Towards an Integrated System for Global Transport Tracking

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TOWARDS AN INTEGRATED SYSTEM FOR GLOBAL TRANSPORT TRACKING

2023

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

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ABOUT PLANET PROJECT

PLANET project aims at boosting the EU's leadership in global logistics flows **by effectively interconnecting infrastructure with cost considerations, geopolitical developments**, as well as **current and emerging transport modes and technological solutions**, enabling an EU-Global network that ensures equitable inclusivity of all participants, increase the prosperity of nations, preserve the environment and enhance Citizens quality of life.

The realization of this vision in PLANET is branded as the EGTN (Integrated Green EU-Global T&L Network).

Physical Internet concepts in combination with disruptive technologies such as **Internet of Things (IoT)** and **Blockchain** will be used by PLANET to move towards more optimal and efficient transport and logistics (T&L).

Accelerating the collaborative transition towards the Physical Internet in the context of the new emerging trade routes

OBJECTIVES

Project Start	01/06/2021
EU Budget	€ 7 097 670
Instrument	MG-2-9-2019
Duration	36 months
Consortium	33 partners from 14 countries

1. Generate a Simulation Capability for the assessment of the expected impact of new trade routes, national strategies and innovations on the TEN-T corridors and European logistics operations.
2. Built an Open cloud-based ICT Infrastructure facilitating the implementation of EGTNs.
3. **Employ** 3 Living Labs to facilitate experimentation and testbeds for project's solutions.
4. Formalize an EU Roadmap along with a Capacity Building effort purposed to accelerate EGTN realisation, closely aligned with prominent T&L blockchain initiatives and the ALICE Physical Internet working groups.
5. Ensure wide Dissemination supported by a clear Commercialisation Strategy and Policy recommendations.

Executive Summary

We present a conceptual solution for tracking and tracing transportation on a global scale. The approach focuses on defining data flows and formats based on the latest versions of GS1 standards[1]. Importantly, this means that so long as each system conforms to the guidelines, a global solution can be comprised of any number of separate systems that are rolled out over time and the systems can choose which parts of their data to share and with whom. The white paper will thus inevitably focus on some of the technical details because these shared details are crucial to avoid the need for a centralized system that stores and controls all the private data.

In short, the proposed solution focuses on defining shared data formats and flows which allows the system to function as a flexible collection of individual systems that keep control of their hardware, software and collected data.

[1] https://www.gs1.org/standards/how-gs1-standards-work

Introduction

This white paper will present a detailed description of the data flow and formats for a global delivery tracking of goods that can process data from various sensor platforms and aggregate large quantities of data from multiple sources in a useful way. The approach follows closely the official GS1 standards and especially the newly developed EPCIS 2.0[2] and is intended as an application of the standards exactly as they are intended to be used.

The example presented will follow the ordering and transportation of an item across multiple continents and modes of transportation. It is a demonstration of how properly emitted local EPCIS events (i.e. ones that only contain knowledge available at a given location and time) can be combined in a knowledge graph that has global knowledge and allows much more complex tracking and analysis operations.

The goal is to give properly-formatted examples of these EPCIS events. When used according to specification, this will allow various tracking systems to communicate such information seamlessly and in fact the example given could in practice be collected by the IoT devices and tracking systems of several different organizations working together to deliver an item.

[2] https://www.gs1.org/standards/epcis

Objects

The first section of the data is dedicated to giving a list of all identifiers that will be used in the example. The collection of GS1 Standards use quite a variety of identifiers for different objects and we aim to give in-context examples of many of them being used. Giving each object their proper identifier is crucial for the proper interoperability of various systems because communication can only occur if the various systems are in agreement for the identifiers of common objects.

Companies, Certificates and Products

The first identifiers we turn our attention to are the ones for the goods, locations and companies involved in the process. This presentation will focus much more on the transportation process itself but the GS1 standards do specify how to present and share detailed information about the certification and production of goods as well.

GTIN, SGTIN and LGTIN

The Serialized Global Trade Identification Number (SGTIN) and Lot Global Trade Identification Number (LGTIN) are the two forms of unique identifier that can be used for the goods being transported. SGTIN is applied to a whole item while LGTIN is used for goods that are produced and delivered in batches.

Sample 1 shows a json-ld event that identifies the “creation” of an object with a new SGTIN including information about its product type, serial number and date of production.

The creation of an LGTIN is almost identical but uses a batch number instead of serial number. The difference comes in future references to them where an SGTIN is an atomic entity whereas future references to an LGTIN need to include the quantity of items along with the identifier. To simplify our presentation, all further examples will refer to the SGTIN.

Finally, it is worth noting the existence of the Global Trade Identification Number (GTIN) which is an identification number for a product rather than an individual item (or batch of


```
[
 {
  "@id":"<https://id.gs1.org/01/09520123456788"
 },
 {
  "@id":"https://gs1.org/voc/IndividualProduct"
 },
 {
  "@id":"https://id.gs1.org/01/09520123456788/21/12345",
  "@type":[
   "https://gs1.org/voc/IndividualProduct"
  ],
  "https://schema.org/model":[
   {
    "@id":"<https://id.gs1.org/01/09520123456788"
   }
  ],
  "https://gs1.org/voc/gtin":[
   {
    "@value":"09520123456788"
   }
  ],
  "https://gs1.org/voc/hasSerialNumber":[
   {
    "@value":"12345"
   }
  ],
  "https://gs1.org/voc/productionDateTime":[
   {
    "@value":"2021-04-04T22:25:00",
    "@type":"http://www.w3.org/2001/XMLSchema#dateTime"
   }
  ]
 }
]
```


JSON-LD Sample 1: SGTIN description

them). This white paper won't focus on the information contained it its description but it is worth noting that access to detailed GTIN information could also be important for shipping decisions (e.g. perishable, fragile or refrigerated goods, weight and dimensions of item).

GTIN	https://id.gs1.org/01/09520123456788
Product Name	Tomato Juicer Heintz TJ-12
Brand Name	Heintz
Brand Owner	https://id.gs1.org/417/095200000002
Manufacturer	https://id.gs1.org/417/095200000013
Manufacturing Plant	https://id.gs1.org/414/095200001237
Certification	https://id.gs1.org/253/09535600000290000234
Country of Origin	https://example.org/resource/iso3166/CN
Gross Weight	"1.23"^^xsd:double
Category	10002007
Additional Property	Ewr wrwer jjikuio

Table 1: Data in GTIN Object

Table 1 above lists the major pieces of information we can expect to find in a json-ld object describing a product GTIN. The identifier itself we already saw referenced in the description of the item (SGTIN) being shipped but there is a lot of data beyond that. Beyond human readable content, there is much information that could be important for shipping such as gross weight of an individual item, location of the manufacturing plant, country of origin and so on. The GEPIR[3] database is intended to eventually make such information available on a global scale.

[3] **https://gepir.gs1.org/index.php/search-by-gtin**

Company and Factory

Following on from the GTIN description, we can note the table included two company identifiers (Brand Owner and Manufacturer) and a location identifier (Manufacturing Plant). Firstly, the companies are identified by a Party Global Location Number (PGLN) with the infix 417. These kinds of identifiers will be used to specify the sender and recipient of the item but also shippers and transportation companies along the route.

Locations are instead identified with the related Serialized Global Location Number (SGLN). *Sample 2* gives a description of a berth within a larger harbor including its precise coordinates and a larger entity it is contained within.

In general, SGLNs can identify physical locations of any size- from a whole international port or city to a specific warehouse or even loading dock. They are important because the coordinates they have allow the connection between the abstract steps of the shipping process and the coordinate readings of sensor platforms.

```
[
 {
  "@id":"https://id.gs1.org/414/6991230000137",
  "@type":[
   "https://gs1.org/voc/Place",
   "http://example.org/BoatBerth"
  ],
  "https://schema.org/name":[
   {
    "@value":"Berth 123 at Guangzhou port"
   }
  ],
  "https://gs1.org/voc/globalLocationNumber":[
   {
    "@value":"6991230000137"
   }
  ],
  "https://gs1.org/voc/geo":[
   {
    "@id":"geo:23.0,113.5"
   }
  ],
  "https://schema.org/containedInPlace":[
   {
    "@id":"https://id.gs1.org/414/6991230000124"
   }
  ]
 }
]
```

JSON-LD Sample 2: SGLN description

Certification process

Finally, its worth nothing that GS1 standards also make provision for describing certifications of varios kinds. This includes both certification of the products (GTIN) themselves and the factories (SGLN) producing them. The GS1 Global Data Synchronisation Network (GS1 GDSN)[4] is intended as the global repository for detailed certification details. Certificates will not tie-in with our demonstration of the power of GS1 standards in shipping but they are a tie into the wider world of goods manufacturing and ordering.

[4] https://www.gs1.org/services/gdsn

Assets

All physical objects used in the process of shipment and transportation fall under the wide class of assets which is broken down into two types of identifiers- The Global Individual Asset Identifier (GIAI) and The Global Returnable Asset Identifier (GRAI).

Asset	Id Type	Id
Sensor Platform	GIAI	https://id.gs1.org/8004/EF:65:5A:8D:73:97
Truck	GIAI	https://id.gs1.org/80030123456789110D5D1B817F818
Crate	GRAI	https://id.gs1.org/8003/00952000000150000123
Container	GRAI	https://id.gs1.org/8003/00000000000000000000

Table 2: Asset Identifiers

Several important objects in our example are different kinds of assets including sensor platforms, all forms of vehicles (e.g. freight train cars, container ships, trucks), crates and containers. Some demonstration identifiers that will be used in following samples are presented in *Table 2*.

Logistic Units and Deliveries

The final class of GS1-defined objects used in our integrated transport example are not related to physical objects but rather the logical or administrative steps of the transportation process. At its heart lies the Serial Shipping Container Code (SSCC) also known as a logistic unit. It is a grouping of items (SGTIN, LGTIN or constituent SSCCs) treated as a single virtual object for the purposes of transport and storage.

The logistic unit is the crucial connection between a package's trip and the raw data provided by various sensor platforms.

Beyond the logistic unit, we also have Global Identification Number for Consignment (GINC) and Global Shipment Identification Number (GSIN). These are both groupings of logistic units, the difference being that GINC defines a group of SSCCs combined for transport purposes i.e. travelling together (e.g. on the same ship) while a GSIN is a grouping based on business logic i.e. a delivery between consignor and consignee sent in multiple parts (logistic units) but a single shipment. In our example we will briefly consider the connection between GSIN and SSCC but we mostly focus on tracking logistic units. The approach can just as easily used to track consignments instead (since they are in the same physical location) or the constituent parts of a shipment (that may or may not be travelling together).

Sensors and Readings

A major update with the release of EPCIS 2.0 is the completely integrated representation of sensor readings within the standard. It now supports a consistent format for detailed description of sensor devices that don't simply provide readings but do it in a self-describing way that allows other systems to reuse it.

Each sensor reading is a single json-ld object of the ObjectEvent type with the OBSERVE action. *Sample 3* shows a simple minimal example of such a sensor reading.

At a glance from the perspective of receiving frequent periodic readings from a sensor, it looks like there is a lot of overhead for what are essentially a few new numbers and indeed much of this information will be repeated with each reading emitted in this format. This means that for storage and processing purposes, the actual readings should indeed be treated as a "simple" time series. This format, however, is intended for communication between disconnected systems.

The self-describing aspect of the data means that each OBSERVE event contains all data required to understand the contents of that report. This means that the format supports seamless stitching of data between multiple disconnected systems as well as piecemeal deployment and modification of IoT devices in all circumstances. This makes it an absolute necessity for stable interoperability between independent solutions and allows a global rollout for solutions without ever losing any historical data.

```
{
"type":"EPCISDocument",
 "schemaVersion":"2.0",
 "creationDate":"2022-10-04T09:55:36.882093",
 "epcisBody":{
  "eventList":[
   {
    "type":"ObjectEvent",
    "action":"OBSERVE",
    "bizStep":"cbv:BizStep-sensor_reporting",
    "eventTime":"2022-10-04T09:55:25+00:00",
    "sensorElementList":[
     {
      "sensorMetadata":{
       "deviceID":"gs1:EF:65:5A:8D:73:97"
      },
      "sensorReport":[
       {
        "type":"gs1:Temperature",
        "value":26.17,
        "uom":"CEL"
       },
       {
        "type":"gs1:Latitude",
        "value":39.4567,
        "uom":"DD",
        "component":"cbv:Comp-latitude"
       }
      ]
     }
    ]
   }
  ]
 }
}
```

JSON-LD Sample 3: Sensor Reading

Figure 1 shows the connection between the constituent elements of the sensor reading event. An IoT device is a kind of sensor platform which is the catch-all category for all devices collecting time series readings of values from the world. Some other kinds of sensor platforms are weather stations, security panels and drones.

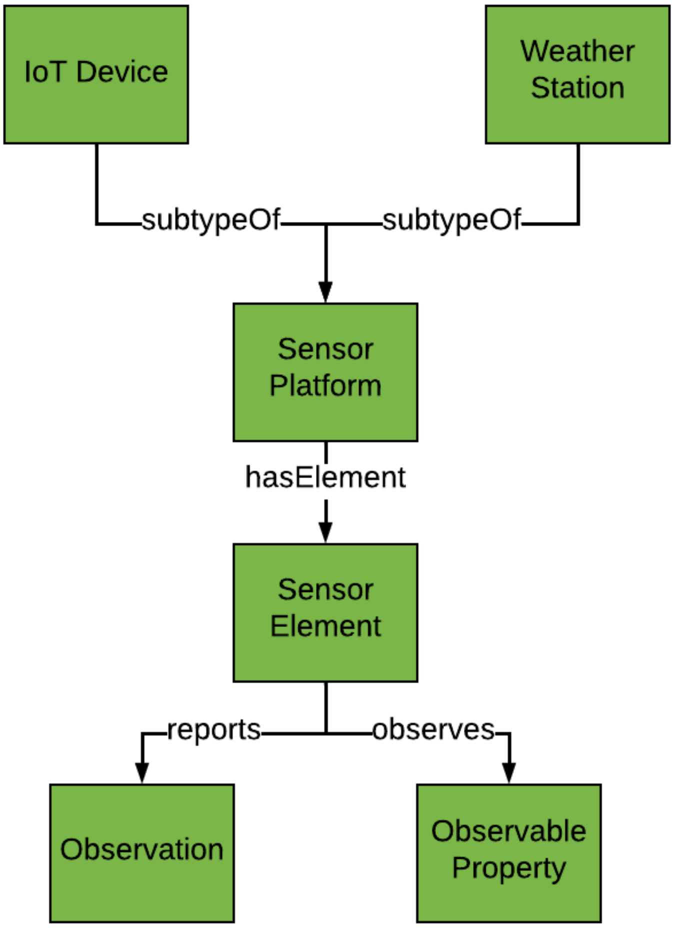

Figure 1: Sensor Reading Structure

IoT device is itself a rather broad category and beyond expecting geolocation, we cannot be certain what particular sensors will be available in each. That is why the example extends with the list of sensor elements that each report what property they are recording and what units its being measured in. GS1 already allows for a variety of typical measurements but custom ones can easily be defined when required.

Time series and Regular Readings

Going back to the contents of *Sample 3*, It is worth considering what common sensor elements might be expectd in IoT tracking devices:

- Battery.
- Longitude & Latitude.
- Altitude.
- Acceleration (3D).
- Temperature.
- Humidity.
- Luminance.

The model is very flexible and not only covers all common sensor types but allows easy extension with custom formats.

> ***IoT devices commonly have capabilities that go well beyond simple tracking of geolocation.***

While our example focuses on the basic tracking aspect, everything presented works equally well for ensuring storage at appropriate temperature for refrigerated goods, identifying rough handling of fragile cargo, opening of container doors in border inspections and much more. These kinds of capabilities can be leveraged in different valuable ways such as getting warnings of accidents and physical inspection of goods and proving compliance with delivery contract specifications for handling.

Exceptional Readings and Alarm Conditions


```
{
 "type": "EPCISDocument",
  "schemaVersion": "2.0",
  "creationDate": "2022-10-05T10:00:00.000000",
  "epcisBody": {
   "eventList": [
    {
     "@type": "epcis:AssociationEvent",
     "epcis:action": "ADD",
     "epcis:bizLocation": {
      "@id": "gs1:414/095200001237"
     },
     "epcis:readPoint": {
      "@id": "gs1:414/095200001237/254/235"
     },
     "epcis:bizStep": {
      "@id": "cbv:BizStep-assembling"
     },
     "epcis:disposition": {
      "@id": "cbv:Disp-in_progress"
     },
     "epcis:parentID": {
      "@id": "gs1:8003012345678911100D5D1B817F818"
     },
     "epcis:childEPCs": {
      "@id": "gs1:EF:65:5A:8D:73:97"
     },
     "epcis:eventTime": {
      "@value": "2022-01-01T00:00:00.000+00:00",
      "@type": "xsd:dateTimeStamp"
     }
   ]
  }
}
```


JSON-LD Sample 4: Sensor Install

In fact, EPCIS 2.0 supports the addition of alarm conditions and custom triggers to readings that can identify extreme events:

- Bumps such as dropping, crashing, rough seas
- Exceedingly high or low temperatures.
- Exposure to light such as door opening.

Each of these can be important both as alerts at the time they are detected, as information about events that happened during shipping after receipt and as aggregate historical data that analyze conditions on a given route.

Finally, there is the question of actually creating the connection between a sensor platform and an asset in which it is installed. This is an AssociationEvent with the ADD action denoting installation and the DELETE action indicating removal. *Sample 4* shows the installation of a new sensor on a truck.

Transportation Steps

With the understanding of the various objects represented by GS1 identifiers and the data emitted by any deployed IoT devices, we turn our attention to the major steps of the transportation process and how they are represented as EPCIS events.

Here we will consider the information we expect to collect from various systems and devices along the route of a package over the course of its trip from its initial sender to its final delivery. The workflow presented is a somewhat simplified example but does cover switching between multiple forms of transport and combining tracking data from multiple sensor platforms along the way.

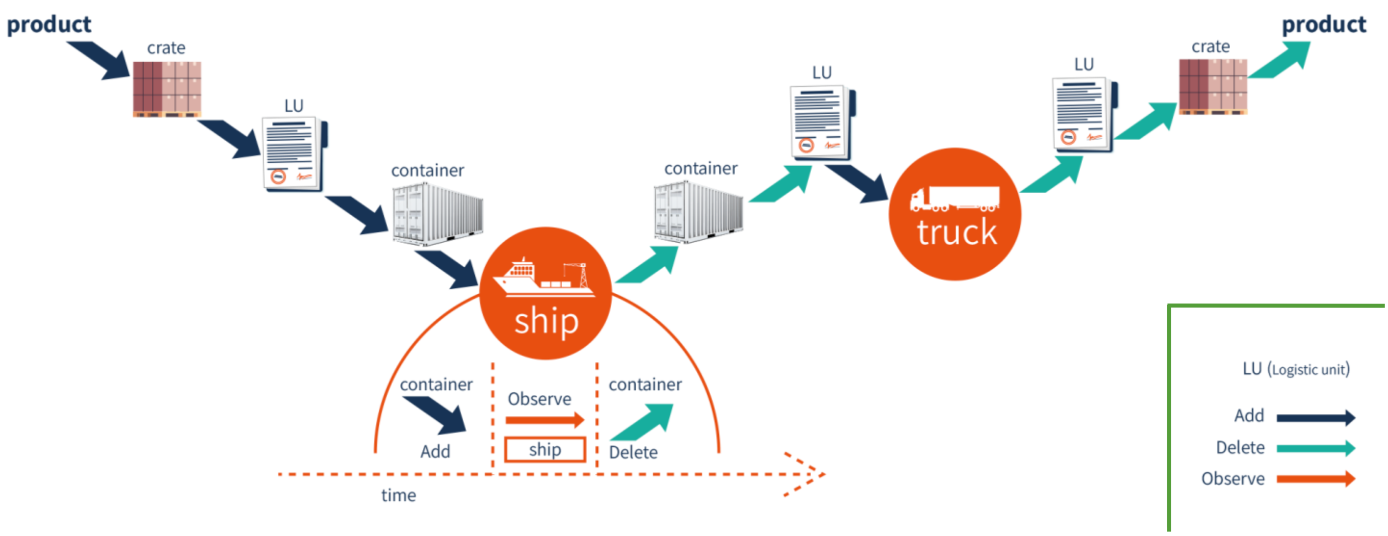

Figure 2: Transportation Steps

Figure 2 visualizes the following steps, each arrow corresponds to a transition represented as an EPCIS event:

1. Shipped item (SGTIN/LGTIN) is put into a crate for transportation (GRAI).
2. A logistics unit (SSCC) for the trip of the crate from source to destination is created.
3. A number of logistic units are combined and loaded into a container (GRAI).
4. The container is loaded on a ship (GIAI) for transportation.
5. The containers are offloaded from the ship at a berth of the harbor.
6. The container is unpacked at the shipper warehouse in the harbor.
7. The logistics unit is loaded onto a truck for delivery from the warehouse.
8. The logistics unit is offloaded from the truck at the destination.
9. Having reached its destination, the logistics unit is done.
10. The item is extracted from the shipping crate.

As indicated blue arrows are ADD actions which correspond to creating, combining or packaging items. The green arrows are DELETE actions which are the inverse- breaking connections. In orange are the OBSERVE actions emitted by IoT devices- in this case we are saying there is a separate IoT device installed on the ship and truck each but as deployment becomes more common, we can expect containers and even individual crates to have their own IoT devices emitting data.

Packages and Assets

One major kind of event in our example is loading (and unloading) items in an asset. This can mean putting items in a crate, putting the physical items constituting a logistics unit into a shipping container or loading up a cargo vehicle such as a truck or container ship.

Sample 5 is an AggregationEvent ADD that describes putting a single object in a crate but the structure of these events is the same in all cases. The childEPCs is a list of objects being loaded (SGTIN, LGTIN, SSCC, etc.) and the parentID is the GIAI or GRAI of the asset that they are being loaded on. The knowledge of what that asset actually is comes from elsewhere, the ADD and DELETE AggregationEvents simply specify the time frame in which the objects were in the asset. Tying this back to the discussion on SensorPlatform installation, we can now see how we combine this knowledge with the knowledge of which sensors are associated with the asset over this time frame to make the connection between the items being transported and the sensor readings.


```
{
"type": "EPCISDocument",
  "schemaVersion": "2.0",
  "creationDate": "2022-07-29T14:00:00.000000",
  "epcisBody": {
   "eventList": [
    {
     "@id": "ni:///sha-256;01?ver=CBV2.0",
     "@type": "epcis:AggregationEvent",
     "epcis:action": "ADD",
     "epcis:bizLocation": {
      "@id": "https://id.gs1.org/414/095200001237"
     },
     "epcis:readPoint": {
      "@id": "https://id.gs1.org/414/095200001237/254/235"
     },
     "epcis:bizStep": {
      "@id": "cbv:BizStep-assembling"
     },
     "epcis:disposition": {
      "@id": "cbv:Disp-in_progress"
     },
     "epcis:parentID": {
      "@id":
"https://id.gs1.org/8003012345678911110D5D1B817F818"
     },
     "epcis:childEPCs": {
      "@id": "https://id.gs1.org/01/01234567891231/21/05001"
     },
     "epcis:eventTime": {
      "@value": "2022-10-04T07:30:00.000000+01:00",
      "@type": "xsd:dateTimeStamp"
     },
     "epcis:recordTime": {
      "@value": "2022-10-04T07:30:00.000000+01:00",
      "@type": "xsd:dateTimeStamp"
     }
    }
   ]
  }
}
```


JSON-LD Sample 5: Put Item in Crate

Logistics Units – Use and Span

Once an item or asset is ready for transportation, a logistics unit needs to be created.

> ***The logistics unit represents a single complete trip and exists for the time it takes the asset to move between the origin and destination.***

Sample 6 demonstrates an event that creates a new SSCC which corresponds to step 2 in our example. It is an ObjectEvent ADD because it is the creation of a (virtual) object and has a corresponding ObjectEvent DELETE in step 9 when the trip is completed. It is worth keeping in mind that logistics units can be indirectly nested e.g. a crate has an SSCC which is loaded in a container which receives its own SSCC for the specific trip. To simplify things we've omitted these from the example but it is worth keeping in mind that in practice there might be additional logistics units for the container and truck trip that have shorter lifespans than the one we're tracking.


```
{
 "type": "EPCISDocument",
 "schemaVersion": "2.0",
 "creationDate": "2022-10-05T10:24:36.287315",
 "epcisBody": {
  "eventList": [
   {
    "@type": "epcis:ObjectEvent",
    "epcis:action": "ADD",
    "epcis:bizStep": {
                    "@id" : "cbv:BizStep-commissioning"
                  },
    "epcis:eventTime": {
                    "@value" : "2022-10-04T07:30:33+01:00",
      "@type": "xsd:dateTimeStamp"
                  } ,
    "epcis:readPoint": {
      "@id": "geo:45.7502535,4.8539748"
    },
    "epcis:disposition": {
                    "@id" : "cbv:Disp-in_progress"
                  },
    "epcis:parentID": {
                    "@id" :
"https://id.gs1.org/00008012349999900016"
                  },
    "epcis:childEPCs": [
                    {
        "@id" :
"https://id.gs1.org/8003012345678911110D5D1B817F818"
                    }
    ]
   }
  ]
 }
}
```


JSON-LD Sample 6: Create Logistics Unit

Now there is also the matter of consignments and shipments and their relation to logistics units. As mentioned in the section on **Objects**, consignments are combinations of logistics units beind transported together and for practical purposes function in an almost identical way. The difference is that a logistics unit is made up of assets (typically reusable assets) while a consignment is made up of logistics units. Shipments will be discussed in more detail in the next section but for our purposes they are mostly just lists of concpetually related logistics units that still need to be tracked separately.

Data Interface and Reasoning

With this, we have seen samples for the types of EPCIS 2.0 json-ld events that make up the steps of the transportation process of a global scale. The final question is how is this all combined to result in a functioning system that can answer useful questions because missing any one of the crucial connections could result in no knowledge being available.

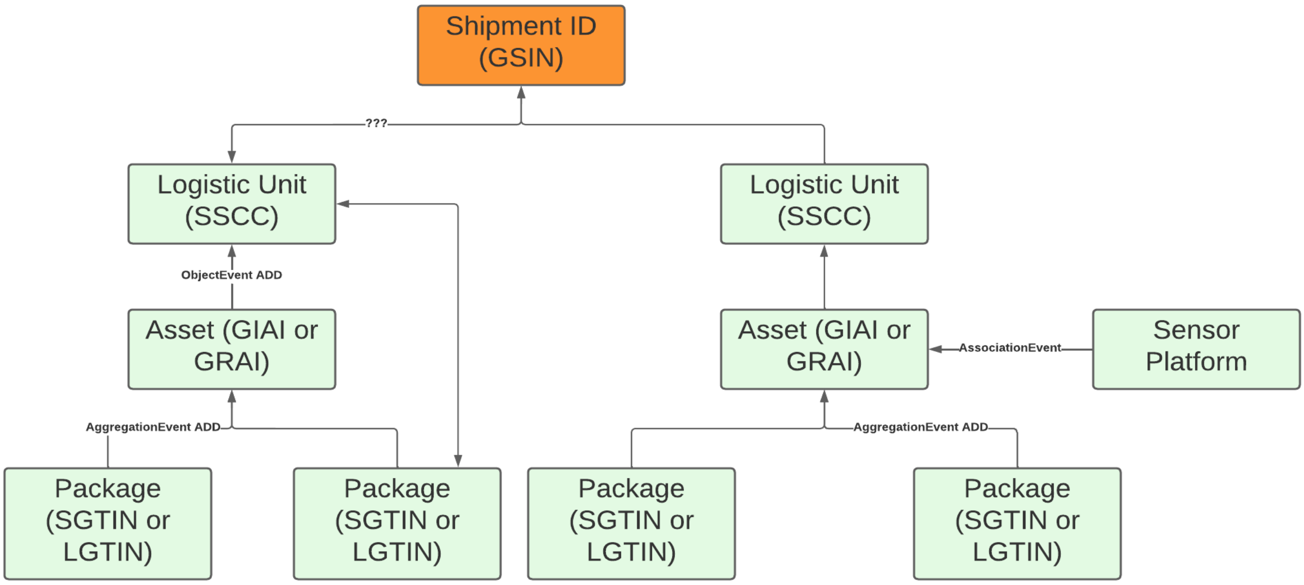

Figure 3: Connections between identifiers

Figure 3 shows the connectons between some of the objects we've discussed. In it we can see both the direct connections coming from the EPCIS events we've seen- SGTIN to GRAI, GRAI to SSCC, SSCC to GIAI, GIAI to GIAI. The key here is to actually infer historical knowledge about the trip from them and there are two important questions.

Firstly, for any package (SGTIN/LGTIN) or shipment (GSIN) being tracked, what are the corresponding SSCCs. For shipments this is quite straightforward but for a package we need to actually infer what SSCC was assigned to its asset at the time of transportation.

Secondly, for any given SSCC, which sensor platforms (GIAI) were tracking its movements at what part of its transit. This can be very straightforward if sensor platforms are only installed once and never moved but the system can work just as well if sensor platforms are moved, replaced, upgraded and so on. The question really becomes, what sensor platform was installed in its associated assets at the time the trip occurred.

Having built the connection between shipped item/shipments and sensor data, the system is actually capable of providing access to fully integrated data such as:

Given an SGTIN, what are the corresponding sensor readings for its full trip?

Given a multi-part shipment, where are each of the parts right now?

So answering those questions requires simply following the inferred connection from SGTIN to SSCC or GSIN to list of SSCCs respectively, from SSCC to GIAI of sensor platform and then request the corresponding sensor readings for that platform.

Conclusion

In summary, here we presented a proposed approach to developing a global solution for tracking and tracing transportation of goods. The approach follows the intended application of the GS1 standards, especially the recently released EPCIS 2.0 and covers not just the physical assets (containers and vehicles) and administrative objects (logistics units, shipments and consignments) related in transporation but also ties into companies, locations and certification.

The solution relies on strictly following a shared data flow and event description format but allows great flexibility in combining physical devices, software services and data collections by different entities. In fact, one of the major advantages of this approach is that there is no need for a central system that has access or control of any of the collected data which means that each company has full control over what and with whom it chooses to share.

Authors and main contributions

Andrey Tagarev (Sirma AI trading as Ontotext)

Alicia Enríquez Manilla (Fundación Valenciaport)

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About PLANET

PLANET addresses the challenges of assessing the impact of emerging global trade corridors on the TEN-T network and ensuring effective integration of the European to the Global Network by focusing in two key R&D pillars:

- A Geo-economics approach, modelling and specifying the dynamics of new trade routes and their impacts on logistics infrastructure & operations, with specific reference to TEN-T;
- An EU-Global network enablement through disruptive concepts and technologies (IoT, Blockchain and PI, 5G, 3D printing, autonomous vehicles /automation, hyperloop) which can shape its future and address its shortcomings, aligned to the DTLF concept of a federated network of T&L platforms.

Contact

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https://www.planetproject.eu/