Cognitive Logistics Operations through Secure, Dynamic and ad-hoc Collaborative Networks: The COG-LO project

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Abstract: This paper outlines the approach followed by the H2020 COG-LO project to realize ad-hoc logistics collaborations. The main goal of COG-LO project is to introduce the concept of Cognitive Logistics Object (CLO): a *virtualized entity that participates in the logistics process, represents different actors such as parcel, truck, traffic light, supporting systems, etc. (depending on the case) and has a different capabilities (from basic functionalities up to autonomous decision making and actuation), which are configured per case.* In the context of COG-LO, a CLO will have different cognition capabilities, will be able to form ad-hoc collaborations by communicating with other CLOs using Social Networks of CLOs and negotiate optimal solutions in response to a particular event. The project will offer the necessary ICT services and demonstrate different collaborative models in both the Post Industry and Logistics Operators.

Keywords: *Cognitive Logistics, Social Internet of Things, Load Factor Optimization, ad-hoc Collaborative Logistics*

1 Introduction

Industry4.0 is a fact. The evolution of IoT and CPS technologies combined with big data analytics will change dramatically the way manufacturing and supply chain is organized. As supply chains are being more digitized, Logistics operators and all stakeholders have to embrace latest technologies in such a way that can achieve ease of access, quick information processing, security, and, most importantly, all of this in one place (TransEU, 2017). According to a Deloitte study (Lacey M. et. all (2015), the Internet of Things paradigm offers a variety of solutions that can cater for improved processes monitoring, optimization and response to changes/events. Such solutions can improve both the Logistics supply and demand processes. Planning, route optimization, capacity sensing (the ability to detect open spaces in a warehouse, port or parking lot), traceability and improved planning are some of the offered qualities/services of these innovative solutions. The same [Deloitte] report points out that **Logistics4.0** can positively influence companies to improve their Logistics operations.

1.1 Logistics4.0 challenges

COG-LO tries to tackle the issue of ad-hoc collaborations and response to different events once a delivery has started. Our approach was based on the below challenges and market needs:

Challenge#1: Load factor and dynamic response to events /ad-hoc orders: Ad-hoc requests and unexpected events pose the need for more flexible logistics processes. In average, ~25% of the total delivery requests for EKOL Logistics (operating in Turkey and whole EU) is on the fly. This can be caused due to the dynamics of the market (e.g. customers with potential urgent deliveries such as medical, critical mechanical/electric parts, unexpected returns, etc.). Also last mile deliveries can be affected by traffic status as well. The result is late deliveries, which can lead to customer dissatisfaction and poor quality with implications also on critical contracts and SLAs. *Flexibility* in such case is of utmost importance. This is more important if we combine it with the load factor optimization. According to EKOL figures, the load factor varies from 15% in Latvia to 83% in Ireland. Logistics operators should be able to (re)schedule or re-plan (using different means) their deliveries making use of data generated by unexpected events (weather, external factors affecting the deliveries), missed deliveries (due to the absence of the recipient for example), traffic status, etc. This includes also decision-making capabilities with regards different and multi-modal delivery scenarios. Also *consolidating (merging) deliveries* can be a solution to this: how to collaborate and merge/consolidate deliveries in response to ad-hoc requests, in such a way that load factor, run empty rate and in general, resources utilization will be optimized.

Challenge#2: The growth of ecommerce and Cross-country deliveries: Globalization is increasing the level of cross-border e-commerce. This is evident considering that - according to DHL report (DHL, 2017) - *thanks to logistics networks and off-the-shelf solutions cross-border is easier than many think*. Nevertheless, inefficient cross-border delivery is consistently in the top three of biggest barriers for online merchants to sell in another EU Member State, as Ecommerce Europe’s Cross-Border E-commerce Barometer 2016 (eCommerce, 2016), already showed in the past: logistics and distribution represent a difficult barrier to tackle for 33% of the companies selling abroad. This implies a synchronization of the cross-border deliveries with the involvement of all stakeholders. *Logistics Operators should agree on common information models and processes* in order to achieve smooth information processing along the delivery processes and traceability from all involved stakeholders. Whereas common information models have been introduced in various EU projects (e.g. EURIDICE, iCarco, e-Freight), *the main challenge is how to exchange such information over secure and private networks that will allow for better and collaborative decision making.*

Challenge#3: New collaborative models integrating the Digital and Physical Internet: In a recent study by CapGemini (CapGemini, 2016), it is argued that supply chains will transform from the isolated/atomic model to a more collaborative one. Currently, *supply chains are characterized by little level of collaboration, scattered approach and every stakeholder owning its business.* Logistics4.0 combined with the high involvement of consumers/ customers at the early stages of the supply chain poses the need of a *new future collaborative model*. According to the same study (CapGemini), the main characteristics of this future model will incorporate consolidation centres, multi-partner information sharing among key stakeholders; and consolidated deliveries using efficient assets. This model-scenario also complements with the issue of merging deliveries on the fly (see Challenge#1) where integration of physical goods happens dynamically in a way to optimize load factor, deliveries and further operation costs. This new trend will lead to the *integration of both Digital and Physical Internet.* This extends beyond digital information sharing and optimization, where all Logistics stakeholders should work on (collaborative) physical integration that maximize the benefits to the end users.

1.2 Contribution and Structure of the Paper

The above challenges are the focus of the H2020 COG-LO project (www.cog-lo.eu). The main goal of the project is to create the necessary framework and tools that will enable future logistics processes to become cognitive and collaborative-interoperable by:

- adding cognitive behaviour to all involved Logistics Operation "objects" (freight, transportation means, systems, etc.), referred to as CLOs (Cognitive Logistics Objects) and
- developing the necessary communication and interoperable environment that will allow those cognitive objects to communicate with each other and share information through secure ad-hoc networks.

To achieve this, the project will offer the following:

- **New cognitive cargo-centric multi-modal transport models:** The project will formalize and model both the operational and system models, which will utilize the new concepts of Cognitive Logistics Objects, Cargo Hitchhiking and Cognitive Advisor. Those models will enable for more flexibility, improved decision making and ad-hoc collaborations.
- **A reference model for future Cognitive Logistics behavior:** This model will provide the necessary knowledge base & capabilities to achieve certain cognitive behaviour of Logistics objects. To achieve this, the project will integrate concepts from the areas of Cognitive Systems, Integrated Reasoning and Learning from local contexts.
- **Artificial Intelligence and data analytics tools with the necessary APIs,** enabling complex event detection, context awareness and decision support at both local and global level, as well as global reasoning, including understanding, assessing alternative and acting. Processing data will include multi-modal sources, structured, unstructured, and real-time data streams.
- **A comprehensive framework for security, privacy and trust,** that will ensure the inherent incorporation of these concerns in the COG-LO systems and operations in a by design fashion and in accordance to the associate regulations, particularly the GDPR. To this end, all appropriate mechanisms of *access and usage control and advanced cryptography* will be employed, considering data ownership, handling policies, and scalability, whereas a *blockchain infrastructure* ***will foster for*** *traceability, transparency and trust.*
- **A collaboration platform powered by Social Internet of Things:** COG-LO will put in place an infrastructure fostering ease of access to the underlying functionality by large logistics operators, SMEs and other stakeholders, enabling their seamless operational integration. This will be achieved through an innovative interaction framework based on dynamic ad hoc social networks referred to as the Social Internet of Things (SIoT). SIoT will allow CLOs to interact and "negotiate" potential alternatives/solutions considering their existing status/needs and exceptions identified.
- **Tweeting CLOs tool:** This will allow CLOs to exchange information in hybrid ad-hoc Social IoT networks about their status and possible needs for collaboration (e.g. opportunities for optimal loading & re-routing in case of exceptions).
- **Cognitive Advisor tool,** which realizes the cognitive behaviour of CLOs based on the reference implementation model.

The rest of the paper is outlined as follows. Section 2 describes the overall cognitive and collaborative logistics framework introduced by COG-LO, followed by the corresponding operational model (Section 3). A brief description of the COG-LO architectural aspects is provided in Section 4, whereas Section 5 outlines the three project pilots. The paper concludes with an outlook about the project innovation potential and anticipated market benefits.

2 The Cognitive and Collaborative Logistics Framework

COG-LO introduces a set of concepts, technological approaches and business models that will help the logistics, ecommerce community to adapt to the dynamics of their operations and improve collaboration. The main principles of COG-LO are illustrated in Figure 1.

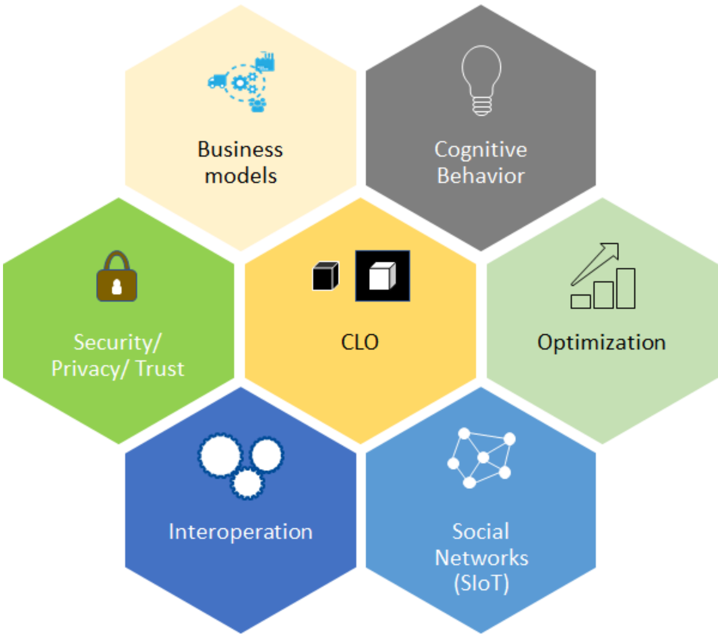

Figure 1: Cognitive Logistics

2.1 The Cognitive Logistics Object (CLO)

At the heart of the framework is the CLO. *A CLO is a* ***virtualized entity*** *that participates in the logistics process, (digitally)* ***represents different actors*** *such as cargo, truck, traffic light, supporting system, etc. (depending on the case) and* ***has a different capabilities*** *(from basic functionalities up to autonomous decision making and actuation), which are* ***configured per case.***

If we try to elaborate on this concept, we have to analyse the main characteristics of the CLO:

#1: A CLO represents different actors in the logistics process*:* COG-LO has a distributed approach: it tries to digitize all involved actors and provide them with capabilities/ services that will allow them to exchange information, understand the context, communicate each other and each other and finally, assess the best alternatives in case of event. Such actors can be:

- The cargo at different hierarchical levels: parcel, palette. Container, etc.
- Transportation means (vehicles, trucks, trains, etc.)
- Supporting services/ICT infrastructure: backend solutions, ERP, warehouse management systems, traffic information systems, ITS, etc.
- Other actors such as: Hubs, parking places, e-shops, ports, etc.

#2: A CLO is a virtualized entity of all involved actors: Following the concept of Digital Twins the CLO will be a digital representation of the above actors (configured per case) in order to participate in different collaborative networks and actions.

#3: A CLO has different capabilities: the main advantage of Digital Twins is that in COG-LO we will be able to provide them different capabilities that represent actions/services and its behaviour in the context of the operations that participate. Those capabilities are the following:

Table 1: CLO capabilities

Capabilities	Explanation
Identification	I have an ID (Barcode, RFID) and I am identifiable
Receive information	Get information (read)
Send information	Sends information
is searchable	is searchable by other CLOs in the context of a social network of things
Specify range	Specify range for the social network to search for other CLOs
Basic processing	Basic calculations and processing: Check against rules, transform measures, etc.
Actuation	Initiating a service or action; example: I can initiate the process of rent a space in a parking slot.
Self-Awareness	I know my status: I know my position, my load factor, which information should I send, what I need for decision making, etc.
Sensing	I can get information relevant to me;
Search other CLOs	I can search for other CLOs in a specific range
Tweeting	I can talk with other CLOs
Decision making	Advanced information processing: Optimization, simulation, etc.

As seen in the table above, a CLO can have capabilities spanning from some basic functionalities (read-send) up to more sophisticated (self-awareness and decision-making).

The cognition is a set of capabilities that enables CLO to understand the information processed and/or contextual awareness, to process decision making as a collaborative part of common infrastructure.

#4: A CLO is configurable per case: It is up to the customer and based on the business/operational model to assign the level of intelligence and cognition in each of the participating CLOs. This approach allows flexibility and different configurations at pilot sites. For instance, in the ELTA urban pilot case, where a parcel is placed into a picking box and the box has to send the request to be picked up, the parcel has some basic functionalities (send information). In other cases, a van can be “cognitive” thus able to understand its status and “alter” behaviour by “talking to other CLOs”. In the following sections (pilot deployments), we present the different CLO definitions and capabilities assignments based on the different business models.

COG-LO will provide the necessary tools to allow for Digital virtualization of all assets. Also will allow the system administrator will assign a set of capabilities thus enabling different configurations per case.

2.2 Business Models

Business models drive the behaviour of the system. it starts with the vision of how the company want to improve itself, given the challenges, opportunities and dynamics of the environment that operates into. In Deliverable *D2.1 - Business cases definition and scope analysis (draft-version)* we have identified the main drivers for changing the exiting model into more collaborative and digitized logistics processes. Such business models can be (COG-LO D2.1)

- Same day delivery
- Faster delivery
- Last mile logistics
- Crowd-logistics
- Regulated postal operations
- Other

Each one of the above has its particularities, constraints, dynamics and requirements both from process reengineering and digitization perspective. Business models define the strategic priorities and criterial for decision-making (SLAs, priorities, etc.). The applicable regulation and legislation is also an important factor that needs to be considered. For example, in the postal industry an important parameter is that postal offices *are obliged* to deliver any parcel irrespective of the distance in the country as a result of a highly regulated domain. This imposes a lot of trigger points (events by which the system will initiate), constraints, SLAs, potential decisions (based on the company's policies) and other factors that have to be considered in a decision making (optimization process).

COG-LO will provide a set of interfaces to model the process, the constraints, rules and characteristics of the pilot case. Different KPIs, priorities will be modelled for the optimization algorithms. Also, the system administrator will be able to model the whole workflow, the different events and potential decisions.

2.3 Social Networks of CLOs - Social Internet of Things (SIoT)

A distributed infrastructure, which is responsible for discovering and managing the social-like relationships between CLOs. The CLO (truck, warehouse, Parking spot, etc.) are potentially able to participate in communities of objects, create groups of interest, and take collaborative actions, joins different ad-hoc social networks (formed in a geographical range) and broadcasts the public information to the rest CLOs (belonging to the ad-hoc social network) in a secure way. For example, the vehicle publishes its specific information about the vehicle's status (what is being carried, destination, load status, etc.

By augmenting CLOs with the social dimension, two major advantages can be achieved:

- An overlay network can be built having the typical features of social networks, i.e., it is navigable and has a small diameter.
- Interactions are preferred between CLOs that are neighbours and more trustworthy.

The actor owning a certain CLO will set the policies that the CLO will implement to establish and maintain the social-like relationships. This is needed to allow users of the COG-LO platform to control the flow of their private information so guaranteeing an acceptable level of privacy, contributing to the overall by design data security and privacy approach of COG-LO.

The following are possible types of relationships:

- *Ownership Object Relationship:* is created between CLOs that belong to the same owner.
- *Co-location Object Relationship:* is created between stationary devices located in the same place (this is also called co-geolocation).
- *Parental Object Relationship:* is created between CLOs of the same model, producer and production batch.

- *Co-work Object Relationship:* is created between CLOs that meet each other at the owners' workplace, as the laptop and printer in the office.
- *Social Object Relationship:* is created as a consequence of frequent meetings between CLOs.

All these social links are created on the basis of the profile of the objects (such as type, active services, installed applications), their activities (such as geographical mobility and transactions carried out) and the characteristics of their owner (such as his/her friendships relationship). It is then of paramount importance to implement the needed functionalities to verify that certain circumstances that bring to the establishment of new friendships occurred. In the resulting social network, every object looks for the desired service by using its relationships, querying its friends and the friends of its friends in a distributed manner; this procedure guarantees an efficient and scalable discovery of CLO and services following the same principles that characterize the social networks for humans.

2.4 Cognitive behaviour

It is a continuous and dynamic process for:

Modelling: Modelling the state of the infrastructure and a real-time observable digital object. It includes modelling the CLOs with different categories and properties, their interrelationships, dynamic parcel inflow and distribution objects with general and localized constraints. Processing these heterogeneous data enables real-time digital state evaluation/representation as a baseline for higher-level cognitive services operation. The infrastructure is represented as a digital graph, with dynamic parcel flow to be operated on.

Monitor: Real-time data, such as ad-hock events and final actions taken by execution CLOs are monitored and processed for real-time assessment of infrastructure state. The updates on current CLOs and relationships are processed to enable updated baseline for events categorization, constraints definition and evaluation of eligible CLOs for local decision-making evaluation.

Understand and Reason: Formalized knowledge base with dynamic knowledge enricher. The basic ontology knowledge base offers definition of basic domain concepts while knowledge enricher enables augmenting the basic knowledge base with additional concepts from web accessible document corpora (such as Wikipedia), as a context rich knowledge representation services.

Negotiate and decision-making: Communicates constraints and activities to be executed with SIoT on the level of executable CLOs (pickup/delivery vehicles). While obtaining additional real-time data, final decision is made based on global constraints of the event and local optimization. The decision can be negotiated iteratively, until final execution is confirmed by the executing CLOs. The complete process flow enables global awareness and effect size estimation with critical constraints evaluation, while performing final decision making localized/distributed (in example, by postal hub).

Cognition will be realized through a Cognitive Advisor tool. This tool operates cognition on different levels, namely as centralized cognitive services and decentralized (local) cognitive services.

Centralised cognitive services present knowledge formalization, complex event categorisation and infrastructure state modelling.

Decentralised cognitive services include predictive analytics, optimisation and negotiation on CLOs service execution level. The local cognition is operationalized by CLOs with cognitive capabilities, topically represented as postal hub (physical entity), which operates on dynamic fleet management, event handling, and negotiation with eligible CLOs.

2.5 Optimization

Optimization is needed for decision-making. The CLO once understands the context and various alternatives (other CLOs and possible actions in response to an event) it should decide on the best alternatives. To do this, it should make use of optimization algorithms, models and services configurable to different circumstances and operations. The optimization module is triggered by events that are detected based on different factors:

Load factor: An event can be fired by the changes in the load factors of vehicles while they are distributing goods. In this case, the optimization module can create optimal consolidation options for the vehicles considering their distance from each other, similarities of destinations or hubs to be visited, and availability of space.

Time: an event can be a regular event, or according to the plan (e.g. the end of a transport phase) or any delays or deviations from current plan, unexpected demands with strict delivery time bounds may require a fast re-routing or re-planning of distribution operations while they are still on the way. The optimization module should be able to provide the optimal and the most practical distribution scenarios to CLOs. In this case, as for all other cases, dealing with the communication delays between the CLOs (vehicles, hubs, centralized planners) and the cognitive advisor would be critical and requires the effort of all technical partners.

Cost: An event can be generated by unexpected costs that are caused by delays of trains, which require replacing the transportation mode with a costly one, breakdowns of the vehicles, delays in customs operations are other factors that require online re-optimization of distribution operations.

Ad-hoc demands: JIT oriented distribution processes may lead to low load factors for the sake of satisfying the ad-hoc demands urgently which is another case where effective and efficient optimization solutions are needed.

Resource restrictions: The actual working times or breaks of drivers, which may be different than the plan according to external conditions may trigger of a re-optimization with limited resources.

SLAs: An event can be generated when some condition in the SLA are violated or are expected to be violated, for example the maximum delay of the transport service.

COG-LO will offer an Optimization Module that addresses the above. This will also include pre-processing and post-processing steps, which are used for pre-process the transport network data, parameter tuning of the optimizer or refining the input and output while communicating with CLOs. These steps can be executed either off-line or on-line and depends on the specific problem definition. The Optimization Module is controlled by the Cognitive Behaviour, which is aware of the current and planned state of the CLOs and the business logic.

2.6 Interoperation

The first essential enabler will be common information models based on exiting standards that will allow for transparent exchange of information among different CLOs. Specifically, these models will provide for a unified way for information representation, capturing data semantics and being a fundamental reference structure for operational development and interoperability. They will capture a variety of concepts, including: a) data stemming from traffic information systems, vehicle data, and other devices; b) information related to enterprise resource and warehouse management; events, and other state data; temporal, spatial, and other context data. Nevertheless, modelling will not focus solely on data; all aspects of the system operation will be comprehensively reflected in the information models, including operations/services, and infrastructure elements themselves.

Given this semantic foundation, all interactions among the entities participating in COG-LO operations will take place through a message bus, which will provide for asynchronous and synchronous communication, data and service access, security, privacy protection and trust establishment. A fundamental duty of the message bus in this direction will be the transformation of the Platform Independent Model (PIM) of the underlying components operational behaviour to a Platform-Specific Model (PSM). Moreover, it will provide a unified solution for accessing information stored in heterogeneous systems or collected on the fly, under a common transactional interface. Based on all the above, the message bus will by extension take over the important duty of orchestrating different services and among different systems, i.e. it will incorporate the appropriate mechanisms for the effective coordination of resources and their actions towards business objectives. According to the proposed approach, workflows will be in charge of orchestrating COG-LO operations and, therefore, COG-LO will put in place the means for workflow modelling, instantiation, execution, and orchestration. Fostering interactivity in the data-intensive COG-LO environments, the project will opt for a workflow management approach adequately capturing both control and data flows, at the same time considering their interdependencies with the participating physical objects. Additionally, adaptability of operational processes will also be supported with respect to all kinds of events, real-time data fluctuations and overall context.

2.7 Security, privacy and trust

COG-LO will introduce data security and privacy awareness into all involved systems and operations. In line with the principles of data security and privacy by design and the legal requirements thereof (e.g., the GDPR), it will be ensured that they will comprise inherent features of the system.

To this end, a fundamental pillar of all information exchange and processing will be a comprehensive policy-based access and usage control framework, which will be used to authorise all COG-LO operations. The framework will be rich in semantics and will consider all aspects that may affect respective decisions, including roles, attributes of all involved entities, contextual parameters, events that have occurred. The policies that will be specified therein and associated mechanisms will reflect necessarily the regulatory framework in force, but also the business rules and corporate policies of involved stakeholders, contractual agreements in place, as well as preferences and rights of affected data subjects.

Another important concept is trust, given that COG-LO offers above all a collaborative environment, in which sensitive data, from both a privacy and business perspective, are potentially expected to circulate among distinct operational and administrative domains. In this context it is important that trust is ensured at multiple levels: each entity has to in principle trust another collaborating entity, in the sense that trust relations must be contractually established; each entity has to be sure that communication indeed takes place with the trusted entity in question as claimed; it has to be ensured that the above are guaranteed based on undeniable, tamper-proof and traceable credentials.

3 COG-LO operational model

The above-described framework is configurable for different operations. In principle, the main functional operational model of COG-LO is presented in the figure below:

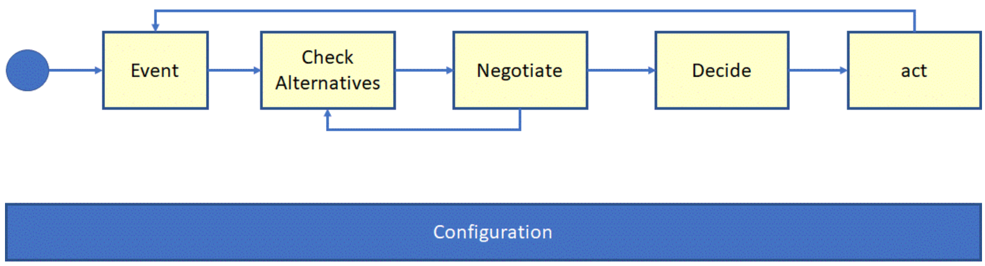

Figure 2: COG-LO Operational model

3.1 Configuration phase

In the configuration phase there should be an Administrator, who together with a COG-LO expert will proceed to the following activities (each of them will be supported by tools and interfaces that will be developed and offered at the final COG-LO prototype):

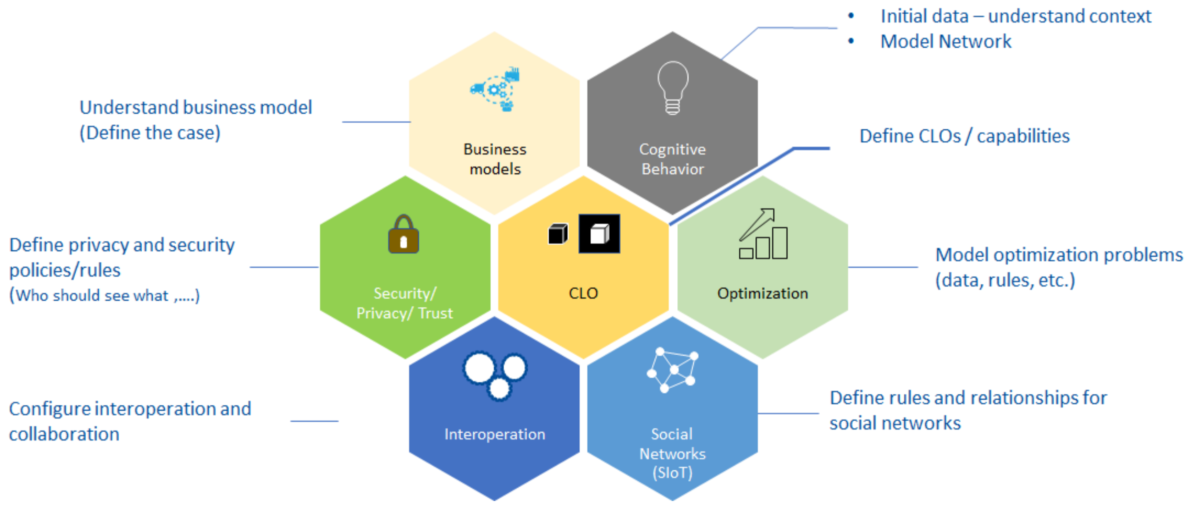

Figure 3: COG-LO configuration

Business models: Study the existing business models: where the company is standing now and what will be the future case for collaborative logistics? This is the result of a strategic analysis and prioritization and has to be clearly defined since it will drive the configuration of the whole system. In this context, the customer needs to model a to-be process model of the logistics operation, illustrating how the new business case will be and all the actors involved.

CLO: based on the operational model defined, the company need to identify the CLOs and assign some capabilities.

Cognitive behaviour: Define description of the initial state of infrastructure to build baseline digital representation of the network. This includes also redefining basic constraints, description of distribution fleet, data models, data integration frameworks (APIs) and final definition of CLOs: basic concepts and attributes/relationships (pickup/delivery points, distribution vehicles depo locations, etc.). The final objective is to consolidate heterogeneous multimodal data and build a model of digital representation of the infrastructure in terms of objects and relationships in real-time. All relevant optimization data should be provided, such as costs and business data, time constraints, etc. The more the data, and more fine grained information, the more COG-LO cognitive services will be utilized.

Optimization: Adapt and configure the optimization solver based on the company needs, the problem definition and algorithm capabilities. In this phase the input data from CLOs and other input sources, is transformed in a way that the Optimization Modules can understand and process to provide the optimal solution. Among this aspect is the problem definition itself, the input format, the event that trigger the solver to run and the output format. The problem definition includes the cost function and the constraints that need to be met. Since solution may not be feasible, the configuration shall define what happens in case of infeasible solution or which constraints can be violated and which cannot.

Social Networks of CLOs: Define the rules and relationships for the social networks; deploy the method for navigating social networks and highlighting interest groups.

Interoperation: Define workflows (from high-level templates), Map company's information to COG-LO semantic framework and define collaboration rules (e.g. I need to leave always 10% free space for unplanned demand for return).

Security/ Privacy/ Trust: Define privacy preferences, access control policies and relevant rules

3.2 Real-time operation

COG-LO starts when the truck leaves the origin point (warehouse, sorting centre, etc.). We consider that a delivery/itinerary plan is produced and is available to be shared in a specific format.

Events

COG-LO will be always triggered by an event, which might be an anomaly of a given status that is not according to the normal situation. Events could be of the following types:

Table 2: Types of Events

Event type	**Description/ example**
Ad-hoc requests from customer	An e-shop, a warehouse that requests a new delivery. Could also be request for returns, etc.
Tweeting from other collaborative CLO	Someone “Tweets” to request a form of collaboration
Rules-based event generation:	Events based on the actual condition and context of the delivery. This includes load factor, costly pick-ups and other KPIs and others that are configured by the customer
Anomaly detection	Any potential anomaly that can happen during the delivery process such as: • Delay in schedule/ forwarding deliveries • Problem in vehicle • Traffic events • Weather, strike, other
Scheduled event (Cross-border deliveries)	A scheduled event that requires special attention and collaboration with other actors. This is more the case of cross-border deliveries.
Human-based events	Anything that is caused by the human factor such as: a sudden illness.

Those events will then trigger the assessment and negotiation phase where the CLOs have to understand the context and find optimal solutions.

Assessment phase (check alternatives + negotiate)

Once an event is found, the CLO needs to assess which are the “available alternatives”. The CLO will establish a social network by defining a specific range. Through the SIoT, the CLO finds those CLOs because the latter always publish information about their status:

- I am a Truck with id ***X***
- I carry ***Y*** type of cargo
- I have ***Z*** capacity
- My destination points are ***d1, d2, d3***,….
- I can carry ***Q*** tons or other metric of cargo

The searching CLO then process the information published by the other CLOs according to the company rules, goals and KPIs and then starts “Tweeting” with them.

The main goal is to filter the available and eligible CLOs that will be considered in the decision making process.

Decide

Based on the context assessment and the available options, the CLO will perform the decision making process. Possible decisions can be:

- *Dynamic re-planning*. Re-planning has also the notion of a route with different modes (inter-modality).

- *Rerouting*: without changing the transportation mode, the truck or vehicle changes the route, in response to the particular event.
- *Cargo hitchhiking*: merging deliveries with other truck, which has the necessary capacity.
- *Parking, other*: in case of a traffic event, extreme weather conditions and other factors.
- *No action*.

The aim is to run simulation and optimization algorithms to suggest optimal solutions for the particular event.

<u>*Act*</u>

The action depends on the authorization of the particular CLO to initiate the solution that has been suggested. This implies an authorization to “approve” the optimal solution(s). COG-LO in the configuration phase will provide the functionality that will allow the system administrator to assign the authorization for a CLO to initiate specific actions and depending on the event.

The action refers to the realization of the optimal suggestion and can be of the following (indicative list):

- Start the process of request for cargo hitchhiking.
- Book a parking slot by calling the relevant service.
- Send rejection reply to a request.

4 Architectural approach

This Section delves into the architectural aspects of the COG-LO project, highlighting its main functional components. Furthermore, it identifies the relation of the project with the concept of the Physical Internet.

4.1 COG-LO and the Physical Internet

COG-LO vision is in-line with Physical Internet, in the sense that it creates a digital open logistics network for new collaborations and synergies that go beyond the traditional supply chains. With regards to the Physical Internet characteristics (Montreuil, 2011), COG-LO contribution is presented as follows.

- In Physical Internet, a CLO can be the π-container, the π-nodes and all other involved actors.
- A CLO (π-container) has connectivity capabilities: it is a connected object propagating information about its status and conditions.
- Using Social Internet of Things, COG-LO will be able to deploy different social networks of things in a secure/private and trusted way.
- Merging deliveries is a concept addressed in COG-LO. This is very similar to the physical internet vision, since it addresses delivery efficiency, cost and other KPIs through ad-hoc collaborations along the route. This is achieved through social internet of things, where CLOs switch among different social networks along the route.
- Similar to the Physical Internet, in COG-LO the CLO propagates information in the network about its status, capacity and potential needs. Through Tweeting CLOs tool, CLOs (π-containers, π-hubs, etc.) will negotiate for potential synergy.
- COG-LO creates new business opportunities for Logistics Service Providers and other stakeholders (ICT, etc.). New collaborations may arise and in different markets as consequence of better utilization of the logistics assets.

4.2 COG-LO system architecture

From technical perspective, the above framework will be realized through the following architectural approach:

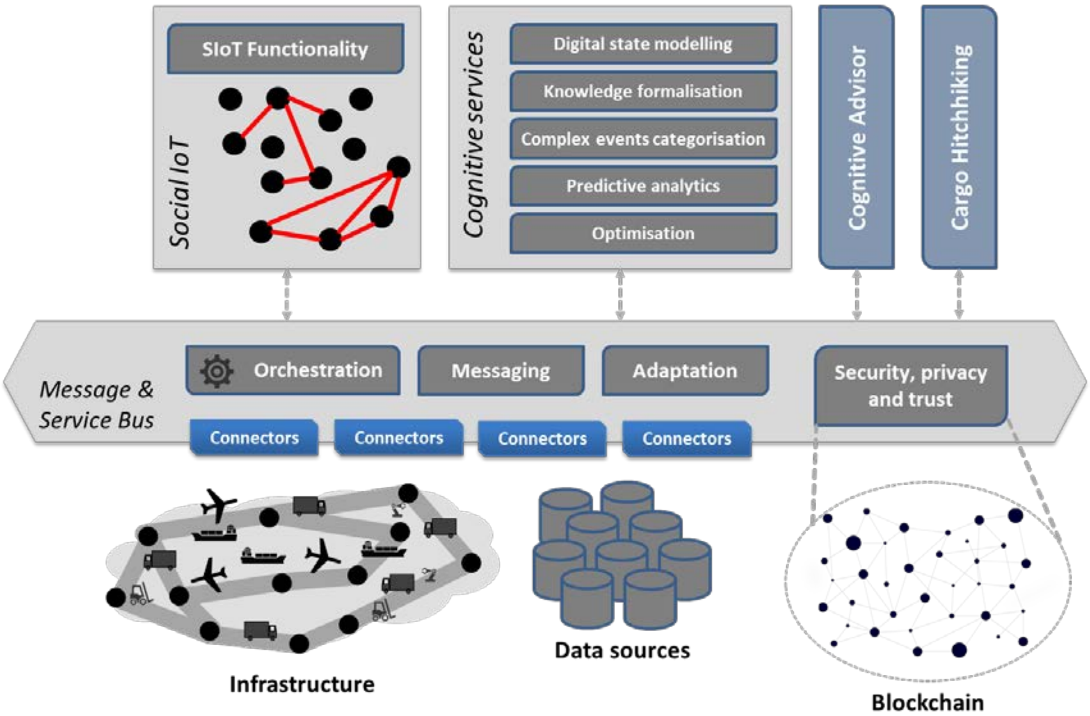

Figure 4: COG-LO Architecture

The physical entities that collectively carry out the actual logistics processes are denoted as the **Infrastructure**. These refer to a variety of concepts, including cargo (parcel, palette, container, etc.), transportation means (vehicles, trucks, trains, etc.), back-end ICT systems and services, as well as infrastructure components, like hubs, parking places, ports, and others. As it will be described below, all these entities have their digital correspondent, denoted as the Cognitive Logistic Object (CLO). The entities of the infrastructure are complemented by the **Data sources**, implying any source of data such as ERP, WMS, ITS, traffic information systems, along with operational and configuration data that are essential for the operation of COG-LO. Overall, the data records under consideration include internal enterprise data (e.g., ERP records, WMS reports, etc.); historical process files; streaming data (broadcasting/community/individual services, etc.); situational and contextual data at local and global level (e.g. traffic status, environmental conditions etc.).

As said above, each entity of the physical world is identified in COG-LO as a CLO. The CLOs reside in the **Social IoT** module of the architecture. This component provides information about CLOs social-like relationships and extends their functionalities by means of Virtual Instances (VI). VIs represent CLOs "digital twins" and are responsible of performing the processing, which cannot be executed locally on the device. The VIs appropriately abstract CLO capabilities, in a way that these, along with the CLO itself, are discoverable and manageable in the context of the COG-LO operation. The capabilities refer to semantically - defined behavioural characteristics of the object, and span from basic functionalities to more sophisticated tasks, including, among others, identification, sending and receiving information, processing data, sensing, actuation, decision making, self-awareness - meaning the ability to know its state, being searchable, etc. At the digital sphere, a CLO is also able to peer with other CLOs, by establishing social relations based on common characteristics, interests or operational purposes, such as location proximity, participation in the same logistics process, etc. By augmenting CLOs with the social dimension, two major advantages can be achieved: (a) an overlay network can be built having the typical features of social networks, i.e., it is navigable and has a small diameter, (b) interactions are preferred between CLOs that are neighbours and more trustworthy. In order to achieve its goal and mission, the Social IoT module of COG-LO is conceptually organised on a constellation of CLOs - implemented as software agents that comprise the digital twins of the physical entities - and in a number of functions for managing the CLOs, such as the CLOs registry, the repository of friendship relations, functions for the establishment and management of relationships and navigation of the social graph, etc.

In order to provide for effective interaction, coordination and orchestration of COG-LO components and operations thereof, the architecture includes the **Message and Service Bus** (MSB), being a mediation middleware between the components of the COG-LO ecosystem. The MSB comprises a message-oriented system providing for both asynchronous and point-to-point message exchange between the system entities, circulation of events, and interaction between the CLOs. An important aspect here concerns the management of interaction channels for enabling the cooperation within *communities* of CLOs; this involves the dynamic establishment of message topics (queues), thus providing for the implementation of the *tweeting* CLOs functionality. Furthermore, the MSB provides for the integration of the infrastructure objects and data sources, by means of appropriate connectors; to this end, a fundamental duty of the MSB is the transformation of the Platform Independent Model (PIM) of the underlying components operational behaviour to the COG-LO Platform-Specific Model (PSM)[1]. The MSB incorporates also the functionality for the orchestration of COG-LO components and operations as regards the execution of workflows.

In addition, the MSB is the main COG-LO system entity for the enforcement of mechanisms for **data security, privacy and trust**. To this end, a variety of mechanisms will be incorporated in the MSB, including: (i) a policy-based access and usage framework for regulating the circulation and usage of information; since the MSB comprises the central interaction point, messaging will be subject to such control, in order to make sure that authorisation constraints are met as regards disclosure of data to system entities; (ii) appropriate software libraries for the enforcement of active *protection* means, such as cryptographic primitives, anonymization and pseudonymization mechanisms; (iii) a comprehensive framework for the establishment of trust, both subjective and objective, between the system entities; to this end, appropriate mechanisms for mutual identification and authentication will be put in place, providing for objective trustworthiness, whereas a distributed ledger will be leveraged for the effective management of corresponding certificates.

The main enabler towards cognitive behaviour in COG-LO will be a set of **Cognitive Services**, providing the necessary logical inference mechanisms for knowledge extraction and formalisation, learning and reasoning, as well as cognitive behaviour of the underlying entities, leveraging multiple analytics technologies. The COG-LO Cognitive Services, therefore, enable core services, including: events categorisation, infrastructure observability, critical constraints assessment and defining eligible CLOs for localised decision making on final activities execution level. The Cognitive Services will be coupled with exact optimisation algorithms and heuristics for enabling CLOs adaptation to operational changes from the external environment in near real-time. In particular, COG-LO couples analytics and optimisation for considering the effect of optimisation control measures to the performance of operations in an environment with continuous external variations.

Finally, the COG-LO architecture includes two tools notable the **Cognitive Advisor** (CA) and the **Cargo Hitchhiking**. The CA, comprising a functional front-end of the Cognitive Services, provides the logistics operator with visualised decision support for routing optimisation. The CA interacts with the MSB to visualise the formalisation, reasoning and cognitive outputs of the Cognitive Services. On the other hand, the Cargo Hitchhiking will reflect the tweeting CLOs functionality, enabling the creation of communities, along with messaging and coordination therein.

5 COG-LO pilots

[1] PIM and PSM are commonly terms used terms in the Model-Driven Architecture literature and standardization — cf. e.g., The Object Management Group (OMG), Model Driven Architecture (MDA), MDA Guide rev. 2.0 OMG Document ormsc/2014-06-01, June 2014, https://www.omg.org/cgi-bin/doc?ormsc/14-06-01.pdf.

COG-LO technology will be validated through 3 pilot cases:

Slovenia Post (PS) and Croatia Post (HP): Optimisation of collection, exchange and delivery of tracked cross-border shipments process between. The challenge is to improve the collaboration in terms of data sharing and optimized deliveries using different hubs and alternative routes where needed (currently only though one hub per country).

Hellenic Post (ELTA): ELTA will demonstrate two basic scenarios: a) load factor optimization in the major Greek backbone logistics route Athens-Thessaloniki through a picking shuttle van integration; b) optimal re-routing of courier resources for the handling of dynamic events (e.g. customers' ad-hoc pickup requests, random traffic events etc.) injected in the route plan during the day, aiming at the minimization of route cost and the fulfilment of agreed timeframe for pickup/delivery guaranteeing high service levels.

EKOL: EKOL, a leading EU Logistics Service Provider, will demonstrate how COG-LO can improve dynamic planning in cargo forwarding at the Port of Trieste. The main challenge is to achieve optimized timing and booking of cargo multimodal transportation by minimizing waiting times and use alternative flows in case of unexpected unavailability/delays.

6 Outlook: innovation potential and market benefits

This paper has described COG-LO, an innovative framework for cognitive and collaborative logistics. Having described the above approach, we can identify three innovation areas that the project tries to address:

Cognitive Behaviour: COG-LO builds on top of the knowledge gained from previous research projects (EURIDICE-FP7, iCargo-FP7). Those projects defined the intelligence framework together with relevant knowledge base and associated services. COG-LO, through the introduction of the CLO. In COG-LO, the CLO have also cognitive capabilities, which extends context awareness to local decision-making.

Ad-hoc CLO collaborative platform with by design security, privacy and trust. This platform will deploy the Social Networks of CLOs bundled with comprehensive access and usage control, information diffusion, and compliant workflows. Such mechanisms will be based on blockchain technology and allow for ad-hoc CLO communication, through the Tweeting CLOs tool.

New business models for logistics players as a result of the proposed technology. Ad-hoc collaborations, load factor optimization and new synergies will be demonstrated in three different scenarios: Cross-country interoperability, flexible intra- and inter- multi-model logistics operations. The consortium consists of three Post Operators, which faces many difficulties in adopting to the dynamics of the market. We will test new practices for ad-hoc delivery requests (shuttle bus in ELTA), new collaborative models with external players and assess the applicability on faster and same day deliveries.

Based on the above-proposed approach, COG-LO can offer the following benefits:

(a) *Better exception management*;

(b) "*Cargo Hitchhiking*", meaning that the cargo can identify combined transportation possibilities with vehicles transferring similar cargo to the same destination. Hence, higher load factors and lower CO_2 emissions will be achieved by engaging fewer vehicles.

(c) *"Tweeting Vehicles":* similar to the *Tweeting CLOs* concept, vehicles communicate each other, exchange <u>public</u> information on load status, cargo type & conditions, etc. to identify possibilities of merging deliveries.

(d) *Improved trust* through the usage of Smart contracts and blockchain.

(e) *Improved transportation planning*; logistics operators will be enabled to identify improved transportation alternatives and new opportunities for business collaborations in order to re-evaluate their transportation models.

(f) *Ease of access and stakeholders' engagement*; leveraging the COG-LO platform, a variety of stakeholders in the supply chain can join the COG-LO ecosystem at minimal cost. Along with the aforementioned, COG-LO will offer additional benefits, such as security, privacy, event and process management at small and large scale.

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References

- CapGemini, 2016: 2016 Future Supply Chain Report, Cap Gemini, https://www.capgemini.com/resources/future_supply_chain_2016
- COG-LO Deliverable D2.1: Business cases definition and scope analysis
- COG-LO Deliverable D2.3: Cognitive Logistics Framework
- DHL, 2017: *The 21st Century Spice Trade: A Guide to the Cross-Border E-Commerce Opportunity*, available to download at: https://www.dpdhl.com/en/media-relations/press-releases/2017/cross-border-e-commerce-growth-opportunities-etail-dhl-report.html
- eCommerce (2017): eCommerce Europe Position Paper, Manifesto for a better parcel delivery market Europe, May 2017
- e-Freight project, https://cordis.europa.eu/
- EURIDICE FP7 Project (https://cordis.europa.eu/project/rcn/100869/factsheet/en)
- iCargo FP7 project (https://cordis.europa.eu/project/rcn/100869/factsheet/en)
- Lacey M., et. All (2015): Matthew Lacey, Helena Lisachuk, Andreas Giannopoulos, Alberto Ogura, Deloitte, 2015: Shipping smarter: IoT opportunities in transport and logistics, 2015, https://dupress.deloitte.com/dup-us-en/focus/internet-of-things/iot-in-shipping-industry.html
- McKinnon A. (2007): CO_2 Emissions from Freight Transport in the UK, Report prepared for the Climate Change Working Group of the Commission for Integrated Transport.
- Montreuil B. (2011): Towards a Physical Internet: Meeting the Global Logistics Sustainability Grand Challenge, Logistics Research, v3, no2-3, 71-87.
- TransEU, 2017: Logistics 4.0 – what does the business need? http://www.trans.eu/en/news/logistics-4-0-what-does-the-business-need