing of the goods, capable to adapt to the configuration changes happened during the shipment.
<i>INN_12</i>		Having available a pervasive and interoperable world of IoT devices, the PI can be seen as an omniscient entity capable to organise all the supply chain from the producer to the costumer, maintain balanced and optimised transactions.

4.4 Innovations Application

In Table 9 the innovative contributions enabled and realised by the instantiation of the described innovative IoT services. Particularly, the last column of Table 9 aims at mapping the enabling innovations derived from the IoT services.

Finally, these contributions derive from the direct integration of the PI Shipping Service and PI Routing Service, capable to retrieve and infer on the collected/computed data and information, thus implementing proactive and adaptive actions to optimise the shipment itself.

Table 7 Innovative contributions of the proposed IoT environment within the ICONET project

<i>LL</i>	<i>Innovation</i>
<i>LL1</i>	The monitoring of the pollution allows to understand critical area, supporting decision making. Its integration with the PI shipment service has the functions, in one hand, to understand the impact generated by PI, in the other to support the optimisation of the logistics service toward a greener logistics ⁵ .
<i>LL2</i>	enabling end-to-end visibility through the entire corridors interfacing with third parties back-end system. The ad-hoc access to the collected/computed information enable a secure switching of visibility to the logistic actor involved currently in the shipment.
<i>LL2</i>	: An IoT Sensor's accelerometer installed on a container carrying fragile goods detects a vibration level exceeding pre-set threshold and share with the PI. This automatically consumed to severe an SLA, ordering the redirection of the shipment to a warehouse instead of the intended delivery point.

³ A motivating example regards the logistics of fruits: introducing ethylene concentration sensors in a fruit container and evaluating its trend, the understanding the level of maturity of the fruits is enabled. This information can support action as blocking the shipment (e.g., rotten) or re-routing it (e.g., too mature to reach the real destination).

⁴ Considering the fruits logistics, if the fruits are too mature the reach the final far destination, the container can be re-routed to other closer markets, attenuating the risks/costs, and optimising the transactions

⁵ This task was disrupted by the COVID-19 pandemic, blocking its development and its integration with the LL1 environment.

5. How to set-up the IoT-enabled PI environment

As described in D2.7, in the ICONET project, PI is seen as a distributed and interoperable network of PI Nodes capable to organise autonomously the logistics network toward its optimisation. In this scenario, a PI node is depicted in Figure 19 and provide the following services:

- : This service exports the shipping instruction to the encapsulation service in order to bundle the shipping items into a PI-units and to enable an efficient and reliable planning of the shipment.
- : provides the functional and procedural means for enabling the efficient and reliable shipping of PI-containers. It sets, manages and closes the shipment between the shipper and each recipient. It defines the type of service to be delivered (normal, express, etc.) and insures the management of receipt acknowledgements. It establishes and rules the procedures and protocols for monitoring, verifying, adjourning, terminating and diversion of shipments.
- : provide the means for efficiently encapsulated products of a user in uniquely identified PI-containers before accessing the PI-networks. It allows linking product supply, realization, distribution and mobility taken at the Logistics Web Service.
- : provides the functional and procedural means for ensuring that PI-containers can be routed within a PI-network and across PI-networks while maintaining the quality of service given by the routing service.
- : provides functional and procedural means for getting a set of PI-containers from its source to its destination in an efficient and reliable manner. It enables and controls the efficient and reliable inter-node transport and handling services to other services.

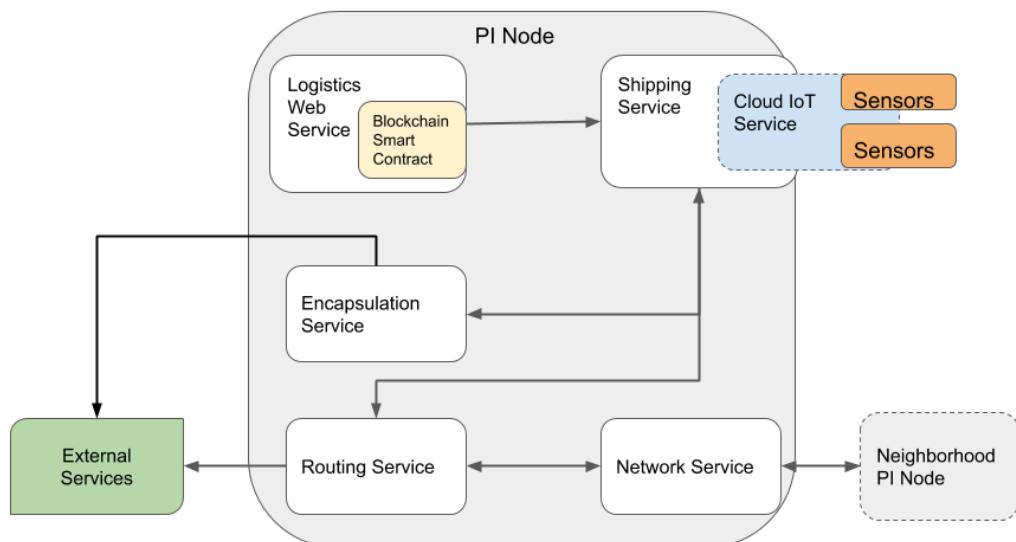


Figure 19 PI Node Block Diagram

Figure 20 shows a workflow diagram capable to highlight the interaction between the different services within the PI Node.



Figure 20 PI Services Workflow

In this scenario, the Encapsulation Service and the Shipping Service create the PI Order related to the shipment that contains several logistics information (e.g., the container id), as well as all the requirements to configure the data acquisition (e.g., set some thresholds). For this reason, the PI order is processed by the Cloud IoT Service to configure and to initialise the data acquisition service.

As introduced in D2.7, the interaction between the Cloud IoT service and the PI node is mapped in the block diagram shown in Figure 21 (regarding the initialisation of the Cloud IoT Service) and Figure 22 (the sharing of the data collected during the shipment).

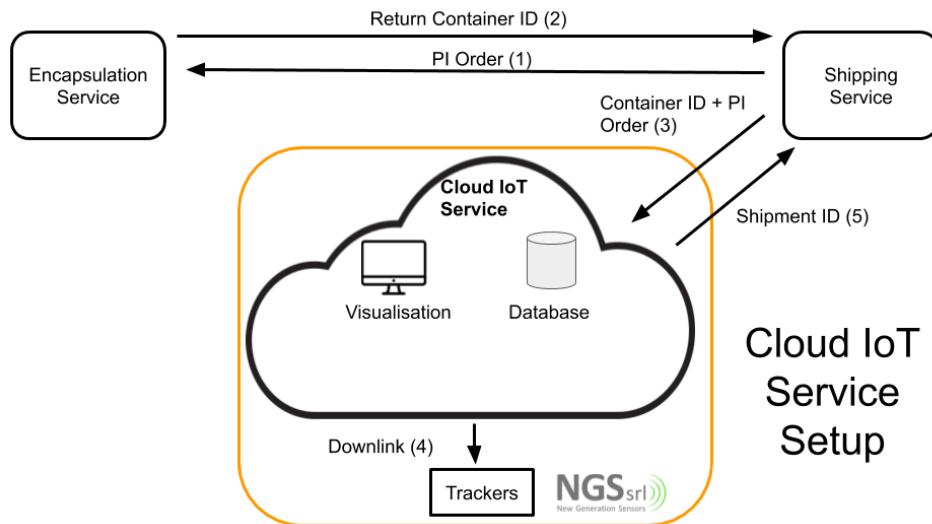


Figure 21 Cloud IoT Service Initialisation

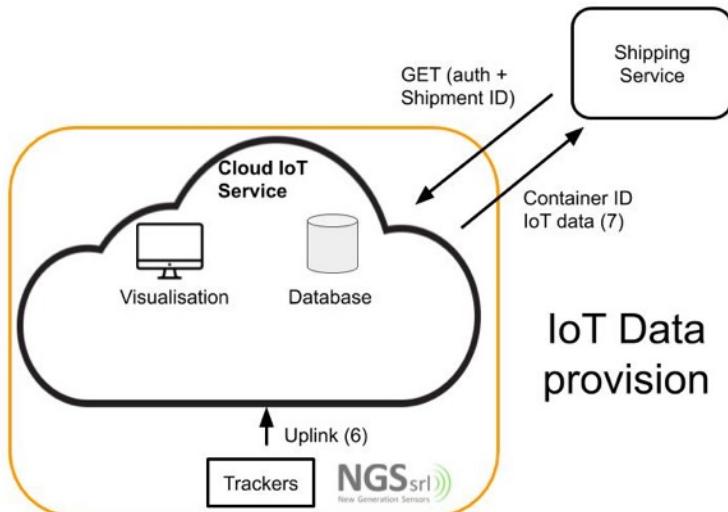


Figure 22 IoT data sharing

5.1 Interactions and data-models

In this section the interaction of the platform with the users, the shipping services, as well as with the IoT devices and the related data-models are described in their final release.

5.1.1 Cloud IoT Service Initialisation service and related data models

According to Figure 21 the following data models are required during the setup phase to initialise the Cloud IoT Service:

- Cloud IoT Service configuration data model included in PI Order from Shipping Service.

- The configuration of the IoT devices data model (transaction 4 in Figure 10), that configure the nodes for a new shipment.
- The returned data model from the Cloud IoT Service to the Shipping Service (transaction 5 in Figure 10). It contains th

Table 8 Description of Cloud IoT Service Data Model Inside a PI Order fields

	Mandatory field for specifying the carrier company
	Mandatory field specifying the trip code
	Mandatory field indicating the order ID
	Mandatory field specifying a unique container ID or container's ISO Alpha Code
	Mandatory field notifying that the container is transferred
	Mandatory field notifying that the container reaches its destination
	Optional field specifying the requirements for a specific shipment
	Optional field indicating the type of measurement
	Optional field for setting up a specific sensor
	Optional field for switching on/off a specific sensor
	Optional field for setting up the measurement unit of a sensor
	Optional field for sending data
	Optional field for setting up thresholds for a specific sensor
	Optional field for setting up minimum threshold
	Optional field for setting up maximum threshold

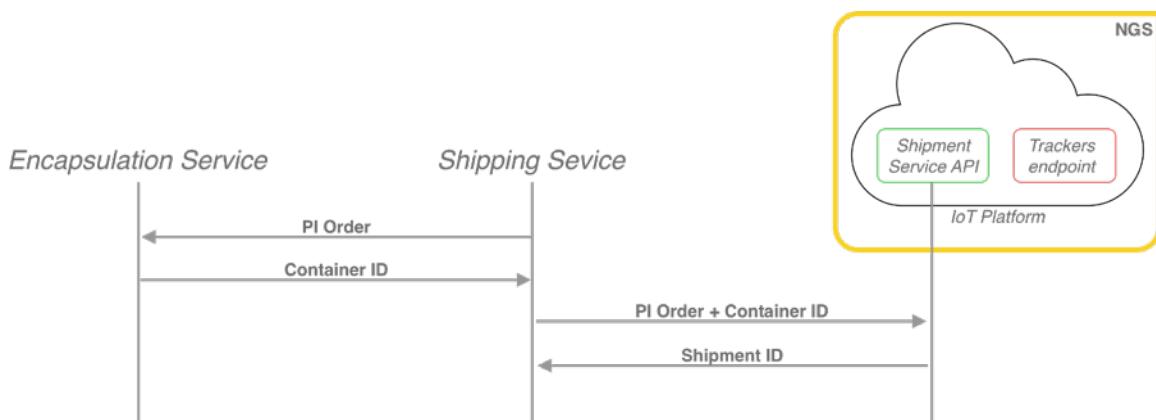


Figure 25 Transactions for configuring Cloud IoT Platform

As depicted in Figure 25, after receiving a PI order containing the data model specified above, the Cloud IoT Service parses and processes the data, and performs the following actions:

1. Setting-up of the Cloud IoT Service, configuring all the internal parameters. Particularly, the Cloud IoT Service considers the requirements from the PI order to set up properly the Cloud IoT Platform

parameter for configuring notification and/or alarm whenever there is a problem occurring during transportation.

2. The Cloud IoT Server answer sharing a unique identifier, called “Shipment ID”, represented in the data-model of Figure 26.
3. Optionally, it will also be in charge of configuring the corresponding tracker/smart router devices. The downlink transaction to configure the IoT tracker/smart router (transaction 4 in Figure 21), is defined in the data-model of Figure 27 (the description of the downlink data model fields is shown in Table 9), however its implementation will not be realised in ICONET project, since not essential for its objectives.

ShipmentID: "5e53ed/c69d4t3actt9c

Figure 26 ShipmentID data-model

```
{
  "t_e":1,
  "h_e":1,
  "s_e":1,
  "l_e":1,
  "p_e":1,
  "po_e":1
}
```

Figure 27 Downlink Data Model

Table 9 Description of Downlink Data Model fields

	Enable/Disable temperature measurement
	Enable/Disable humidity measurement
	Enable/Disable shock detection
	Enable/Disable light measurement

5.1.2 Operativity interactions and related data-models

After the configuration phase described in the previous section, the Cloud IoT Service is configured to operate within the PI environment. Accordingly with Figure 21, the Cloud IoT Service will be in charge of:

1. Collecting the data from the IoT devices (transaction 6 in Figure 21), exploiting the data-model in Figure 28 (in Table 10 each field of the data-model is detailed). In fact, the IoT devices dispatch periodically toward the Cloud IoT Service the collected data and saved in the platform database. When a transaction is recognised (i.e., between the PI order reception and the end of transaction notification) this data is linked with the shipment, otherwise the data are stored to track the container (supporting the asset management).
2. Sharing the data gathered with all PI users involved in the shipment (transaction 7 in Figure 21), implementing the interaction depicted in Figure 28. The data-model shown in Figure 30 is used to share this information with the PI users exploiting a secure and ad-hoc transaction, as described in Sec. 5 (in Table 11 each field of the data-model is detailed).

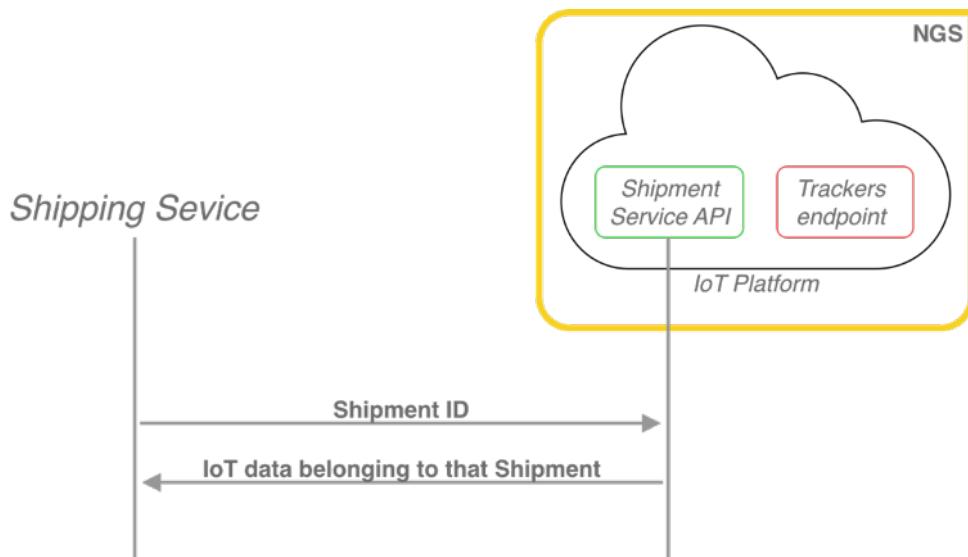


Figure 28 Transactions during IoT Provision

```
{
  "MAC": "SI:MU:LA:T0:R0:11",
  "day": "080520",
  "hour": "102419",
  "east": "10.48891",
  "north": "43.68538",
  "code": "0x00",
  "temperature": "27.5",
  "humidity": "30.85",
  "light": "3.74",
  "bat": "9.55",
  "ax": "16",
  "ay": "-9",
  "az": "985"
}
```

Figure 29 Uplink Data Model

Table 10 Description of Uplink Data Model fields

	Unique MAC address of a tracker
	date field specified at UTC+0
	hour field specified at UTC+0
	Longitude
	Latitude
	Code indicating system status and events
	Temperature in C degree
	Humidity in Percentage
	Luminance in lux
	Battery level in V
	Acceleration along x axis measured in mg
	Acceleration along y axis measured in mg

	Acceleration along z axis measured in mg
<pre>{ "trackerData": [{ "status": ["NORMAL"], "measurements": { "temperature": 27.5, "humidity": 30.85, "luminance": 3.74, "acceleration": { "x": 16.0, "y": -9.0, "z": 985.0 }, "gps": { "lat": 45.46878276231161, "long": 9.187005582927071 }, "battery": 9.55 }, "timestamp": "2012-02-20T11:07:00+00:00" }, ...] }</pre>	

Figure 30 IoT Cloud Service Data Model

Table 11 Description of the IoT Cloud Service Data Model fields

	Mandatory field returning a list of trackers data
	Mandatory field indicating trackers status
	Mandatory field including measurement information from a tracker
	Optional field for temperature measured in C degree
	Optional field for humidity measured in percentage
	Optional field for luminance measured in lux
	Optional field for acceleration in three axes x, y, z
	Mandatory field including gps data
	Mandatory field for latitude in decimal degree
	Mandatory field for longitude in decimal degree
	Optional field for battery measured in Volt
	ISO format timestamp at UTC+0

5.1.3 Events, metadata and statistics gathering and data models

A set of RESTful APIs is implemented to share events and metadata related to a certain shipment, exploiting the handshakes depicted in Figure 31 and Figure 32, and the data models in Figure 33 and Figure 34 respectively (their fields are described in Table 12 and Table 13).

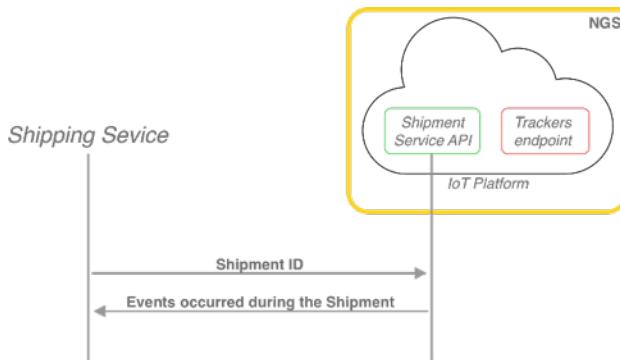


Figure 31 Handshake to retrieve the events (GET method)

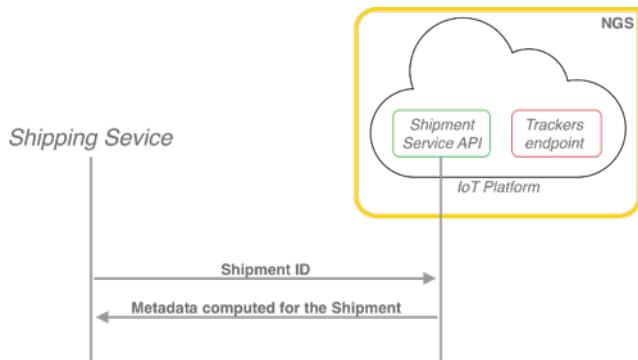


Figure 32 Handshake to retrieve the metadata (GET method)

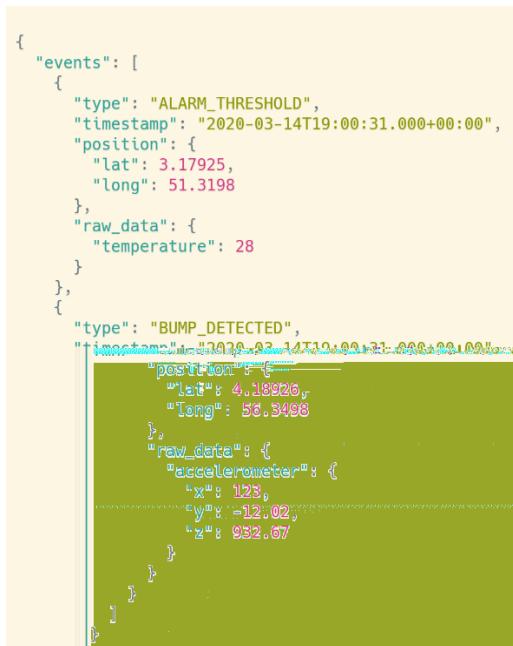


Figure 33 Data model to share events

```

{
  "city": "London",
  "state_district": "Greater London",
  "state": "England",
  "postcode": "SE10 8TH",
  "country": "United Kingdom",
  "country_code": "gb"

  "id_address": {
    "house_number": 77,
    "road": "Via Mosè Bianchi",
    "suburb": "Cassina Amata",
    "town": "Senago",
    "county": "Milano",
    "state": "Lombardia",
    "postcode": 20037
  }

  "coordinates": {
    "lat": 41.9028,
    "long": 12.4583
  }

  "country": "Italy",
  "country_code": "it"

  "art_timestamp": "2020-03-14T19:00:31.000+00:00",
  "id_timestamp": "2020-03-14T19:00:31.000+00:00",
  "speed_avg": 80,
  "latency": 70200,
  "stopped_time": 3600,
  "stance_traveled": 112430
  "crossed_country": [
    "United Kingdom (GB)",
    "France (FR)",
    "België - Belgique - Belg",
    "Luxembourg (LU)",
    "France (FR)",
    "Deutschland (DE)",
    "Switzerland (CH)"
  ],
  "lat": 41.9028,
  "long": 12.4583
}

```

Figure 34 Data model to share metadata

Table 12 Description of the Events Data Model fields

	Field returning a list of events happened during the shipment
	Type of event – e.g., “ALARM THRESHOLD” when a threshold is exceeded
	ISO format timestamp at UTC+0
	GPS coordinates where the event happened, represented as latitude (“lat”) and longitude (“long”)

Table 13 Description of the Metadata Data Model fields

	Field returning the address where the shipment is started/ended
	Addressed fields
	Field returning the timestamp (ISO format UTC+0) when the shipment is started/ended
	Average speed in a shipment.
	Duration of the trip in second
	It measures the time that a container stay stopped within a shipment in seconds
	Distance travelled in meters
	List of crossed countries

On the other hand, statistics provide the general overview of the PI - for example suggesting the average duration of a trip along a corridor. For this reason, all the requests will be considered set of parameters to uniquely define conditions to retrieve the information, as depicted in Figure 35. As matter of example, in Figure 36 to retrieve the average distance between two points, the GPS coordinates of the start and the end points must be provided as parameter in the GET HTTPS request.

In Figure 37, the generic data model to share the statistics information. It is a very simple data model data and returns the required “<statistics>”, where “<parameter>” is related with the requested statistics (e.g., “distance”, “time”, “efficiency”, ...)

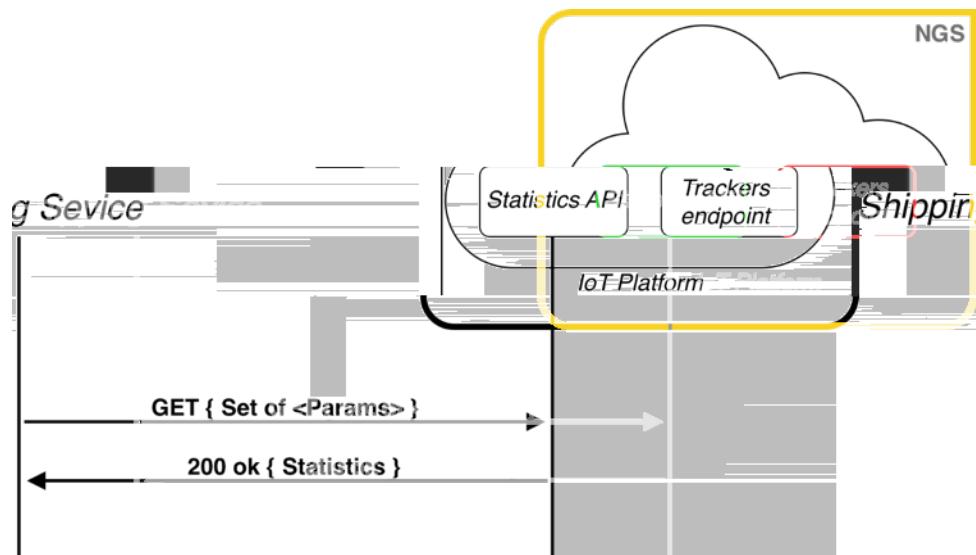


Figure 35 Generic handshake to retrieve statistics information

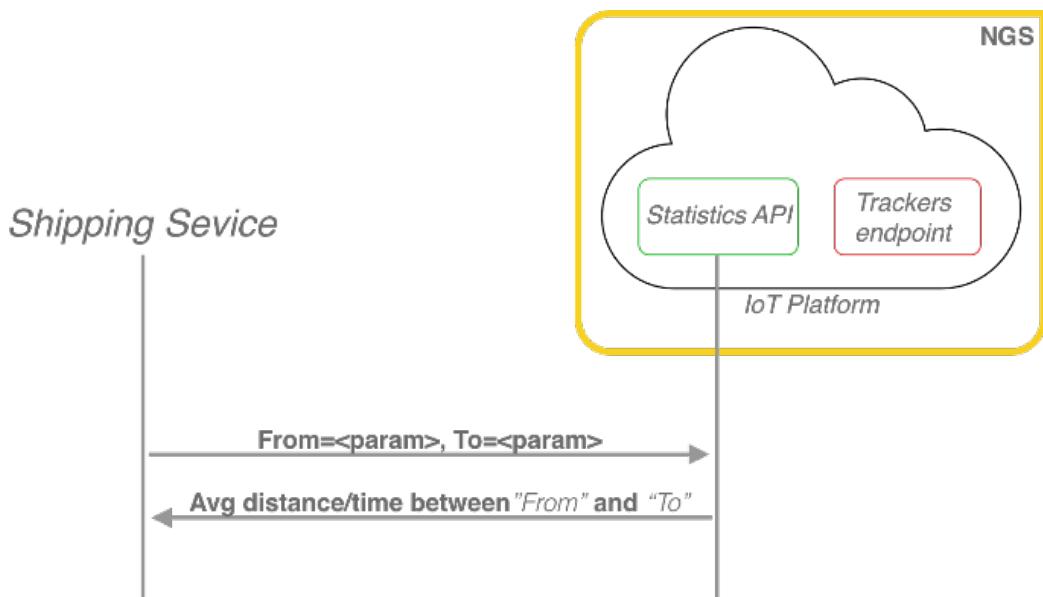


Figure 36 Handshake to retrieve the Avg. distance (GET method)

```

{
  "<statistics>": 66000
}
  
```

Figure 37 Generic data model to share statistics

5.2 Data collection

5.2.1 How to authenticate a device

All the IoT devices must be authenticated (ad-hoc access control) to join and participate to the activities of the Cloud IoT platform. In fact, the data gathered by the IoT devices are the basis for implement the routing algorithms and the data-oriented and fact-oriented decision making policies, so authentication procedures must be implemented to guarantee the authenticity of the data. To realise such procedure, we use the “standard basic authentication” of http that implement the IETF standard RFC 7617 (IETF, 2015). In this scenario, each IoT device must provide an authorised username and password when it is making a request to access the Cloud IoT platform. Further technical details will be provided in Sec. 6.7.

5.2.2 Data collection from real devices

The IoT devices considered are installed in 4 containers, as well as installed in some private vehicles of NGS people. The device is sending every 10 minutes the information collected regarding the associated container, but it is configured to be triggered if a certain event happens. In this scenario, the information collected and shared with the Cloud IoT Platform can be classified as follow (see also Figure 38):

1. . These data are collected synchronously with the sampling period. Data collected with the Time Driven paradigm is position and time, and data gathered from sensors' ICs (i.e., T/H, acceleration, battery). This information is immediately dispatched toward the Cloud IoT Platform.
2. . These measurements happen when certain events (i.e., bump, movement after a stopping period) trigger the device to collect data. In this scenario, the event data is collected, tagged with position and time information, and stored to be sent with the following Synchronous measurement.

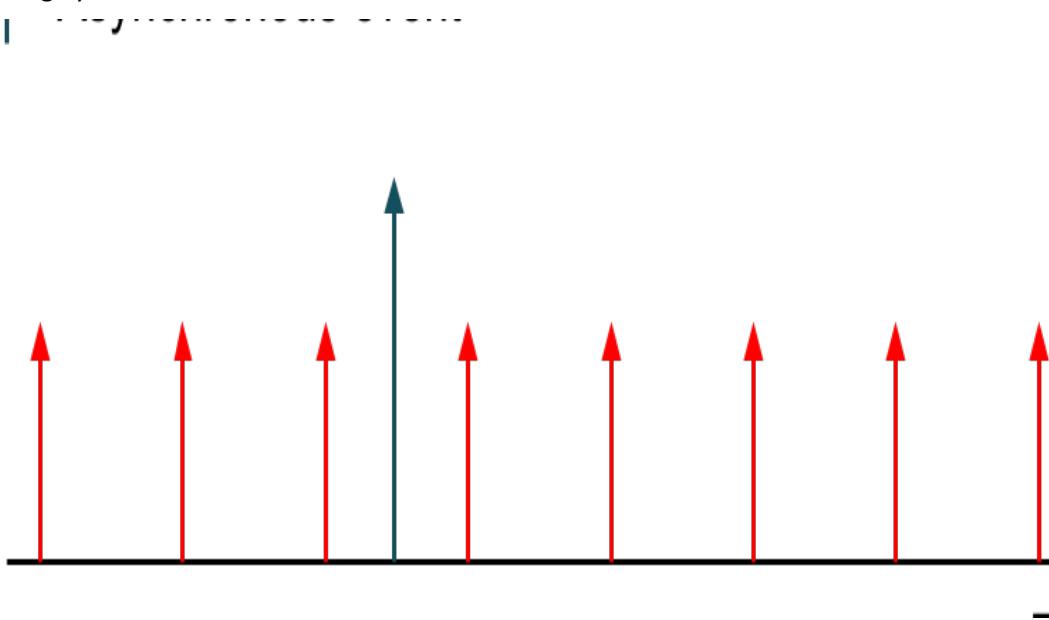


Figure 38 Time Driven Acquisition vs. Asynchronous events

The system can communicate remotely selecting between the enabled communications protocols, following one of the following approaches:

1. . The system will exploit the mobile connectivity enabled by the IoT devices to dispatch remotely the collected data as depicted in Figure 39. In this case, GPRS, NB-IoT and LTE Cat-M can be used to implement the communication transaction. In the ICONET project, only the former protocol is considered, since the limitation of NB-IoT and LTE Cat-M described in D2.6 and D2.7. This approach is in line with the DCSA protocol guidelines, described in Sec. 3.3.1.



Figure 39 Stand-alone approach

2. The single IoT Device can select to communicate with a local gateway (in line with DCSA approach) exploiting low power consumption protocols, thus reducing the battery power consumption and the maintenance costs of the devices. In this scenario, all the IoT device will authenticate with an IoT gateway installed in PI-means or PI-Hub, that will be in charge of dispatching the data toward the Cloud IoT Platform, as depicted in Figure 40. The considered gateway is based on the hardware described in Sec. 7, connected toward the Cloud IoT platform using different protocols to connect with the Internet: i.e., Wi-Fi, Ethernet (implementing a direct transaction toward the Cloud IoT Platform) and mobile.

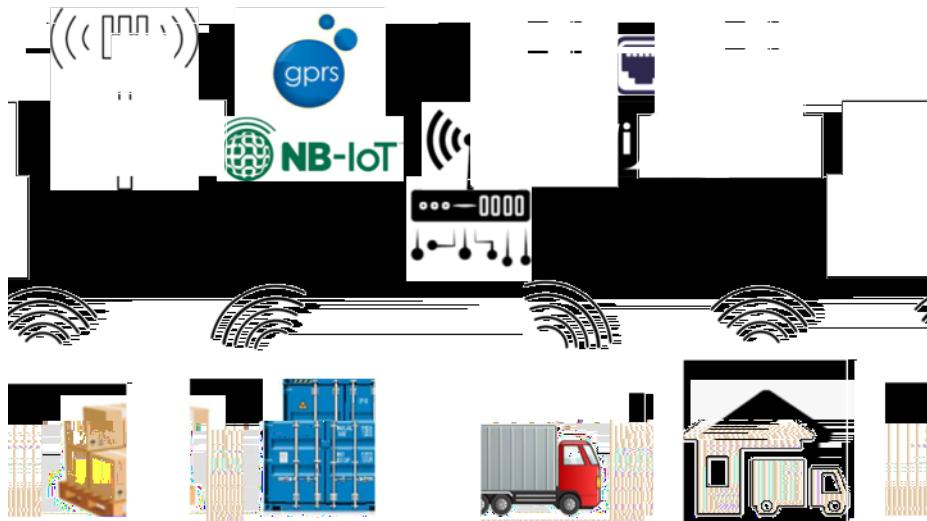


Figure 40 Cooperative approach

In the ICONET project, we present a real deployment of the IoT devices in LL2 and a lab demo to demonstrate the feasibility of the proposed approach, being completely in line with the open architecture proposed by DCSA.

5.2.3 Simulator

The simulation of the LL2 is focused on the evaluation of the performance of the IoT and the Cloud-based ICT Infrastructure for PoC Integration to foster the intermodal transportation. In this environment, due to the situation caused by the COVID-19, the objective was to develop a simulation model that would feed position data and movement events to the IoT service, as the sensors would do.

In the simulation model, nodes, containers and transports have been used as the basic elements. The nodes correspond to physical locations where trucks can make decisions and log additional events. Trucks are in charge of moving the containers with the sensors, following defined behaviour rules, defined by other ICONET services. Some example of the simulator output are shown in Figure 42, Figure 43 and Figure 44.

APIs are used to connect to services and exchange information. In the endpoints of the APIs are hosted web services, these services are made with the https protocol, through asynchronous requests. The information is transmitted through JSON by using Restful requests. Four types of messages are exchanged with the IoT tracking API (see also Figure 41):

1. (PUT): the shipment is registered within the ICONET IoT Cloud platform with the identifiers of the container, the carrier, the order, the origin and the destination. The service returns a unique identifier for the shipment.
2. (POST): before starting to log the location and trip events, it must be initialized. The endpoint includes the shipment identifier.
3. (POST): The simulated IoT sensor periodically records the location as well as the conditions of light, humidity, acceleration on three axes... When a sudden movement occurs, a message is also sent with the code corresponding to the direction of the movement.
4. (POST): once the trip is over, the sending is closed at the same endpoint that uses the message 2.

This model is the first step to develop a Physical Internet Simulator in which the different ICONET services can be tested and integrated together.

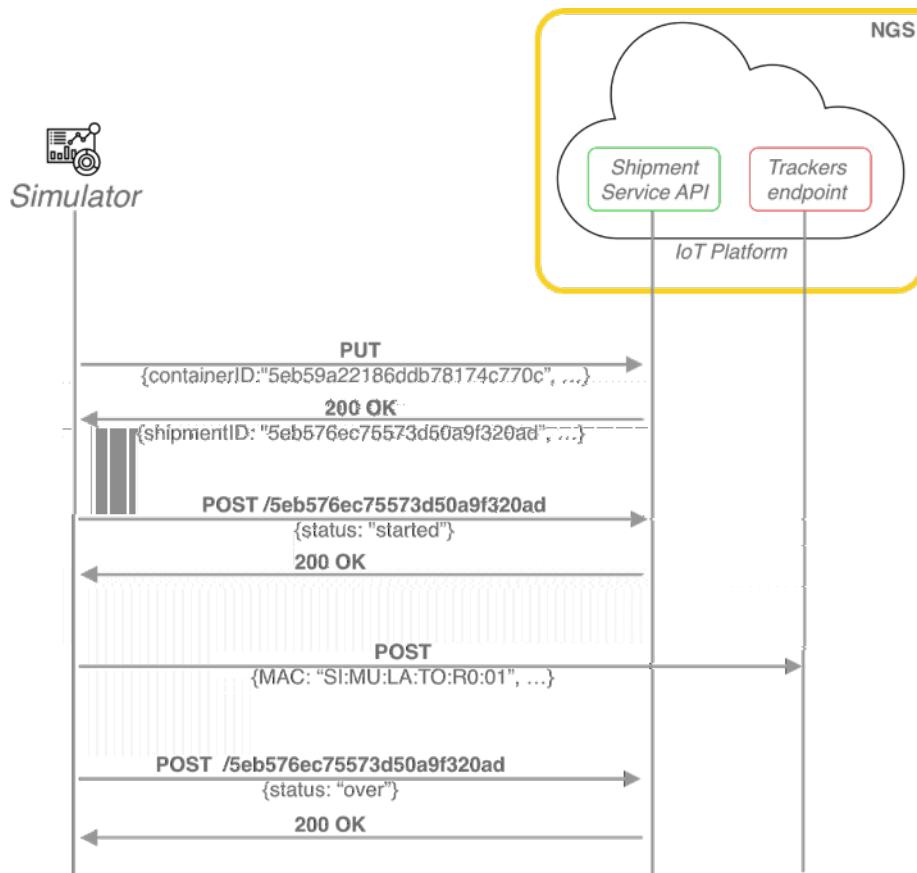


Figure 41 Handshake to set-up the simulated environment



Figure 42 Simulator example

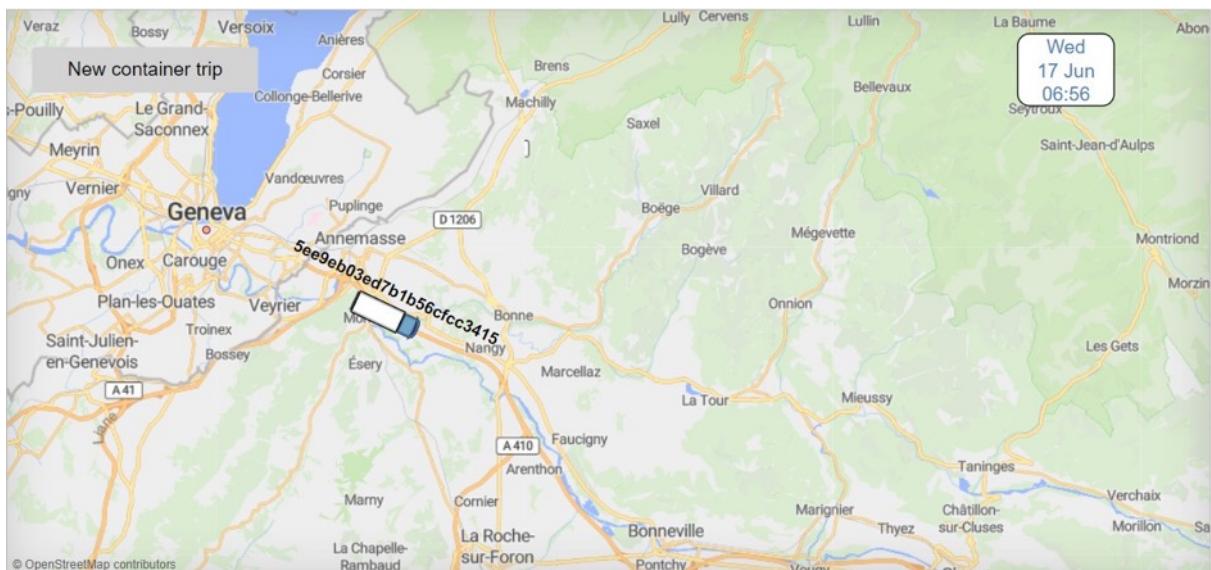


Figure 43 Simulator example



Figure 44 Simulator example

5.3 How to set up a PI order

Setting up a PI order in the PI environment means to define the rules of engagement of the shipment, thus configuring the data to be collected and the related events, as well as providing the start of the shipment. At this stage, a unique relation between the goods, the container and the devices installed on it must be generated, thus associating the involved entities, and allowing the ad-hoc sharing of the information regarding the shipment. The handshake shown in Figure 45 allows the setting-up of the PI order, implementing the following actions (all these actions are implemented following the guidelines defined in Sec. 5.1):

1. The PI order is sent by the PI Shipping Service and it is received by the Cloud IoT Platform allowing the unique association between it, the selected container and the connected IoT device. Moreover, the PI order is in charge of configuring the monitoring rules of the IoT device.
2. The platform set up the event manager with the received requirements (if any), see Sec. 5.1.1.
3. The platform acknowledges the PI reception and the correct configuration returning toward the PI Shipping Service a unique token, the “ ”, that identify uniquely the new shipment. This token will be used by the PI-users to retrieve in an ad-hoc manner the data associated to the considered shipment (for further details, look at Sec. 5.4.1).
4. The PI Shipping Service notifies the Cloud IoT Platform the start of the shipment: only at this time all the data collected by the related IoT device (exploiting the HTTPS “POST” method) are uniquely linked with the shipment.
5. The data are collected continuously and asynchronously by the IoT device and stored in the IoT platform. At this time, having available the ShipmentID and the authorisations to monitor the shipment, it is possible to retrieve real-time the information exploiting HTTPS APIs or the GUIs (described in Sec. 6 - The Cloud IoT Platform).
6. At the end of the shipment, the PI Shipping Service notifies this information the Cloud IoT Platform, thus “detaching” the information gathered by the IoT device installed on top of the container from the considered shipment. Of course, having available the ShipmentID and the correct authorisations to access, the information regarding the shipment can be retrieved also its end.

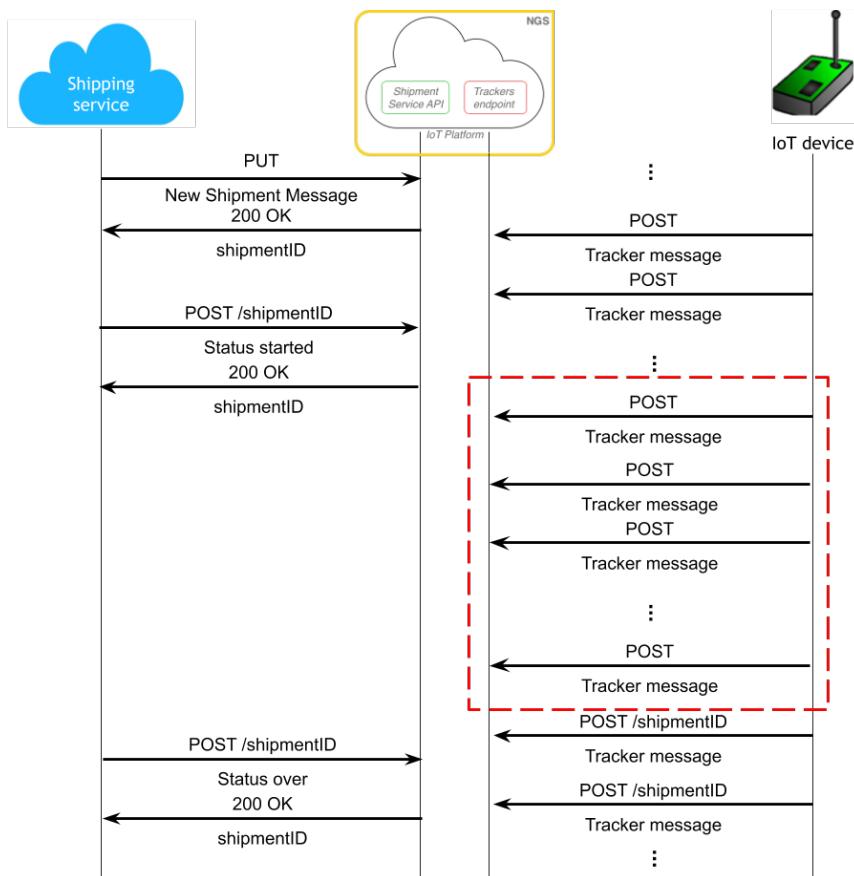


Figure 45 Handshake to set up a PI order

5.4 How to access the data, events, metadata and statistics

After the reception of the PI order and of the start of the shipment notification from the PI Shipping Service, data collected can be shared with both the Shipping Service module and all the authorised users in a secure and ad-hoc manner. Particularly, user-name and the password related to a certain user and the unique identifier “ShipmentID” must be authorised to collect data from the considered shipment. In this scenario, the following reporting operation can be implemented:

1. deployed on the container exploiting REST interfaces, to feed PI environment as well as to integrate with third parties' platforms. This data and information can be retrieved during (real-time) and after the end of the shipment.
2. All the authorised users can require visual reports during (real-time) and after the end of the shipment.
3. All the authorised users can require added value information regarding the considered shipment (i.e., events and metadata). Moreover, aggregated and anonymised statistics can be generated by the platform to dimension the performance of the specific routes or corridors.
4. After the end of the shipment, a complete pdf report containing all the information gathered from the field and computed (i.e., events, metadata and statistics) can be generated.

5.4.1 PI users' authentication

As for IoT devices (see Sec. 5.2.1), also PI users must authenticate within the Cloud IoT platform, thus implementing an ad-hoc access: the same standardised approach is implemented considering “standard basic authentication” of http that implement the IETF standard RFC 7617 (IETF, 2015).

However, while the IoT device must provide data continuously to the platform, the PI-users must access only to the information related to the shipments where it is directly involved, thus guaranteeing the privacy issues. As depicted in Figure 46, the PI users' involvement is communicated to the Cloud IoT service by the PI order, sent at the beginning of the transaction to set-up the shipment. In this scenario, the Cloud IoT platform generated a group of PI users identified by the retrieved “ShipmentID” (see Sec. 5.3), that allows them the ad-hoc access to the data and information gathered or computed.

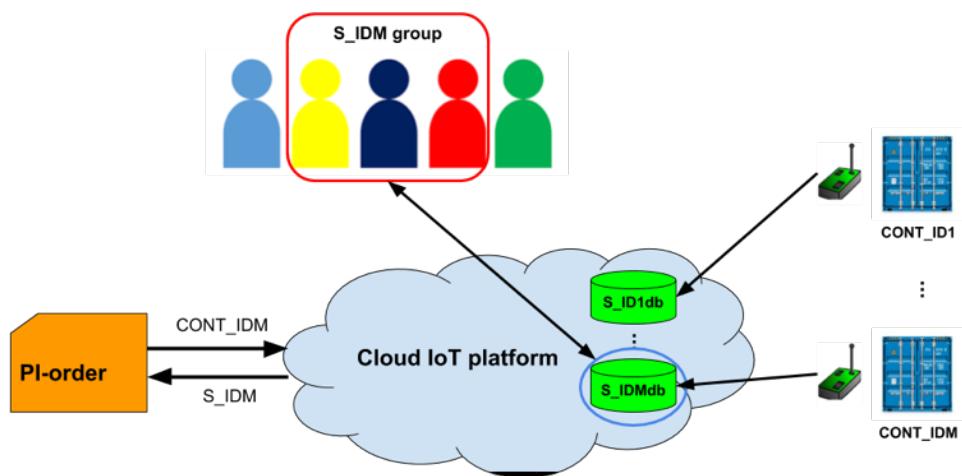


Figure 46 PI user ad-hoc access

5.4.2 Retrieving the data collected

To retrieve the data the PI Shipping Service must require the data related to the considered shipment using the unique “ShipmentID” exploiting the HTTPS “GET” method, as depicted in Figure 47: the platform will

answer with the data-model defined in Sec. 5.1.2. All authorised PI users (see the previous section) can access in this manner, but also dedicated REST interfaces can be integrated on the Platform.

Figure 47 Handshake to retrieve the data (GET method)

5.4.3

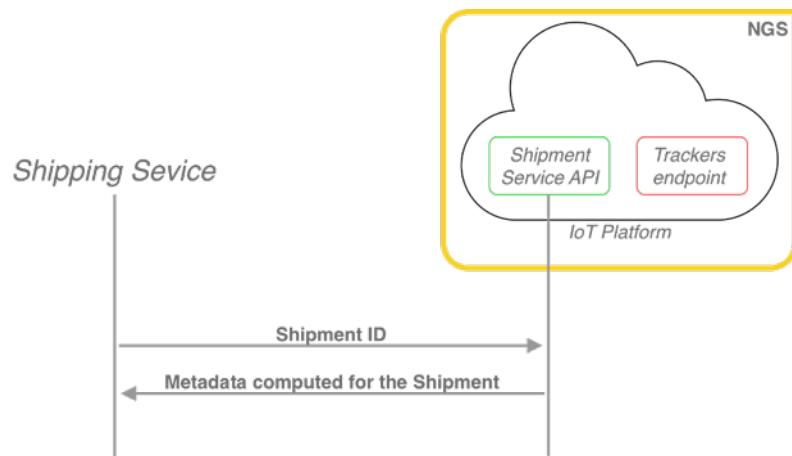


Figure 49 Handshake to retrieve the metadata (GET method)

3. represent aggregated data related with the analysis of multiple shipments (e.g., the average duration of the shipments in a certain corridor). In this case the handshake foresees parametric request (e.g., which corridor must be considered) as depicted in Figure 50.

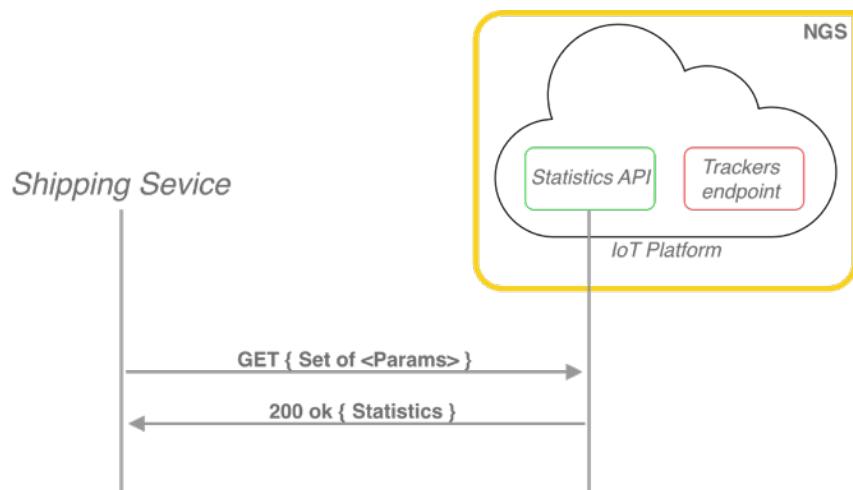


Figure 50 Handshake to retrieve the Avg. distance (GET method)

5.4.4 Retrieving visual reports

The data gathered and the information extracted can be represented as two different graphical reporting interfaces described below:

1. The (web page) where each PI-user can enter, authenticating its credentials (see Sec. 5.4.1), and visualise both (also during the shipment) all the shipments authorised (i.e., only the shipments related with the user) both in real-time and terminated shipments. The dashboard oversees visualising all the data and the information collected during the shipment, as well as all the metadata computed at the end of the transaction.

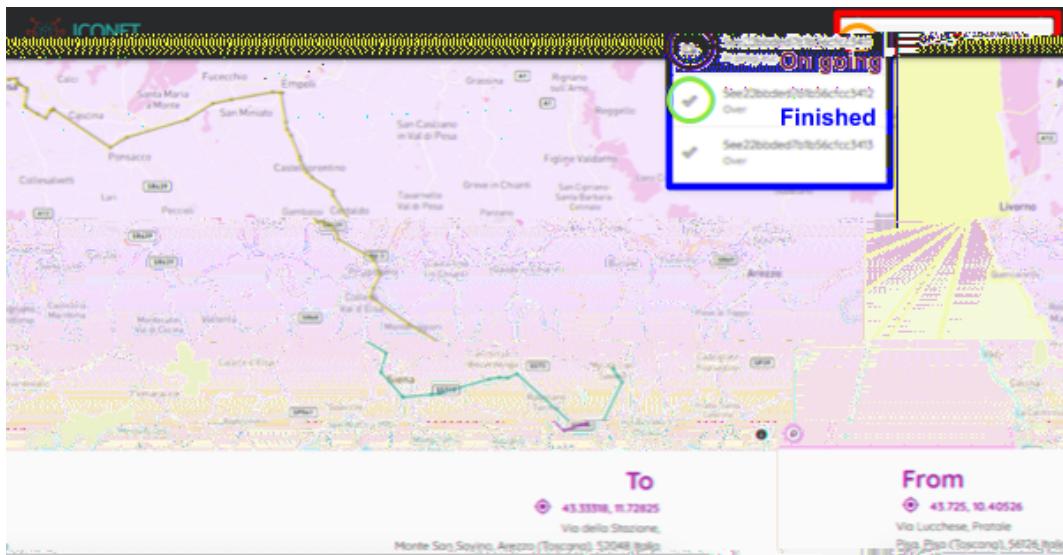


Figure 51 Dashboard and ad-hoc access

2. A PDF report, automatically generated at the end of the shipment that contains all the data gathered during it, as well as all the events, metadata and statistics computed by the analytics engine. The pdf file can be retrieved implementing an http request to the Cloud IoT platform, of course providing the needed authorisation credentials (username, password, shipmentID).

5.5 Toward the supply chain complete visibility

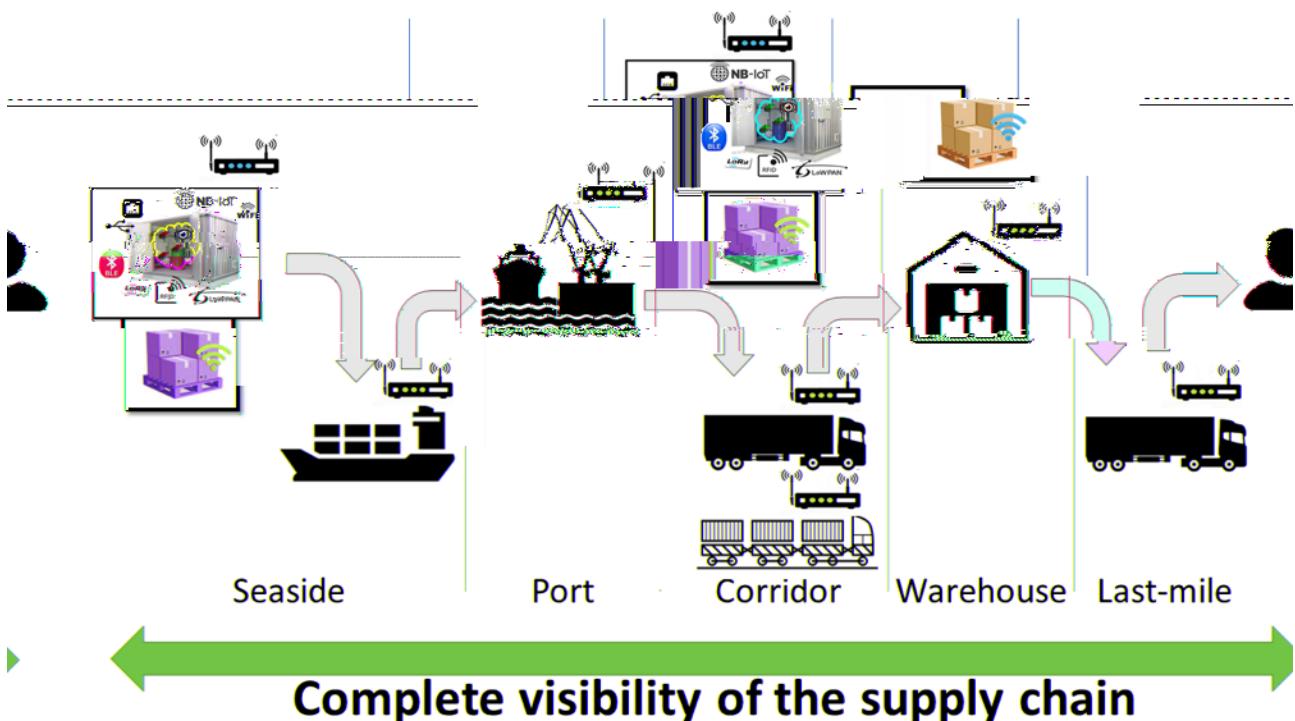


Figure 52 Supply chain complete visibility

Figure 52 represents how we want to transform the current supply chain scenario (depicted in Figure 1), implementing its complete visibility: an environment ubiquitously connected where goods can be tracked and monitored at different granularity, thus providing added value information from the sender facility toward the final user, passing through all the ICONET LLs. In this scenario, the Smart PI Pallets is assembled within the sender facility and encapsulated in the Smart PI Container. At this point their shipment is started, and the tracking and monitoring service is instantiated (as described in the previous sections). Knowing the correct position of the container/pallet, the goods are routed all along intermodal PI corridors and PI hubs,

until the arrival at the “proxy” warehouse. The shipment is tracked and monitored all along the logistics network, exploiting the added value information coming from the IoT devices. This allows the implementation of adaptive routing actions, effective and fact-based operations, and the enablement of a deterministic scheduling of the activities. When the container, reach the “proxy” warehouse it is disassembled and the Smart PI Pallet can be tracked and monitored exploiting the IoT gateways installed on the PI infrastructure, as well as in the PI Means in the last-mile logistics operations.

5.5.1 LL2 implementation and the COVID-19 pandemic

In LL2 – Corridor Centric PI Network the ICONET Project investigates the progressive transformation of a typical transport corridor into a PI corridor. LL2 objectives regard:

1. The realisation of an IoT system capable to implement the goods' tracking and the monitoring functionalities all along the PI corridors.
2. The improvement of the efficiency of the supply chain, toward the realisation of an optimised logistics network, less expensive and greener.
3. The increase of the reliability of multimodal transports, therefore facilitating syncro-modality at operational level and enabling proactive, data-oriented, and fact-oriented decision making.

IoT's application in the real-life transport corridors is investigated through the installation of trackers in containers and reporting information exploiting GUIs and PDF reports, enhancing visibility and container's location awareness, expected to lead in optimized utilization of both transport and logistics resources. All the shipments considered in LL2 consist of fully loaded containers starting and ending from warehouses, and only tracking, and on-board sensors' monitoring services are required. No other sensors inside or outside (the smart seal) are required and allowed.

As per the project parameters and LL2 set up, the tracking and monitoring of the containers for transporting the goods on two multimodal corridors from Belgium to UK and to Italy, shown in Figure 53 and Figure 54 was established. To implement this service, two containers by the ITC had to be dedicated for this task, and two trackers were to be prepared, installed and activated in accordance with the LL2 plan.

The pandemic took a toll on the supply Chain activities and understandably the deployment of the trackers was hugely delayed. The disruptions in the traffic across Logistics corridors created in the line of service, delayed the whole deployment process in terms of the setup, charging, interfacing, testing and installing of the devices. Moreover, the integration activities with external platform was also affected. In an effort to mitigate the negative impact of the conditions (as discussed previously in this document) in close collaboration with the partner and the ITC, specific data sets were used as per agreed scenarios and respecting confidentiality conditions certain evaluation and data exploitation resulted thereon. Furthermore, even more devices were deployed to alleviate the situation and accelerate the data recording of the devices in the field.

Other issues caused by the COVID-19 pandemic related to LL2 and the derived mitigation activities are detailed in Sec. 2.2.

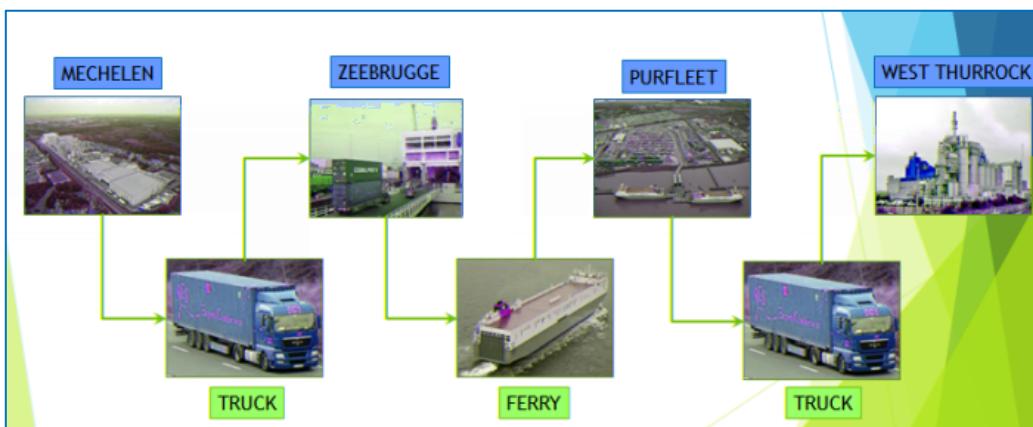


Figure 53 Corridor Mechelen (B) – West Thurrock (UK)

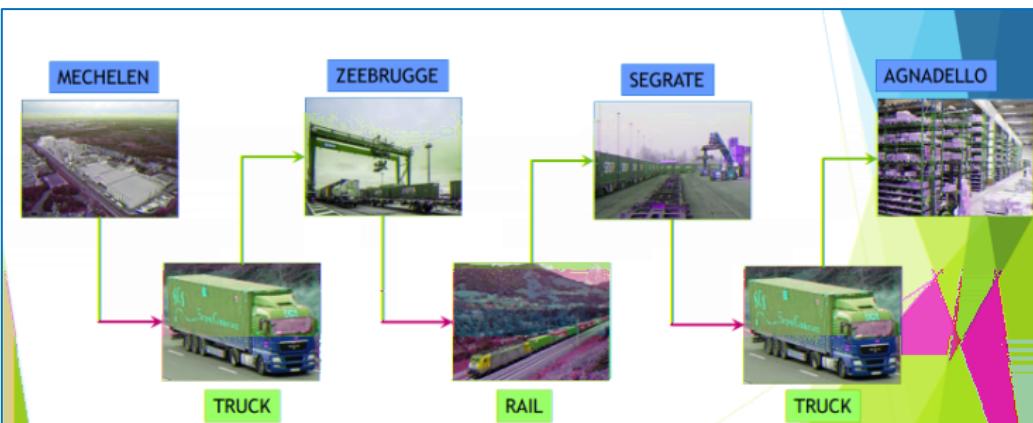


Figure 54 Corridor Mechelen (B) – Agnadello (!)

5.5.2 Challenges faced and results for LL2

In the following table, the challenges faced and the achieved results to realise the first prototype the LL2 are listed.

Challenge	Description and results
<i>E a f NB I T ea ea e e e eff ce ac e</i>	Currently, NB-IoT is not available for international logistics transactions (no international roaming, for more details see D2.6). For this reason, GPRS is considered and an energy saving protocol based on duty cycle is implemented (data are sampled and dispatched every 10 min). To obtain improved results on battery duration, a new board is developed to optimise the power consumption
<i>I e e ab</i>	<p>The standardisation scenario is analysed to be compliant with the standardisation paths related to the logistics environment. All the works described in this deliverable are designed to be compliant with this standardisation framework (related to the technical and syntactic interoperability), as detailed in Sec. 3.3. Future developments of the prototypes described in this report will follow the guidelines of the forthcoming standards, to reach higher levels of interoperability.</p> <p>This approach has allowed on one hand to ease the integration with other partners modules, on the other to dispatch the data gathered by the IoT Cloud Platform toward third parties platform, such as Synchrosupply by Inform. In the latter case, a preliminary integration through a secure POST transaction is done, integrating with Synchrosupply (see Figure 55, where the screenshot of visualisation of the received messages is shown). However, further and more detailed tests will be realised in the next months.</p>

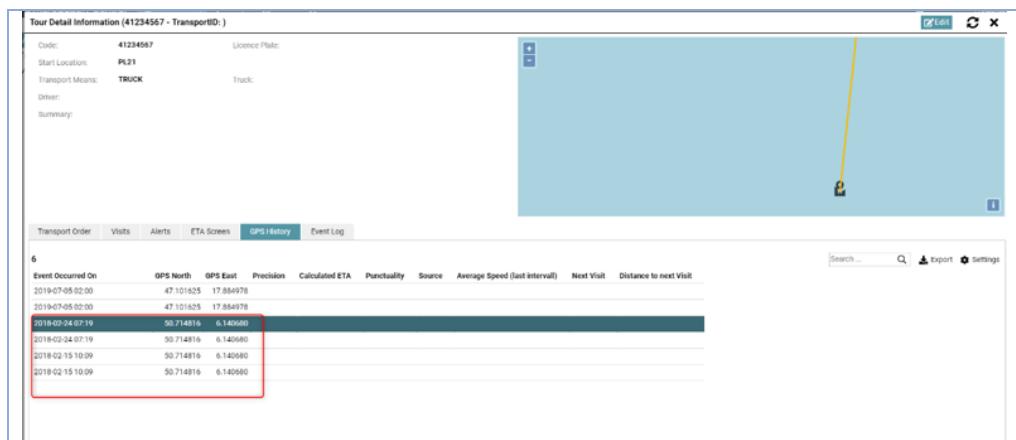


Figure 55 Preliminary integration test with Syncrosupply

Re e c
e ea

The system is configured to store in a limited buffer the data collected when the connectivity is missing (e.g., in the middle of the sea).

O b a d e
a g

The system collects measurement coming from the on-board sensors, dispatching those remotely. Some sensors are configured to trigger events, also during their sleep state.

E e fca

We have focused on the acceleration analysis, implemented following an asynchronous approach (i.e., interrupts). These analyses have allowed to implement:

1. The motion detection is based on thresholds obtained following an empirical approach. The motion detection is a useful data to determine how long a container stays stopped in a certain zone, as well as an important information to improve the power saving policy.
2. The bump detection is based on the results coming from some scientific papers and it allows the determination of the bumps that affect the container.

Finally, configurable threshold exceedance functionalities are implemented to generate events related with the temperature and/or the humidity and/or light. These functionalities can be enabled and configured by the PI order during the shipment setting-up procedures (see Sec. 5.3).

5.5.3 LL2 System performance

To demonstrate the working principle of the proposed solution, in the following a container is followed in his trips all along EU. We consider data gathered from the simulator (see Sec. 5.2.3), to have a general vision of all the trips of a container, thus demonstrating the logistics network performance in terms of efficiency in both the goods dispatchment and the container usage.

In this scenario, we have generated 17 trips for the container "5eb59a6fcfd1014c38d15688" as detailed in Table 14, where the start and the end of the shipment and the "shipmentID" assigned by the Cloud IoT services to each PI order.

Table 14 Lists of trips for the container “5eb59a6fcfd1014c38d15688”

	5eb59a6fcfd1014c38d15 688	Agnadello, Milano (IT)	West Thurrock, Kent (GB)
	5eb59a6fcfd1014c38d15 688	West Thurrock, Kent (GB)	Agnadello, Milano (IT)
	5eb59a6fcfd1014c38d15 688	Agnadello, Milano (IT)	Rumst, Antwerpen (BE)
	5eb59a6fcfd1014c38d15 688	Rumst, Antwerpen (BE)	West Thurrock, Kent (GB)
	5eb59a6fcfd1014c38d15 688	West Thurrock, Kent (GB)	Agnadello, Milano (IT)
	5eb59a6fcfd1014c38d15 688	Agnadello, Milano (IT)	West Thurrock, Kent (GB)
	5eb59a6fcfd1014c38d15 688	West Thurrock, Kent (GB)	Agnadello, Milano (IT)
	5eb59a6fcfd1014c38d15 688	Agnadello, Milano (IT)	Rumst, Antwerpen (BE)
	5eb59a6fcfd1014c38d15 688	Rumst, Antwerpen (BE)	West Thurrock, Kent (GB)

When each shipment starts (after the reception of the start signal), all the data gathered from the IoT devices related to the considered container are made available to the group of stakeholders identified by the assigned “shipmentID”: this data can be gathered by those exploiting the APIs described in Sec. 5.4 or the GUI (raw data and events can be gathered real-time, metadata only after the end of the shipment). In Figure 56 the screenshot of the GUI related of the shipment “5f44c0d8ec0aa4db149695ae” route is depicted, highlighting the point of sampling (black dots) as well as where events happens (red dots, in this case only where the shipment was stopped). Figure 57 shows the real time measurements during the shipments, in this case the temperature inside the container.

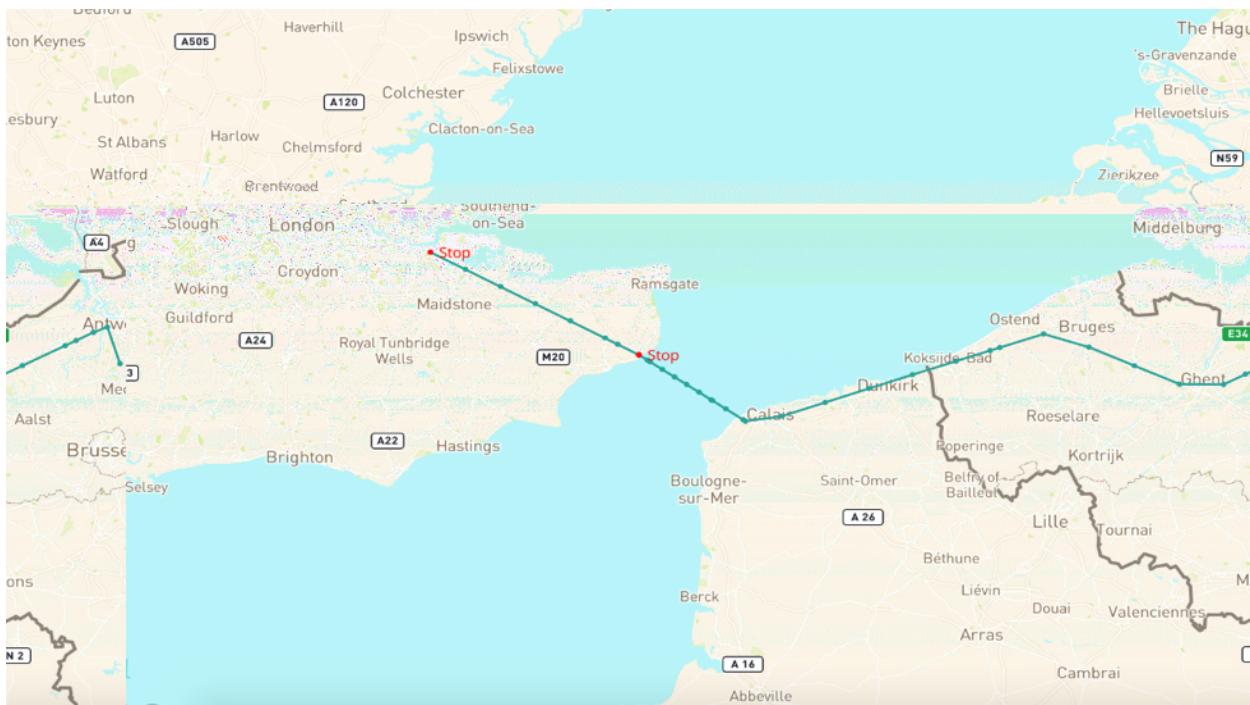


Figure 56 Route related at the shipment 5f44cod8ecoaa4db149695ae

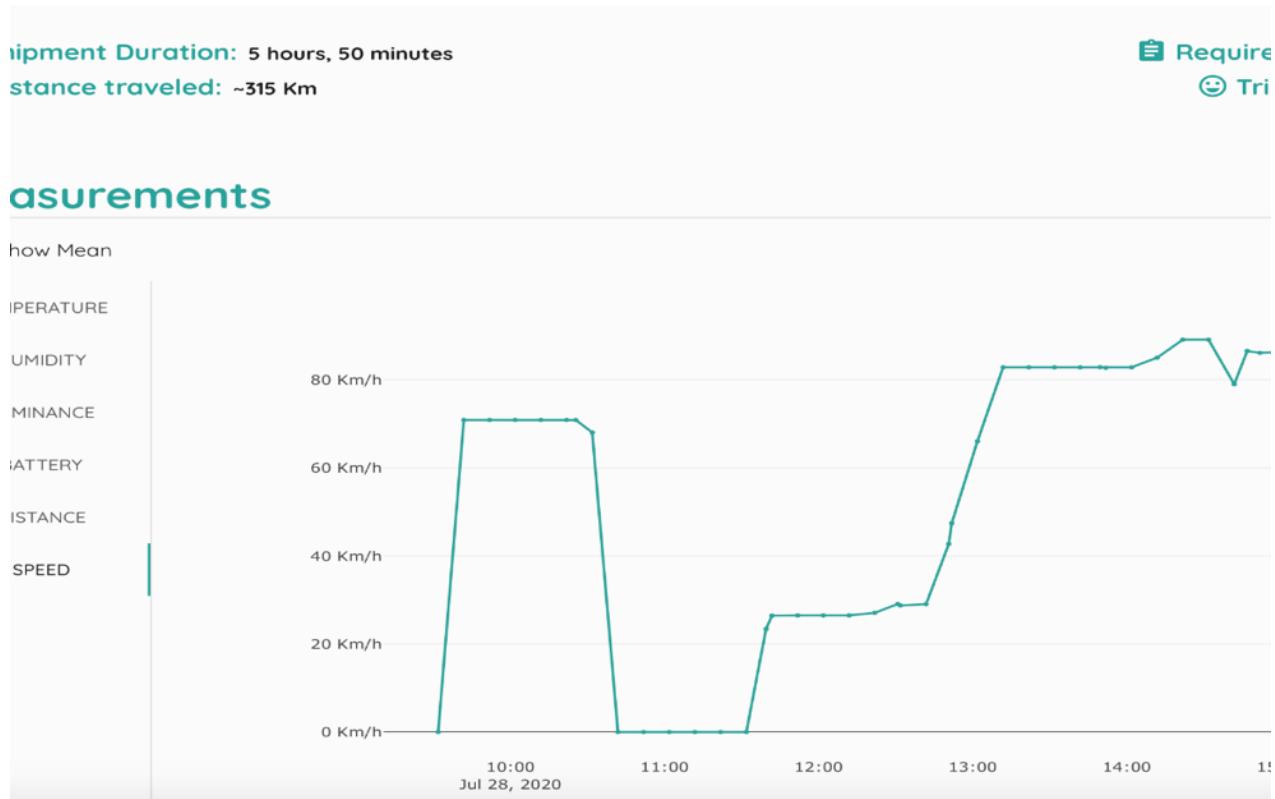


Figure 57 Shipment real time measurements

Finally, when the shipment is ended, the container is disassociated to the transaction, all the metadata are computed, and all the statistics updated. Table 15 shows the summary of the statistics parameters computed for each shipment. These parameters support the logistics decision making operations to understand the efficiency of the transaction, analysing the efficiency information provided. Particularly, analysing the Shipment efficiency in Table 15, the stop time with respect of the moving time of the shipment can be evaluated, while the raw data regarding the routes (e.g., Figure 56 and Figure 57) can support the understanding of the reasons of this stops (e.g., delay on crossdocking, queues, etc.). This analysis can be supported by the comparison between the average speed and the average speed without stops. The

Table 15 Shipments summary table

shipmentID	containerID	startsAt	endsAt	Duration [hh:mm:ss]	From	To	Distance [Km]	Stop Time [min]	Efficiency ⁶ [%]	Speed Avg. [Km/h]	Speed Avg. NoStop [Km/h]
5f44bce0ec0 aa4db14969 5ac	5eb59a6fcfd1 014c38d1568 8	2020-06-27 T04:33:59.00 0Z	2020-06-27 T23:15:06.00 0Z	18:41:07	Agnadello, Milano (IT)	West Thurrock, Kent (GB)	~1138.8	01:00:00	94.65	~62.4	~65.2
5f44bf0dec0 aa4db14969 5ad	5eb59a6fcfd1 014c38d1568 8	2020-07-01 T07:22:00.00 0Z	2020-07-02 T02:02:06.00 0Z	18:40:06	West Thurrock, Kent (GB)	Agnadello, Milano (IT)	~1131.0	00:40:00	96.43	~61.8	~63.7
5f44c0d8ec0 aa4db14969 5ae	5eb59a6fcfd1 014c38d1568 8	2020-07-03 T10:11:31.00 0Z	2020-07-04 T05:41:31.00 0Z	19:30:00	Agnadello, Milano (IT)	Rumst, Antwerpen (BE)	~1160.4	01:00:00	94.87	~60.0	~62.7
5f44c29fec0a a4db149695 af	5eb59a6fcfd1 014c38d1568 8	2020-07- 13T19:06:12. 000Z	2020-07- 14T02:16:12. 000Z	07:10:00	Rumst, Antwerpen (BE)	West Thurrock, Kent (GB)	~315.52	00:50:00	88.37	~44.5	~49.8
5f44c2f1ec0a a4db149695 b0	5eb59a6fcfd1 014c38d1568 8	2020-07- 14T16:04:05. 000Z	2020-07- 15T07:34:05. 000Z	15:30:00	West Thurrock, Kent (GB)	Agnadello, Milano (IT)	~1073.1	00:50:00	94.62	~70.4	~73.5
5f44c384ec0 aa4db14969 5b1	5eb59a6fcfd1 014c38d1568 8	2020-07- 20T13:28:09. 000Z	2020-07- 21T08:38:09. 000Z	19:10:00	Agnadello, Milano (IT)	West Thurrock, Kent (GB)	~1123.1	01:00:00	94.78	~59.4	~62.2
5f44c477ec0 aa4db14969 5b2	5eb59a6fcfd1 014c38d1568 8	2020-07- 21T14:10:41. 000Z	2020-07- 22T07:30:41. 000Z	17:20:00	West Thurrock, Kent (GB)	Agnadello, Milano (IT)	~1236.9	01:00:00	94.23	~72.5	~76.2
5f44c53bec0 aa4db14969 5b3	5eb59a6fcfd1 014c38d1568 8	2020-07- 24T10:57:38. 000Z	2020-07- 25T03:17:38. 000Z	16:20:00	Agnadello, Milano (IT)	Rumst, Antwerpen (BE)	~952.0	01:00:00	93.88	~58.9	~61.8
5f44c598ec0 aa4db14969 5b4	5eb59a6fcfd1 014c38d1568 8	2020-07- 27T08:59:11. 000Z	2020-07- 27T13:39:11. 000Z	04:40:00	Rumst, Antwerpen (BE)	West Thurrock, Kent (GB)	~307.74	00:30:00	89.29	~65.9	~73.3
5f44c60fec0a a4db149695 b5	5eb59a6fcfd1 014c38d1568 8	2020-07- 28T09:31:46. 000Z	2020-07- 28T15:21:46. 000Z	05:50:00	West Thurrock, Kent (GB)	Rumst, Antwerpen (BE)	~316.0	01:00:00	82.86	~55.9	~65.0
5f44c647ec0 aa4db14969 5b6	5eb59a6fcfd1 014c38d1568 8	2020-07- 28T21:21:56. 000Z	2020-07- 29T02:27:57. 000Z	05:06:01	Rumst, Antwerpen (BE)	West Thurrock, Kent (GB)	~320.41	00:40:00	86.93	~65.2	~72.9
5f44c6cce0a a4db149695 b7	5eb59a6fcfd1 014c38d1568 8	2020-08- 03T06:34:25. 000Z	2020-08- 04T00:54:25. 000Z	18:20:00	West Thurrock, Kent (GB)	Agnadello, Milano (IT)	~1087.6	00:40:00	96.36	~59.9	~61.7

⁶ Shipment efficiency

5f44c89bec0 aa4db14969 5b8	5eb59a6fcfd1 014c38d1568 8	2020-08- 014c38d1568 000Z	2020-08- 05T08:04:17. 000Z	12:40:00	Agnadello, Milano (IT)	Rumst, Antwerpen (BE)	~816.8	01:00:00	92.11	~65.0	~70.0	
5f44c8e2ec0 aa4db14969 5b9	5eb59a6fcfd1 014c38d1568 8	2020-08- 014c38d1568 000Z	2020-08- 06T06:01:08. 000Z	06:26:22	Rumst, Antwerpen (BE)	West Thurrock, Kent (GB)	~313.8	00:50:00	87.06	~50.9	~57.1	
5f44c945ec0 aa4db14969 5ba	5eb59a6fcfd1 014c38d1568 8	2020-08- 014c38d1568 000Z	2020-08- 10T11:27:48. 000Z	07:20:00	West Thurrock, Kent (GB)	Rumst, Antwerpen (BE)	~316.7	01:10:00	84.09	~47.1	~54.2	
5f44c971ec0 aa4db14969 5bb	5eb59a6fcfd1 014c38d1568 8	2020-08- 014c38d1568 000Z	2020-08- 11T13:06:01. 000Z	17:50:00	Rumst, Antwerpen (BE)	Agnadello, Milano (IT)	~1165.0	00:50:00	95.33	~65.3	~68.0	
5f44c9bdec0 aa4db14969 5bc	5eb59a6fcfd1 014c38d1568 8	2020-08- 014c38d1568 000Z	2020-08- 12T14:56:33. 000Z	13T10:06:33. 000Z	19:10:00	Agnadello, Milano (IT)	West Thurrock, Kent (GB)	~1145.1	01:10:00	93.91	~60.0	~63.2

Table 16 Statistics

From	To	Avg Duration [hh:mm:ss]	Min Duration [hh:mm:ss]	Max Duration [hh:mm:ss]
Agnadello, Milano (IT)	Rumst, Antwerpen (BE)	16:10:00	12:40:00	19:30:00
Agnadello, Milano (IT)	West Thurrock, Kent (GB)	19:00:22	18:41:07	19:10:00
Rumst, Antwerpen (BE)	Agnadello, Milano (IT)	17:50:00	17:50:00	17:50:00
Rumst, Antwerpen (BE)	West Thurrock, Kent (GB)	05:50:36	04:40:00	07:10:00
West Thurrock, Kent (GB)	Agnadello, Milano (IT)	17:27:31	15:30:00	18:40:06
West Thurrock, Kent (GB)	Rumst, Antwerpen (BE)	06:35:00	05:50:00	07:20:00
From	To	Avg Stop Time [hh:mm:ss]	Min Stop Time [hh:mm:ss]	Max StopTime [hh:mm:ss]
Agnadello, Milano (IT)	Rumst, Antwerpen (BE)	01:00:00	01:00:00	01:00:00
Agnadello, Milano (IT)	West Thurrock, Kent (GB)	01:03:20	01:00:00	01:10:00
Rumst, Antwerpen (BE)	Agnadello, Milano (IT)	00:50:00	00:50:00	00:50:00
Rumst, Antwerpen (BE)	West Thurrock, Kent (GB)	00:42:30	00:30:00	00:50:00
West Thurrock, Kent (GB)	Agnadello, Milano (IT)	00:47:30	00:40:00	01:00:00
West Thurrock, Kent (GB)	Rumst, Antwerpen (BE)	01:05:00	01:00:00	01:10:00
From	To	Avg Efficiency [%]	Min Efficiency [%]	Max Efficiency [%]
Agnadello, Milano (IT)	Rumst, Antwerpen (BE)	94	92	95
Agnadello, Milano (IT)	West Thurrock, Kent (GB)	94	94	95
Rumst, Antwerpen (BE)	Agnadello, Milano (IT)	95	95	95
Rumst, Antwerpen (BE)	West Thurrock, Kent (GB)	88	87	89
West Thurrock, Kent (GB)	Agnadello, Milano (IT)	95	94	96
West Thurrock, Kent (GB)	Rumst, Antwerpen (BE)	83	82	84
From	To	Avg Distance Traveled [Km]	Min Distance Traveled [Km]	Max Distance Traveled [Km]
Agnadello, Milano (IT)	Rumst, Antwerpen (BE)	976	817	1160
Agnadello, Milano (IT)	West Thurrock, Kent (GB)	1136	1123	1145
Rumst, Antwerpen (BE)	Agnadello, Milano (IT)	1165	1165	1165
Rumst, Antwerpen (BE)	West Thurrock, Kent (GB)	314	308	320
West Thurrock, Kent (GB)	Agnadello, Milano (IT)	1132	1073	1237
West Thurrock, Kent (GB)	Rumst, Antwerpen (BE)	316	316	317
From	To	Avg Avg. Speed [Km/h]	Min Avg. Speed [Km/h]	Max Avg. Speed [Km/h]
Agnadello, Milano (IT)	Rumst, Antwerpen (BE)	61	59	65
Agnadello, Milano (IT)	West Thurrock, Kent (GB)	61	59	62
Rumst, Antwerpen (BE)	Agnadello, Milano (IT)	65	65	65
Rumst, Antwerpen (BE)	West Thurrock, Kent (GB)	57	44	66
West Thurrock, Kent (GB)	Agnadello, Milano (IT)	66	60	73
West Thurrock, Kent (GB)	Rumst, Antwerpen (BE)	52	47	56
From	To	Avg Avg. Speed NoStop [Km/h]	Min Avg. Speed NoStop [Km/h]	Max Avg. Speed NoStop [Km/h]

Agnadello, Milano (IT)	Rumst, Antwerpen (BE)	65	62	70
Agnadello, Milano (IT)	West Thurrock, Kent (GB)	64	62	65
Rumst, Antwerpen (BE)	Agnadello, Milano (IT)	68	68	68
Rumst, Antwerpen (BE)	West Thurrock, Kent (GB)	63	50	73
West Thurrock, Kent (GB)	Agnadello, Milano (IT)	69	62	76
West Thurrock, Kent (GB)	Rumst, Antwerpen (BE)	60	54	65

6. The Cloud IoT Platform

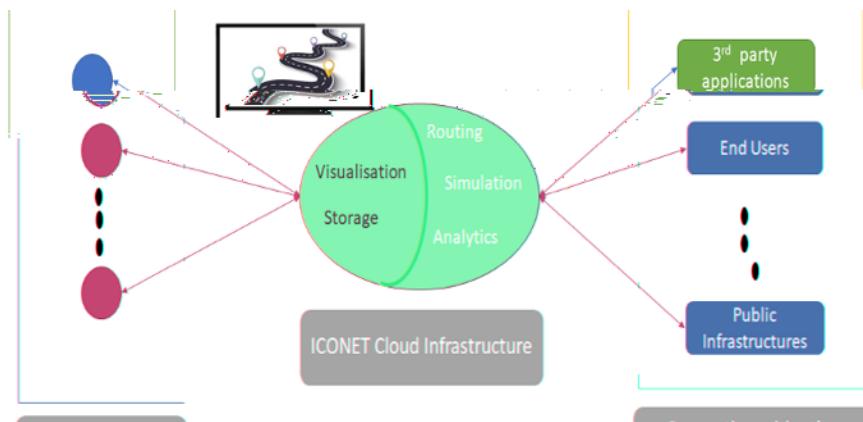


Figure 59 The Cloud IoT Platform

6.1 The ICONET Cloud PoC overview

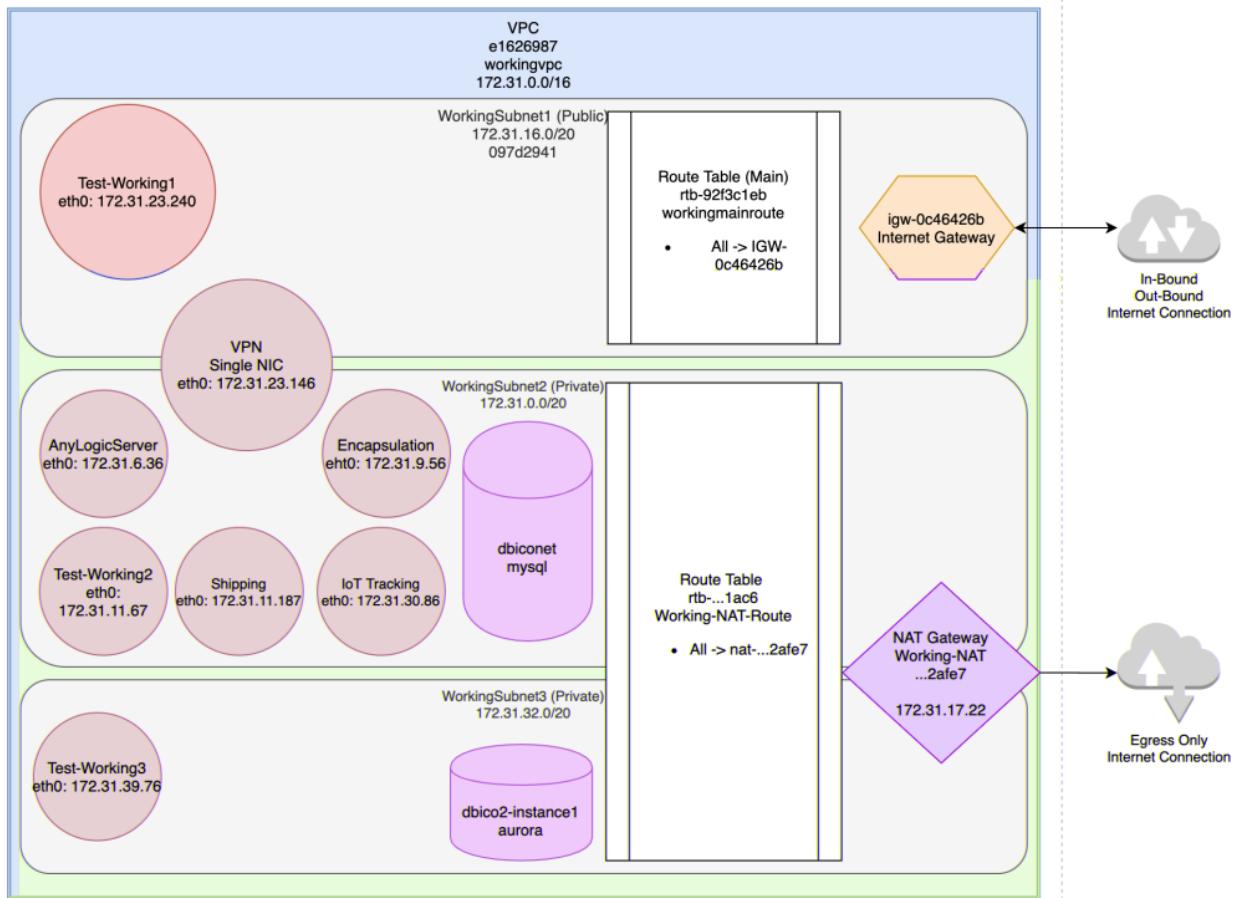


Figure 60 The ICONET PoC - AWS VPC Network Map

6.2 The Cloud IoT Platform – Final Release

- 1. The IoT manager**
- 2. The Storage manager**
- 3. Analytics**
- 4. Interactions/APIs,**
- 5. The Graphical User Interface,**

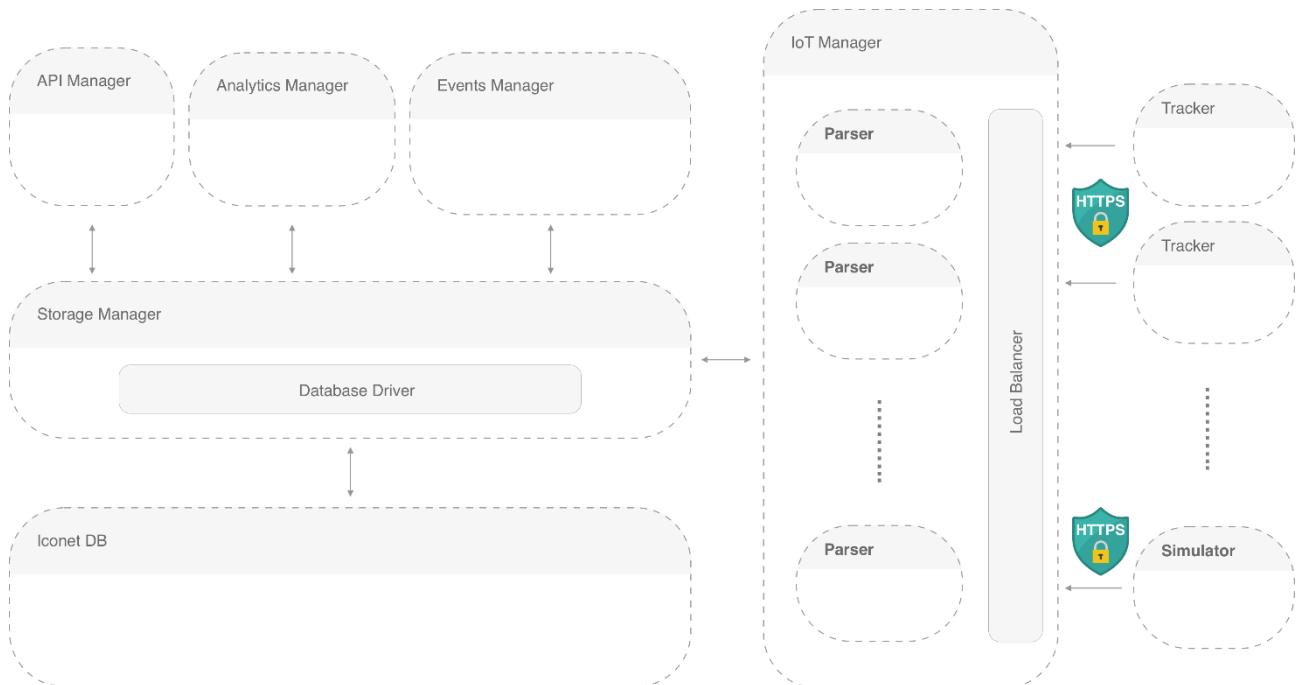


Figure 61 Cloud IoT Platform final architecture

6.3 The IoT manager

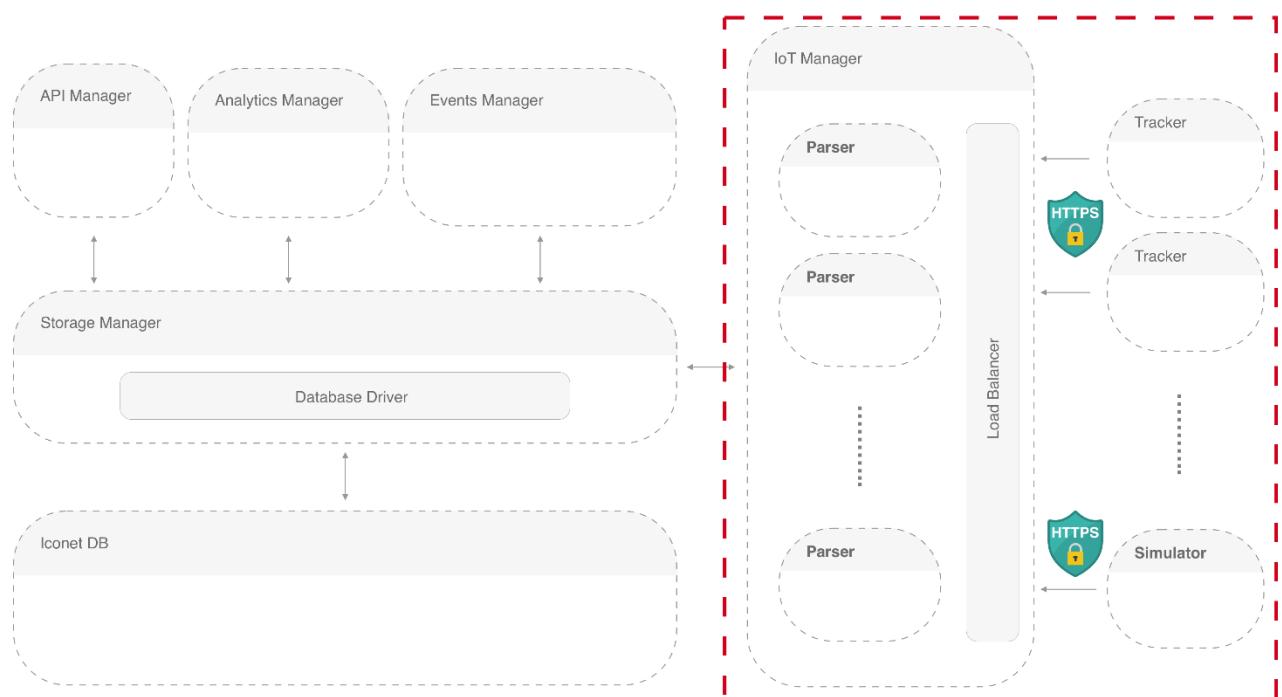


Figure 62 The IoT manager

6.4 The Storage manager

Figure 63 The storage manager

On-line analysis

Mining analysis

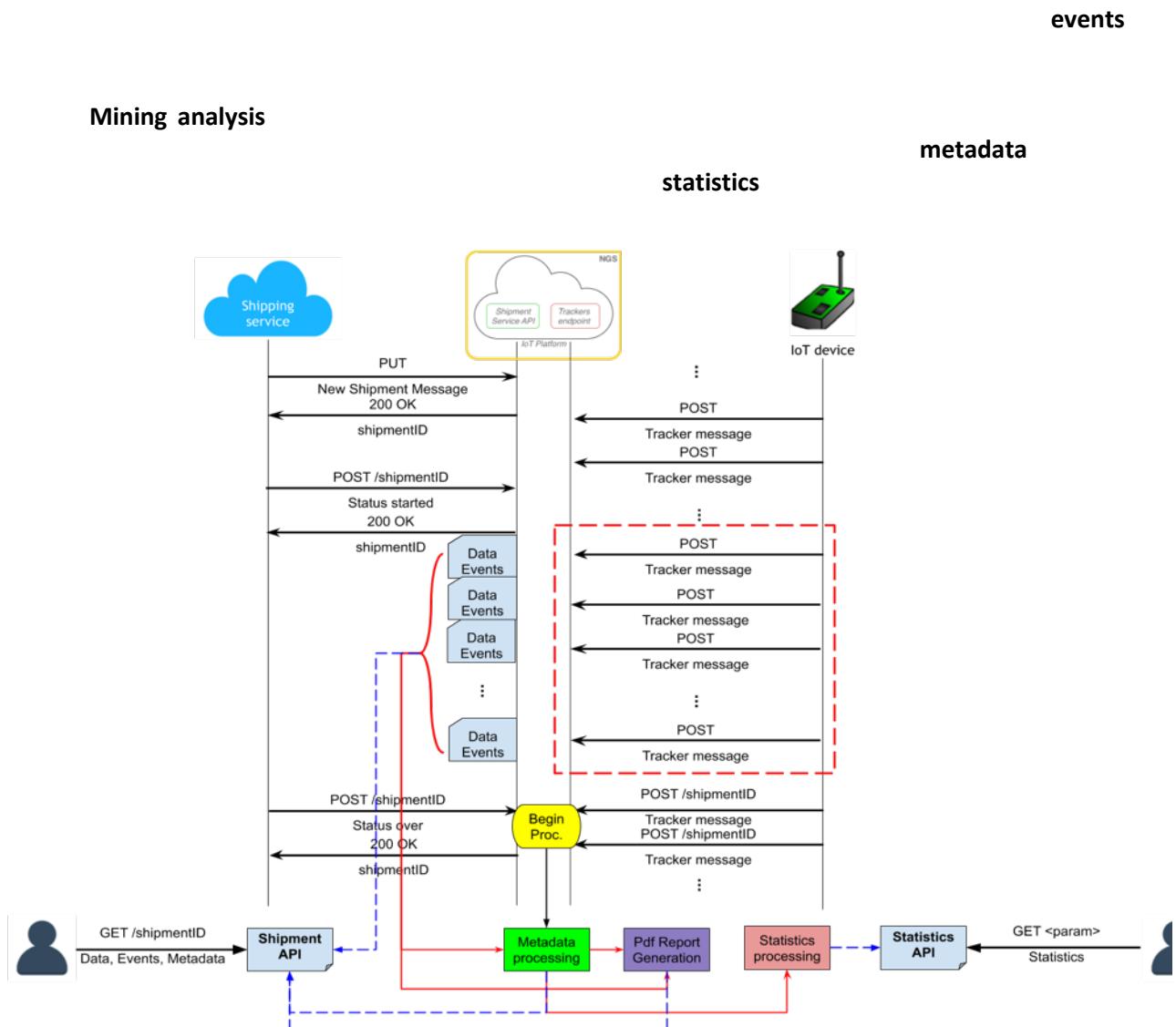


Figure 65 Data Collection - Event, metadata and statistics computation

6.6 APIs manager

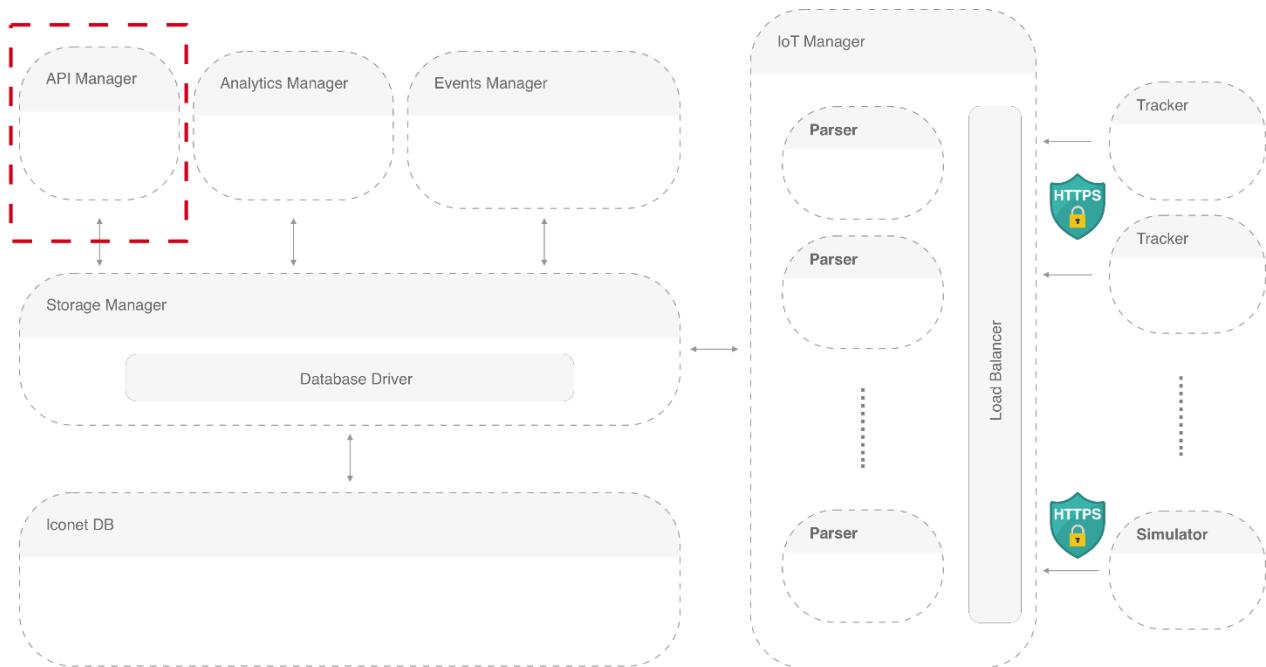


Figure 66 API Manager

7

Shipment Service APIs

Statistics API

6.6.1 Shipment Service APIs

Shipment Service APIs

Creation and listing APIs

Show and Modify APIs

Retrieve data APIs

⁷ The usage of the OpenAPI standard enables the use of all the tools available in its ecosystem from the interactive visualization to the code generation, easing the integration and increasing the interoperability.

Table 17 The shipment service APIs

	Name	HTTPS Meth.	Description
Creation and listing APIs		PUT	
		GET	
Show and Modify APIs		GET	
		POST	
Retrieve data APIs		GET	
		GET	
		GET	
		GET	

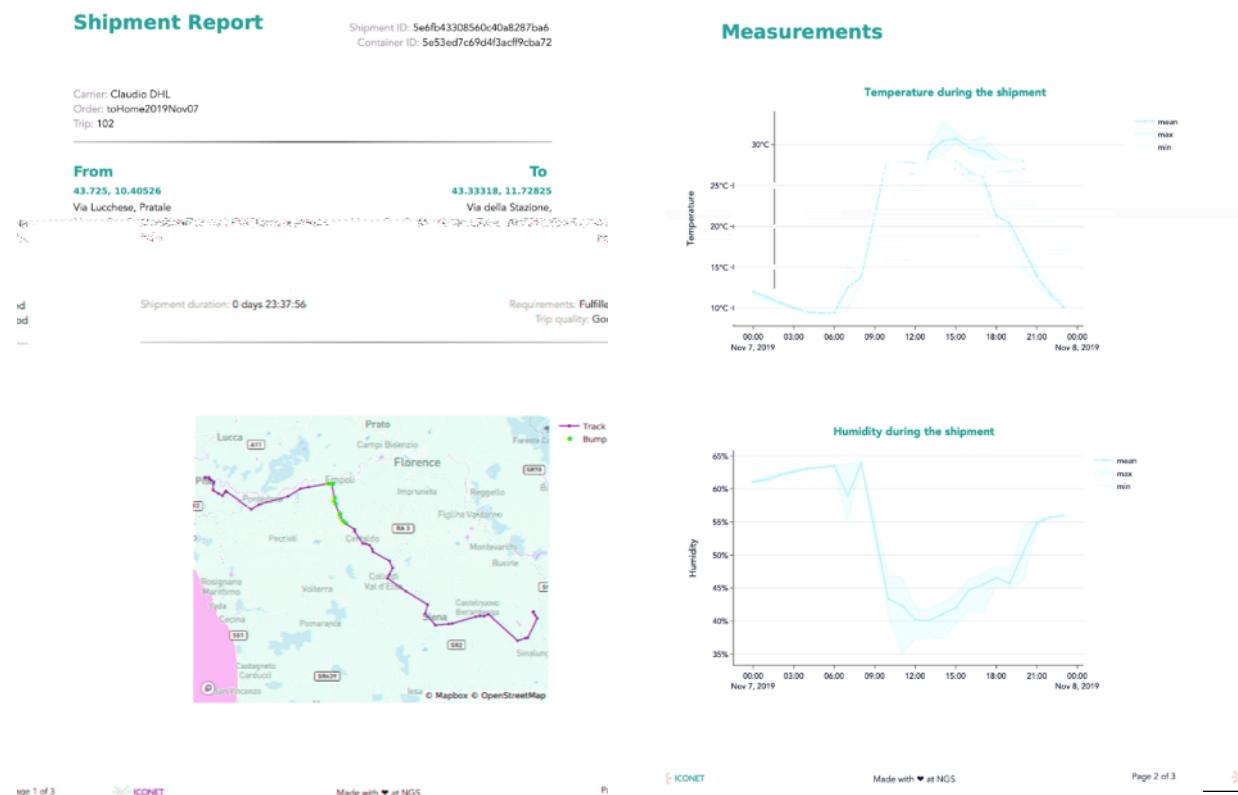


Figure 67 Pdf report sample

6.6.2 Shipment Statistics APIs

Shipment Statistics APIs

Table 18 The statistics API

Name	HTTPS Meth.	Description
Average duration	GET	

Average distance	GET	
Time of stop	GET	
Container efficiency	GET	

6.6.3 The Graphical User Interface (GUI)

Authentication

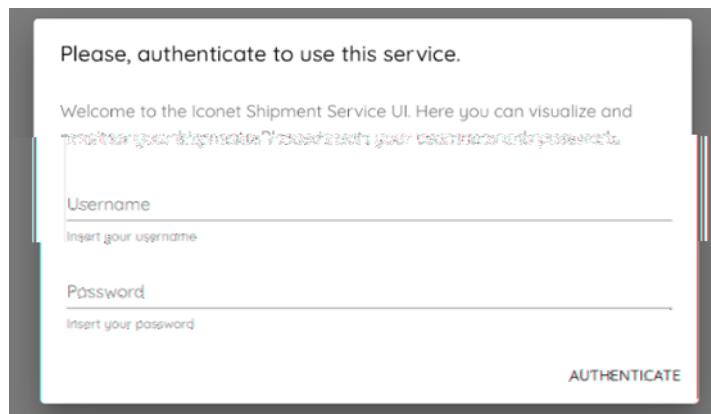


Figure 68 Authentication

Shipment route map and measurement summary

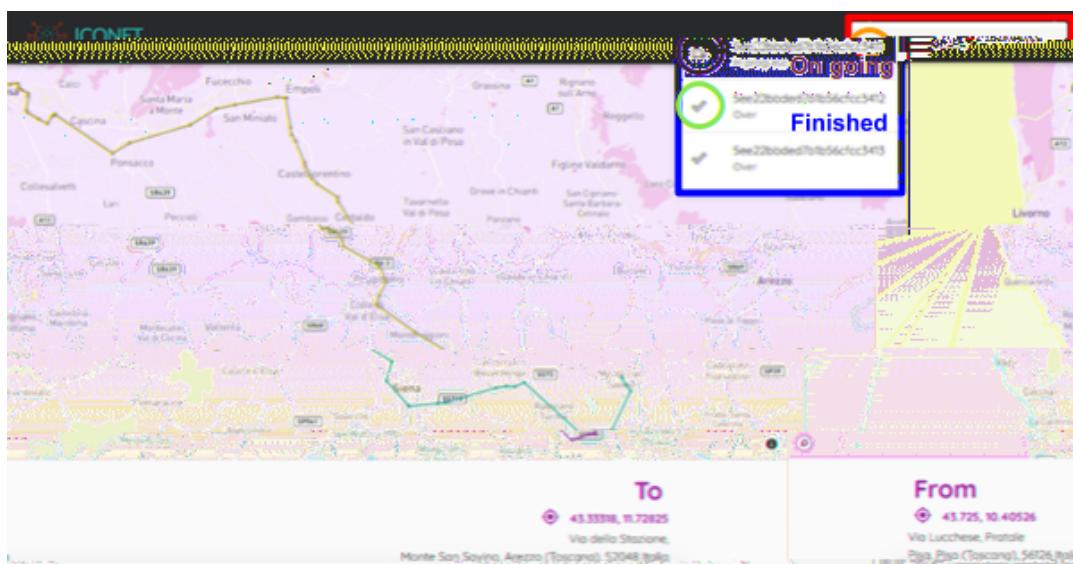


Figure 69 Shipment route map and Shipment selection

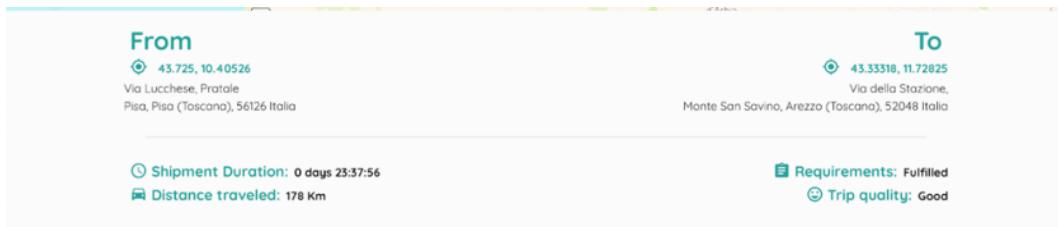


Figure 70 Measurement summary

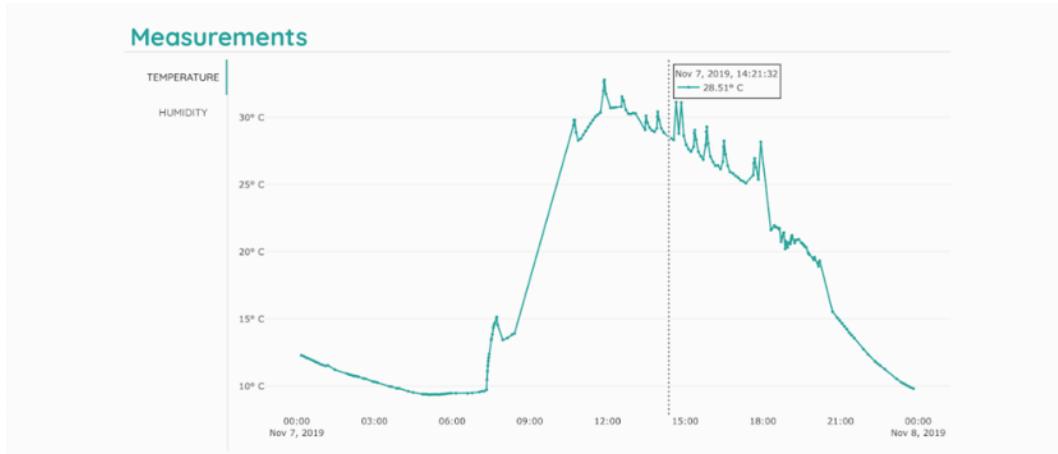


Figure 71 Measurement summary

6.7 Security and ad-hoc access

Stand-alone configuration

Cooperative configuration

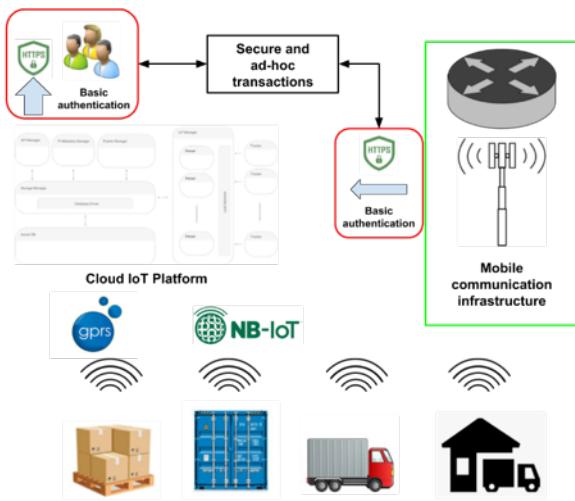


Figure 72 Security and access control in a stand-alone configuration

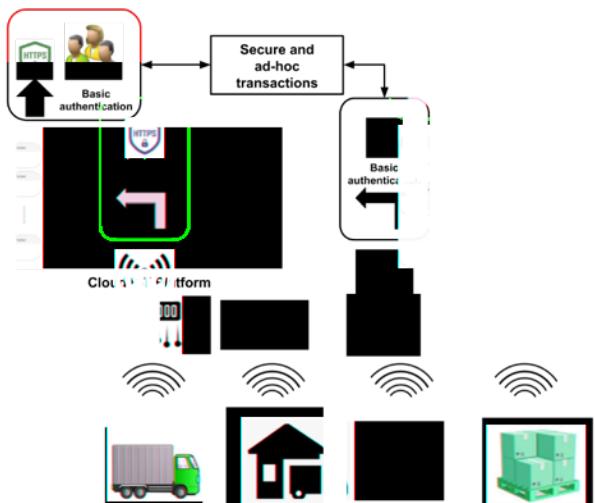


Figure 73 Security and access control in a cooperative configuration

6.7.1 HTTPS

Access authentication

Protection of the confidentiality and integrity of the exchanged data

HTTPS protects the transactions against man-in-the-middle⁸ eavesdropping⁹ and tampering¹⁰ attacks.

confidentiality	clients' authentication	data integrity
------------------------	--------------------------------	-----------------------

⁸ Man-in-the-middle attack is an attack where the attacker secretly relays and possibly alters the communications between two parties who believe that they are directly communicating with each other

⁹ Eavesdropping is the act of secretly or stealthily listening to the private conversation or communications of others without their consent.

¹⁰ Tampering means a deliberate altering or adulteration of the information.

6.7.2 Basic Authentication

11

Authentication

Authorisation

access control/ad-hoc access

6.8 The running platform and the deployment on AWS

12

¹¹ Base64 is a group of binary-to-text encoding schemes that represent binary data in an ASCII string format by translating it into a radix-64 representation

¹² Experiments done exploiting the open source software called Postman - <https://www.postman.com/>.

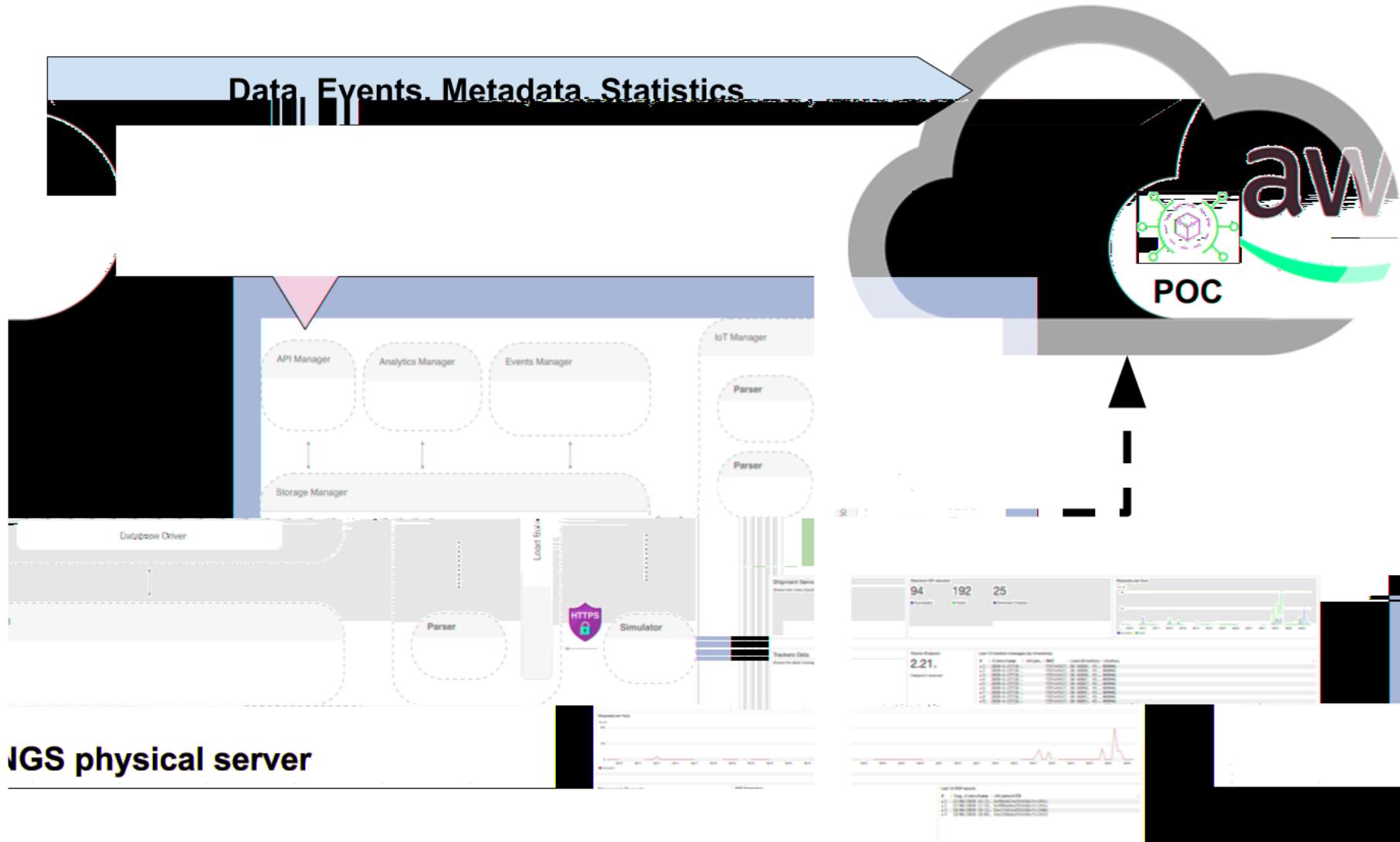


Figure 74 The Cloud IoT Platform deployment

On the other side, the AWS Cloud management functionalities are used to manage and analyse the logs coming from the platform (see Figure 75), allowing the realisation of a platform management system, to

- Monitor the platform transactions (maintaining the confidentiality of the data related to the considered ITC).
- Generate and notify alerts if a system component fails.
- Visualise in a dashboard (depicted in Figure 76) the usage of the platform and its performance.

```

▶ 2020-08-16T21:16:42.101+02:00 [16/08/2020 19:16:42,100] INFO | tracker_handler | Request contains 1 messages
▶ 2020-08-16T21:16:42.101+02:00 [16/08/2020 19:16:42,101] DEBUG | tracker_parser | Parser with id f286e701-9bf1-4bc0-ba7d-7cb2932a2d3c is going to
▶ 2020-08-16T21:16:42.101+02:00 [16/08/2020 19:16:42,101] DEBUG | sensor_parser | Parsing temperature: already in CELSIUS, no conversion.
▶ 2020-08-16T21:16:42.101+02:00 [16/08/2020 19:16:42,101] DEBUG | sensor_parser | Parsing humidity: already in PERCENTAGE, no conversion.
▶ 2020-08-16T21:16:42.102+02:00 [16/08/2020 19:16:42,101] DEBUG | sensor_parser | Parsing luminance: already in LUX, no conversion.
▶ 2020-08-16T21:16:42.102+02:00 [16/08/2020 19:16:42,102] DEBUG | sensor_parser | Parsing Accelerometer: already in MILLI_G, no conversion.
▶ 2020-08-16T21:16:42.102+02:00 [16/08/2020 19:16:42,102] DEBUG | sensor_parser | Parsing GPS: already in DECIMAL_DEGREE, no conversion.
▶ 2020-08-16T21:16:42.102+02:00 [16/08/2020 19:16:42,102] DEBUG | sensor_parser | Parsing battery: already in VOLT, no conversion.
▶ 2020-08-16T21:16:42.102+02:00 [16/08/2020 19:16:42,102] DEBUG | beatrak_parser | Parsing status: received 0x02, extracted events: [<Status.STOP: 0x02>]
▶ 2020-08-16T21:16:42.103+02:00 [16/08/2020 19:16:42,103] DEBUG | beatrak_parser | Received time: received 160820 191634.40. (last.. 2020-08-16T19:05:59)
▶ 2020-08-16T21:16:42.103+02:00 [16/08/2020 19:16:42,103] DEBUG | client | Retrive shipment bound to a container with id Sefo08e9321ff0d068a1edeb
▶ 2020-08-16T21:16:42.115+02:00 [16/08/2020 19:16:42,114] WARNING | client | No active shipment was found (with container with id Sefo08e9321ff0d068a1edeb)
▶ 2020-08-16T21:16:42.115+02:00 [16/08/2020 19:16:42,115] DEBUG | tracker_parser | Shipment association: active shipment for container Sefo08e9321ff0d068a1edeb
▶ 2020-08-16T21:16:42.115+02:00 [16/08/2020 19:16:42,115] DEBUG | tracker_handler | Extracted tracker data: {'MACAddress': 'f563bb72e698', 'status': ['STOP'], 'measurements': {'temperature': 30.14, 'humidity': 62.93, 'luminance': 0.0, 'accelerometer': {'x': -80.0, 'y': 81.0, 'z': 990.0, 'type': 'three'}, 'gps': {'type': 'Point', 'coordinates': [15.85114, 38.63197]}, 'battery': 10.28}, 'timestamp': datetime(2020, 8, 16, 19, 16, 34, tzinfo=datetime.timezone.utc), 'containerID': ObjectID('5ef008e9321ff0d068a1edeb')}
▶ 2020-08-16T21:16:42.127+02:00 [16/08/2020 19:16:42,127] DEBUG | client | TrackerData stored
▶ 2020-08-16T21:16:42.127+02:00 [16/08/2020 19:16:42,127] INFO | tracker_handler | Tracker data stored
▶ 2020-08-16T21:16:42.127+02:00 [16/08/2020 19:16:42,127] INFO | tracker_handler | Stored 1/1 messages

```

Figure 75 Logs regarding data acquisition

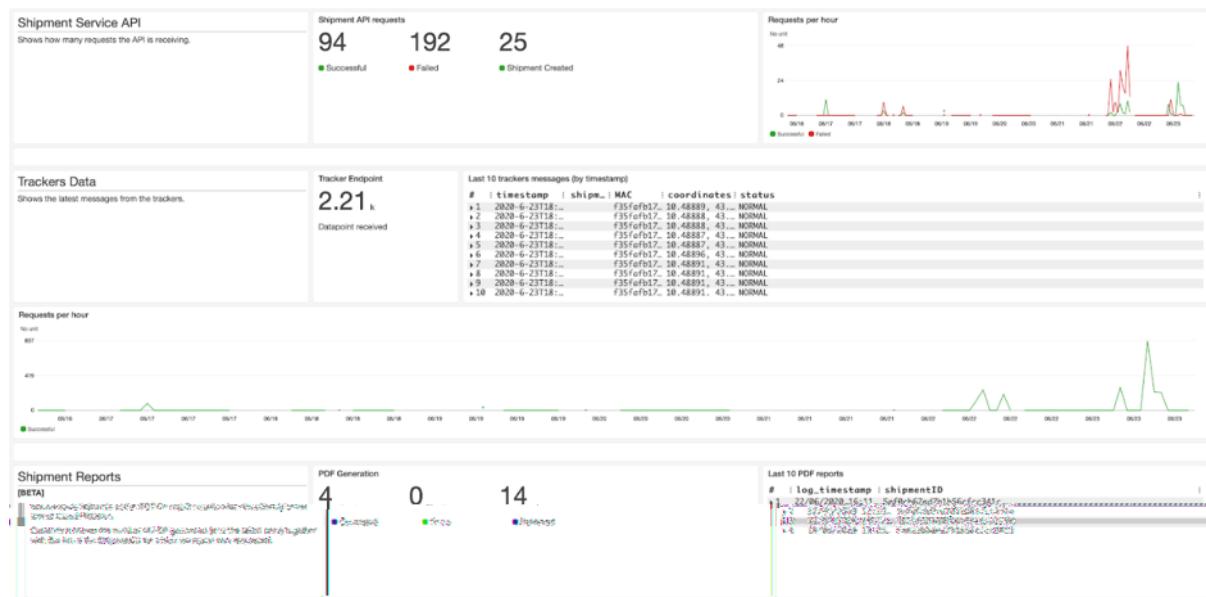


Figure 76 Logs analysis dashboard

7. The Tracker and the Smart Router

Trackers and Smart Routers are two essential devices to ensure continuous tracking and monitoring service of the Smart PI Containers (see Sec. 3.5.1). They are built on a common hardware platform, that can be configured from the remote platform to satisfy the needs of the shipment (described in the PI order, see Sec. 5.3). The functionalities of the Trackers and the Smart Routers are summarised in Table 19, while the interaction model of the Tracker/Smart Router is depicted in Figure 36.

Table 19 Tracker vs Smart Router

Functionalities	Smart Router	Tracker
Collect information regarding position and time of a container	Yes	Yes
Collect added value measurement exploiting on board sensors	Yes	Yes
Monitor the presence of connected goods encapsulated within it (e.g., Smart PI Pallets)	Yes	No
Collect added value environmental data inside/outside the container, exploiting short range IoT protocols	Yes	No
Communicate remotely exploiting different protocols the data collected	Yes	Yes
Provide the possibility to receive configuration/actuation messages from remote	Yes	Yes
Implementing data logging functionalities in case of missing collection	Yes	Yes
Low power consumption, battery powered, power saving policies	Yes	Yes

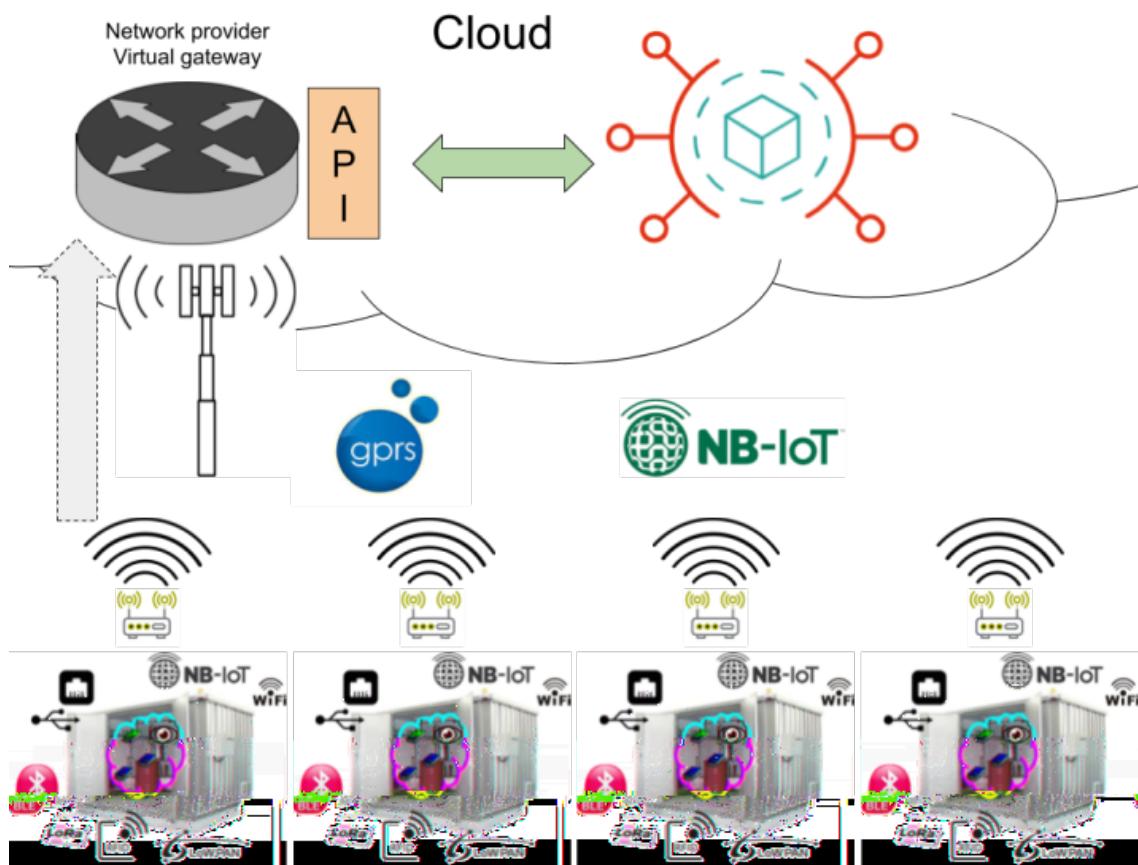


Figure 36 Tracker/Smart Router interaction model

7.1 The ICONET Smart router characteristics

The ICONET Smart Router represents the key components in charge of:

1. Integrating added value on-board sensors (i.e., temperature-humidity, acceleration, and light) capable to generate asynchronous events such as bump detection, movement detection, temperature thresholds exceeding and door open/close detection.
2. Implementing an internal and external container connectivity, thus allowing the management of the encapsulation of the connected goods as well as their (distributed) monitoring, allowing the integration of a scalable set of IoT devices capable of providing added value measurements, and the monitoring of the container itself (e.g., connected seals status).
3. Tagging the data and information gathered from both the IoT devices and the on-board sensors with their geo&time-reference, allowing to understand the place and the time where certain events have happened, as well as the implementation of the track&trace service.
4. Implementing an improved interoperable connectivity, integrating five different protocols in the same board (i.e., GPRS, NB-IoT, LTE Cat-M1, BLE, IEEE802.15.4). Particularly, the solution is 5G ready, and compliant with the guidelines of DSCA standard release 1 and with the CALM ITS station. For further details, see Sec. 7.4.
5. Designed to realise the features of the ICONET IoT architecture.
6. Energy saving design, though to be battery powered and enforced by an (solar) energy harvesting functionality, thus improving its integrability and reducing its maintenance.

7.2 The ICONET Smart Router Reference Implementation

Both the Tracker and the Smart Router are based on the full-fledged release of the Micro-FLEXX board (see Figure 77). On the other hand, Figure 78 shows the final FSM to implement the Smart Router and the Tracker (without considering the state highlighted in green).

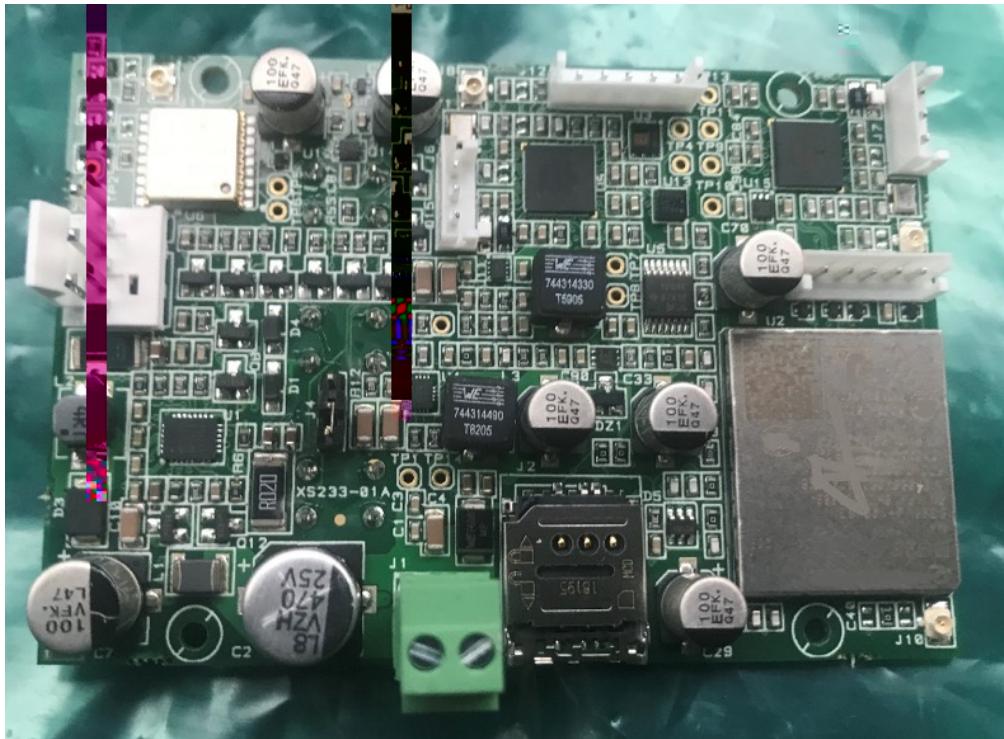


Figure 77 The Micro-Flexx board

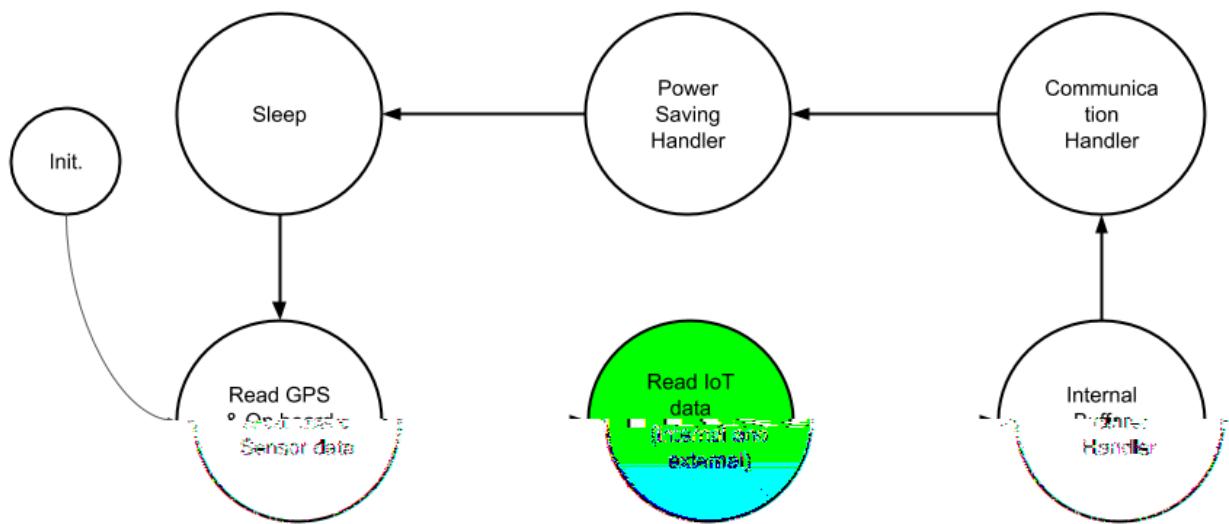


Figure 78 Tracker/Smart Router FSM

7.3 Micro-FLEXX details and performance

The reasons of the development of the Micro-FLEXX board in Figure 77 derives from the impossibility to exploit already existing programmable platforms (IoT tracker companies do not provide the possibility to customise their hardware) since not optimised for the purposes of the ICONET project. The one we have considered at the beginning of the project (RAK, s.d.) was characterised in D2.6 and has the following limitations:

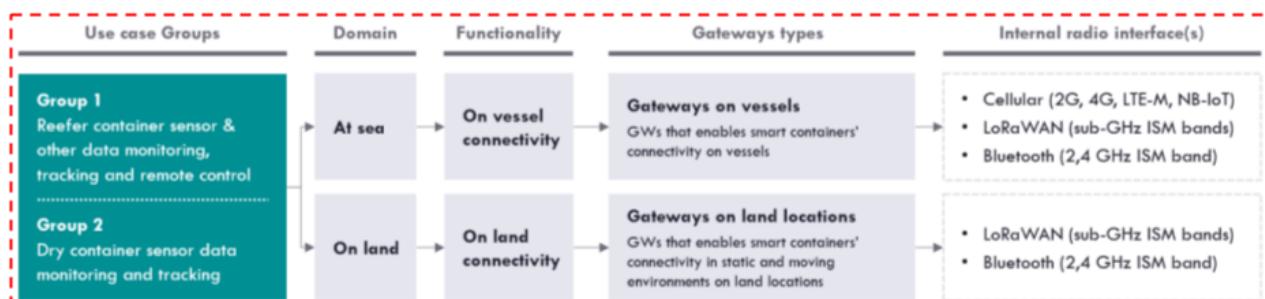
1. The main limitation regards the not optimised power supply sub-component. Particularly, the GPS supply circuit drowns current continuously, also during the sleep period. In the following table the comparison of the power consumption, coming from laboratory experiments, is shown, demonstrating a consumption optimisation of almost the 20%.

Table 20 Power consumption comparison

Board	Battery capacity (Wh)	Duration (Days)	Consumption per day (Wh/days)
RAK	18.5	16	1
Micro FLEXX	24	30	0,8

2. Lack of network interfaces. The proposed solution enables only one BLE network interface, as well as NB-IoT/GPRS.

7.4 Standardisation considerations



Referencing to the specification of DCSA standard release 1 (Digital Container Shipping Association (DCSA), 2020), the gateway capable to interact with the Smart PI containers - in the contingent case, with the Smart Routers – can implement a sub-set of protocols between cellular (2G, 4G, LTE-M, NB-IoT), LoRaWAN,

Bluetooth. In this scenario, the Smart Router is compliant with DCSA standard, installing the following four protocols: 2G, LTE-M, NB-IoT and Bluetooth.

Moreover, it is compliant with ISO ITS stack (ISO/TC204, s.d.) integrating also IEEE.802.15.4, thus allowing the integration of the 6LoWPAN (ISO, 2016) and CoAP (ISO, 2016) facilities. Finally, it is 5G ready since it integrated both the forerunner protocols NB-IoT and LTE Cat-M.

8. The Smart Gateway

The Smart Gateway is the edge computer capable of managing different IoT protocols and collecting the data coming from distributed sensors or from the tracker/smart routers associated with containers, as depicted in Figure 38.

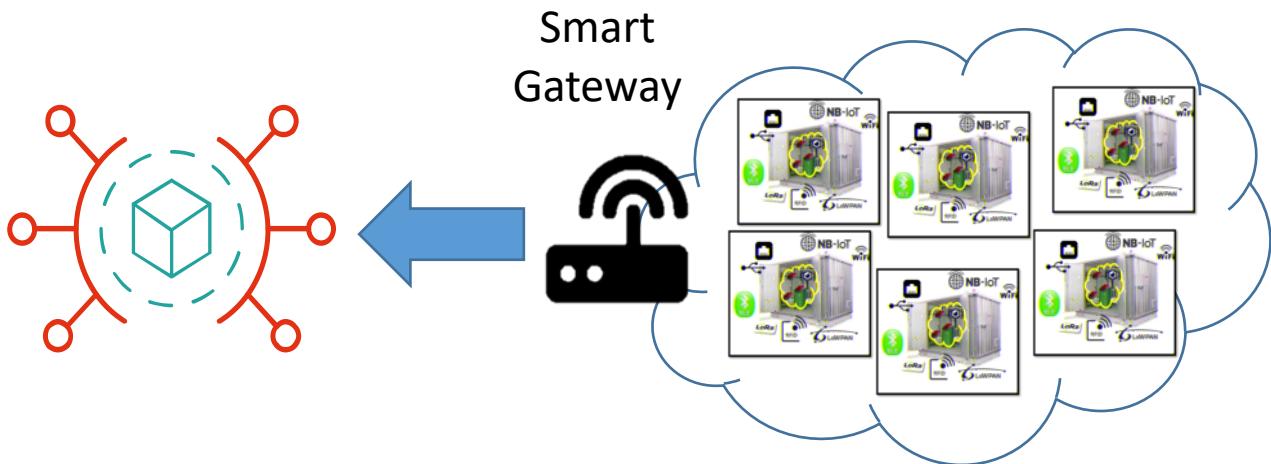


Figure 79 FLEXX gateway interaction model

Referencing at the DSCA reference architecture (see Sec. 3.3.1 - DCSA standard for digital containers) this device behaves logically as the gateway located on the vessels, on the trucks, on the train and on the barge: it enables the on-board IoT connectivity, thus, in the PI vision, providing information regarding the encapsulation of the container and of the goods.

According to DCSA standard guidelines (Digital Container Shipping Association (DCSA), 2020), the smart gateway characteristics are in-line with the requirements for realising the first two proposes, related on tracking and monitoring both reefer and dry container (see Figure 80): the smart gateway could be used for providing IoT connectivity to smart containers on vessels and on land, supporting two over three protocols (i.e., LoRaWAN and Bluetooth) listed in the aforementioned standards, as shown in Figure 80. Thus, the proposed smart gateway ensures the technical interoperability for logistics application for two group use cases by satisfying this standard.

Use case Groups	Domain	Functionality	Gateways types	Internal radio interface(s)
Group 1 Reefer container sensor & other data monitoring, tracking and remote control	At sea	On vessel connectivity	Gateways on vessels GWs that enables smart containers' connectivity on vessels	<ul style="list-style-type: none"> Cellular (2G, 4G, LTE-M, NB-IoT) LoRaWAN (sub-GHz ISM bands) Bluetooth (2,4 GHz ISM band)
	On land	On land connectivity	Gateways on land locations GWs that enables smart containers' connectivity in static and moving environments on land locations	<ul style="list-style-type: none"> LoRaWAN (sub-GHz ISM bands) Bluetooth (2,4 GHz ISM band)
Group 3 Automatic electronic container registration	On Land	Event based connectivity	Gateways at event locations GWs that enables the automatic ID registration of containers passing through critical journey milestones locations	<ul style="list-style-type: none"> RFID (UHF ISM bands)
		Operational support	Handheld gateways Handheld GWs that enables the automatic configuration of IoT devices and registration of containers by op. teams	<ul style="list-style-type: none"> NFC (13,56 MHz ISM band)

Figure 80 DSCA IoT protocols

As discussed in both D2.6 and D2.7, its software architecture is inspired by the outcomes of the Horizon 2020 project called AGILE-IoT (3), referencing on the open source library thought for the realisation of modular

and configurable gateways. In the following sections, the implementation details for the realisation of the smart gateway are detailed.

8.1 The smart gateway implementation

In this section we describe the architecture of the generic framework that NGS is developing to manage the configuration of the Smart Gateway service. In Figure 81, the architecture of the framework is described, following the guidelines of the AGILE-IOT project. Particularly, the system contains three main services:

- **IoT Protocol Service:** capable to manage both: (i) the data acquisition from the IoT sensor nodes efficiently acquire sensor data, and (ii) the IoT sensor nodes configuration. This service includes subservices for different IoT protocols such as BLE, LoRa, etc.
- **Data Storage Service:** capable to manage a local database to store the data. As matter of example, this service can be configured to save in case the remote connectivity is not available.
- **Communication Service:** this service can enable the data exchange with remote platforms. The services' API will be implemented following the interoperability guidelines coming from D1.6 and D2.7.
- **Application** that configures the gateway to implement certain behaviours. The mentioned application is realised exploiting the web-oriented scripting approach and it is detailed in Sec. 8.1.1.

Figure 81 Smart Gateway Reference Architecture

8.1.1 The Smart Gateway Application

Starting from the framework architecture of Figure 81, we have configured the Smart Gateway application capable of managing different protocol services (e.g., BLE, LoRa, CoAP). It acquires meaningful data from the IoT environment and from the on-board GPS module, then construct the messages to satisfy the defined in D2.7 data-models. In case there is no connectivity to the Cloud IoT Platform, these messages are transferred to the Storage Service. Otherwise, the data can be transmitted directly to the Cloud IoT Platform, managing a Multiprotocol remote communication.

8.1.2 The Smart Gateway Board

FLEXX gateway v.2.0 board is the base of the Smart Gateway. Its implementation was complete

ARM Cortex-A8 @ 1 GHz, 4 GB eMMC memory, 512 MB of RAM

SIM card

GPS/GLONASS sensor

IoT wireless interfaces v.1.0: LoRa Concentrator, BLE

Remote connection with Wi-Fi, Ethernet, NB-IoT (5G)/GPRS transceiver

Up to 24VDC power supply

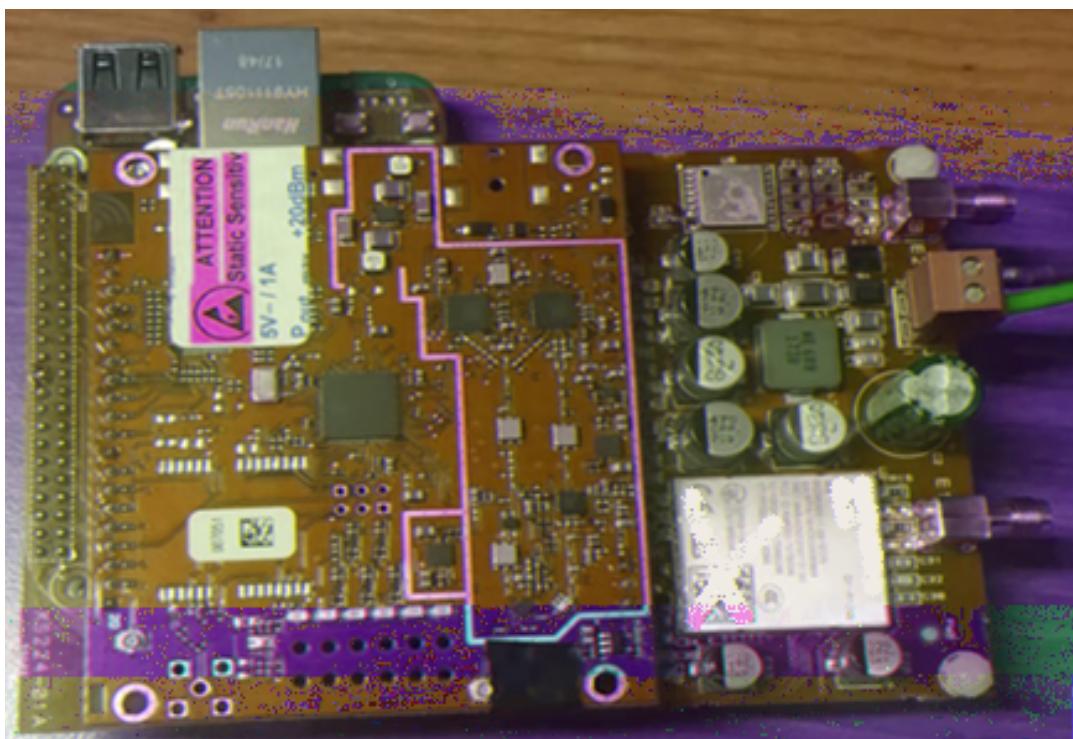


Figure 82 Smart Gateway hardware

9. Conclusions

The ICONET project aims to implement the first prototype of PI to realise efficient and interoperable logistics transactions, thus reducing their cost and their impact on the environment. This report is the direct consequence of D1.6, where the specifications and the general IoT architecture are defined and it concludes the series of three deliverables to report the technical advances regarding the realisation of an IoT environment for the PI: D2.6 and D2.7.

Particularly, the impact of the visionary and innovative IoT architecture, capable to interact with multi-domain networks (logistics, ITS, smart city – being compliant with well-recognised standards) supports the ICONET environment (so the envisioned PI environment), thus allowing seamless and cost-efficient implementation of end-to-end visibility toward the improvement of the efficiency and the proactiveness of the logistics network.

The integration of the mentioned visionary architecture with the Cloud IoT Platform has allowed the realisation of innovative approaches, capable to support the realisation of a smart and proactive PI environments. In fact, analysing the findings highlighted in this report, the innovations generated by the proposed approach can be classified in 3 categories, following the different level of abstraction of the IoT environment:

1. The "Premise layer", where the realisation of the IoT architecture depicted in Figure 2 enables improvement in pervasivity and the interoperability. In this scenario, data exchange and collection with/from other linked domains (i.e., ITS), and an improved granularity in the goods and assets tracking and monitoring are enabled. Such approach gives to PI the capability to monitor, manage and optimise the whole supply chain at different levels, proposing a comprehensive environment capable to monitor goods, encapsulations, assets, means and infrastructure, and transforming these in added value Physical Internet components.
2. The "Analytics layer" aims at implementing in depth analysis of the shipments in terms of efficiency and quality. The analytics layer provides anonymised information derived from the aggregation of the shipments data and features. The output of this analytics component represents the characterisation of the PI network and represents an important support for the PI in the decision making and optimisation paths. In fact, it suggests the main criticalities on the supply chain, regarding the shipments' duration and quality, supporting the PI actions toward their optimisation.
3. The "PI Integration layer" represent the innovative functionalities and services enabled by the smart integration with the higher level PI components. In this scenario, the real data collected and processed by the Cloud IoT Platform (i.e., events, meta-data and statistics) are the main support on the proactive and real time decision making. Proactive routing and assets' visibility and management improvements are enabled by this integration, giving to PI the possibility to have a continuous, complete, and detailed vision of the supply chain. In this manner, PI can improve the optimisation activities intervening directly and continuously on the supply chain transaction, toward their optimisation in term of cost and environmental impacts.

D2.8 aims at reporting the final release of the technical components to satisfy the business requirements (summarised in Sec. 3.1) and to implement the ICONET IoT architecture (see Figure 2), both defined in D1.6. Moreover, it reports how the open, distributed, and interoperable IoT environment supports the realisation of the PI network, seen as a set of independent and distributed PI nodes that interoperate to organise autonomously the logistics network toward its optimisation. In fact, it suggests a set of direction to follow to realise the supply chain complete visibility claim, seen as:

1. An **interoperable IoT environment** where different parties can cooperate implementing different business models. In this scenario, the standardisation framework is analysed, and the ICONET approaches, architecture and the prototypes are positioned within it.
2. An **improved monitoring environment** where goods and their encapsulation are tracked at different granularity. Smart PI Container, Smart PI Pallet and Smart PI packet are defined to monitor the goods and track their encapsulation, as well as monitoring the assets itself. For further detail see Sec. 3.5.1 and 3.5.2.

3. **A scalable and specialised set of monitoring functionalities.** The ICONET IoT architecture allows the realisation of an improved monitoring granularity, enabling the realisation of special and dedicated functionalities on each Smart PI Pallet. This feature allows the implementation of a scalable set of interoperable special devices that represent a scalable set of special functionalities. For further detail see Sec. 3.5.1 and 3.5.2.
4. **Accessible and comprehensible Cloud IoT platform**, in charge of making available the collected data and the processed information to all the user involved in the PI transaction. A secure and ad-hoc access paradigm is implemented to protect the data flows toward the right owners. Big-data analytics is implemented to support the fact-based and data-oriented decision making. For further detail see Sec. 5.4.

This deliverable concludes the set of three advance report regarding the development of IoT technical components capable to enable the aforementioned characteristics for the realisation of the supply chain complete visibility. Each of these components is described in a dedicated section, to provide its definitive features:

- The **Smart Router** oversees providing information about position and time of the Smart PI container, as well as to monitor it internally with a pervasive and ad-hoc sensor network. It is the enabler for the realisation of the improved granularity in the goods monitoring, supporting the definition of the Smart PI Pallet and the Smart PI packet. Moreover, it enables the distributed monitoring, allowing the introduction a scalable set of IoT devices (internal and external the container) capable to collect added value information. The smart router is positioned in the standardisation path as compliant with the requirements with DCSA, ISO and 5G guidelines.
- The **Smart Gateway** oversees managing the connectivity within PI-means and PI-infrastructure. The smart gateway is fully compliant with the specification suggested to realise such type of devices by DCSA standard.
- The **IoT Cloud platform** oversees storing the collected data by the IoT devices, as well as to implement secure and ad-hoc transactions sharing the correct information with the stakeholder involved in a certain supply chain transaction.

From the technical point of view, this report describes the completion of the Cloud IoT platform, the core components to implement interactions between IoT devices in the field and the PI world, toward the improvement and the optimisation of the logistics services. In the following, the final finding related with the realisation of the Cloud IoT platform are listed:

1. Investigate regarding **PI common language**, suggesting interaction models from sensors or toward the users. While in D2.7, we have proposed the exploitation of the generic SensML standard approach to implement a semantic interoperability in the IoT transactions, in D2.8 we consider the general view proposed by DCSA standardisation framework. DCSA is the association of the containers' shippers, and the standard released in May 2020 defines approaches thought by the business stakeholders for the business realisation. At this stage, the technical and syntactic interoperability with this standard is guaranteed, while the semantic is guaranteed agreeing on a set of data models with the other project partners. As future work, we expect the DCSA standard next release to improve the semantic interoperability considering the suggested and standardised the data models (for further details see Sec. 3.4.2 and 3.4.4).
2. **Realisation of a secure and ad-hoc set of APIs to collect and share the data, based on standardised approaches**, implementing high level interoperability techniques, capable to support the forthcoming standard release (e.g., DCSA standard release 2).
3. **Cyber-secure and ad-hoc access**. Data privacy and protection is one of the hot topics in the IoT and Internet domain. In this report we describe our approach considering the standardised approaches currently used in the Internet world to implement secure and ad-hoc transaction from the sensors or toward the PI world. Also in this scenario, we are waiting for the suggestions from the DCSA standard release 3, related to the security and privacy issues. For further details see Sec. 3.4.3 and 3.4.4.
4. **Generation of events derived from the measurement gathered by the IoT devices**. Events represent punctual information extracted from the measurements of the sensors installed on the

IoT devices within the smart container e.g., bump detection, movement detection, threshold exceeding, etc. This information allows to provide advanced service the storage status of the goods all along the supply chain. Introducing the Smart PI Pallet concepts, the local detection of important, dedicated, and special events, without the needs of reconfiguring the whole system. For further detail see Sec. 3.5.1 and 3.5.2.

5. Big data analysis on the data retrieved from the IoT devices generating **high level metadata and statistics** (see Sec. 5.1.3). In this manner, raw data will be transformed in more comprehensible and aggregated information, added value services are provided to the PI users (to increase their satisfaction and trust), a strong instrument to support fact-based data-oriented decision making is provided.
6. Realising an **ergonomics Graphical User Interface (GUI)**, capable to visualise in a comprehensible manner the route and the status of the containers. A **PDF report generator** completes the visual reporting portfolio proposed by the ICONET Cloud IoT platform.

Finally, this report is released with two months of delay because the COVID-19 pandemic that has affected the development, as well as the deployment of the IoT devices on the field. In several points of the report the criticalities introduced by the pandemic are highlighted, as well as the actions to mitigate its impact. The main to highlight is the realisation in cooperation with ITA of a **tool to emulate the IoT devices behaviours**, producing coherent routes and capable to interact with the Cloud IoT platform as the real component.

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