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A Cloud Platform to support Collaboration in Supply Networks

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Abstract: Collaboration is a trend in supply networks management, based on the jointly planning, coordination and integration of processes, participating all network entities. Due to the current characteristics of uncertainty in the markets and economic crisis, there is a need to encourage collaboration tools to reduce costs and increase trust and accountability to market requirements. This study presents an overview of the research carried out in the H2020 European Project: Cloud Collaborative Manufacturing Networks (C2NET), which is directed towards the development a cloud platform that consist of, optimization tools, collaboration tools to support and agile management of the network. The collaborative cloud platform allows to collect real time information coming from real-world resources and considering all the actors involved in the process. The collaborative cloud provides real time data gathered from the entire network partners in order to improve their decision-making processes.

Key words: Cloud Platform, Collaborative Networks, Collaborative Processes, Plans Optimization.

1. Introduction

Globalization, Information and Communication Technologies (ICT) and innovation processes have revolutionised in the recent decades the organisation of value chains. Although the Small and Medium Enterprises (SMEs) represent 99% (European Comission, 2013) of European enterprises, their decadence has increased in recent years due to the current economic situation. The European Commission notes that collaboration among the network enterprises may be reasonable to prevent the decline of traditional specialisation of SMEs strategy (European Comission, 2012).

In the global economy, there is an increasing interest in new organizational structures to flexible enough to respond to market changes and at the same time to perform collaborative projects. Enterprise networks have been identified as fundamental instruments to the implementation of the 2020 strategy of the European Union (EU). The EU initiative "Innovation Union" and "An integrated industrial policy for the globalization era" (European Commission, 2014), specifically refers to enterprise networks as key tools for achieving this strategy. Currently, industry competitiveness and growth leads towards innovative high performance industrial systems and agile companies interconnected through the creation and consolidation of collaborative networks. Traditional supply chains are based on centralized decision-making, where most of the players must adapt to the constraints defined by a few models. Real-world experiences show that when making decisions is not collaboratively performed lower performances are achieved, and in current highly dynamic markets, this generates large inefficiencies in the performance of the entire network.

The key factor to address these emerging challenges is the enterprises collaboration. The collaborative manufacturing ensures constant feedback circuit, unbroken communication between product designers, engineers, manufacturing facilities and customers. In collaborative supply networks, manufacturers can offer value-added services (e.g. maintenance, updating...) or even sell their products "as a service". The remotely management of services helps to

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improve equipment uptime, reduce service costs (e.g. travel expenses...), increasing the efficiency of services and accelerating the processes innovation (e.g., remote update software of the devices).

Motivated by this situation, this paper describes the planned work to be carry out along the H2020 European Project: Cloud Collaborative Manufacturing Networks (C2NET). To this end, this paper is organised as follows: in Section 2 a state of the art is presented, centring its attention on the most relevant research areas related with the collaborative context. Section 3 focuses on the description of C2NET European Project, including the objectives, expected results and expected impacts derived from its exploitation. In Section 4 a more detailed description of the C2NET contribution regarding the optimization and simulation algorithms for Collaborative Manufacturing and Logistics Processes (CMLP) is proposed. Finally, Section 5 provides the main conclusions and future research work.

2. State of the Art

Globalisation and competitive environments, in which enterprises are embedded, trigger the appeareance of new patterns of operation among manufacturing and service enterprises operation. Over the last decade, collaboration has emerged as new way on how enterprises make their business, due to the competitive advantages associated. Camarinha-Matos and Afsarmanesh (2005) established the bases of Collaborative Networks (CN) discipline and proposed a common definition: CN consist of a variety of heterogeneous autonomous entities, geographically distributed, in which participants collaborate to achieve a common goal and base their interactions through computer networks. In order to face dynamic and turbulent environments enterprises participation in CN allows them to increase their agility, responsiveness and resilience.

Particularly, SMEs are commonly characterised by having limited resources and capabilities to efficiently establish collaborative relationships (Matopoulus *et al.,* 2007). So that, there is a gap in terms of SMEs affordable tools (in term of cost and usability) to help them to support their decisions and processes in the collaborative context. In order to face potential barriers that can appear when SMEs participate in collaborative processes, joint efforts must be performed to achieve the desired collaborative scenarios.

The restructuration of SMEs internal operations, the exchange information, the information systems interoperability, the coordination of SMEs production processes and planning processes, the alignment of enterprises strategies and goals, the achievement of suitable levels of trust, the agreements in practices, and the alignment of values (Bititci *et al.,* 2007; Macedo *et al.,* 2010; Andres and Poler, 2014) are part of the tasks to be performed by enterprises if they are willing to achieve sustainable and stable collaborative relationships. In the light of this, a set of 13 research areas are identified of interest in the collaborative networks context to support enterprises in the participation of collaborative process. These areas are briefly described next as part of the literature review research in the CN context:

Agile Supply Chain. According to Lee (2004), an agile supply chain is a set of partners that responding quickly to short-term changes in demand (or supply) and handling external disruptions smoothly. Recently various initiatives have appeared for analysing and supporting the deployment of agility in supply chain. Such initiatives are SOA and Web Service based (Zhang *et al.,* 2012).

Cloud Computing. Cloud Computing is defined as the on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (Mell and Grance, 2011). Automation in cloud systems makes it possible to manage the data centres so that they deliver portions of themselves (in the form of virtual machines and networks) (Amazon EC2, 2012). In the light of this, cloud services must, guarantee what is known as a Service Level Agreement (SLA) (Buyya *et al.,* 2009).

Enterprise Applications. Aim to facilitate the management of the different areas of an enterprise. Ranging from micro mechatronics systems (MEMS), MES and intelligent manufacturing systems (IMS) to ERP, APS and Customer Relationship Management (CRM) (Ollero *et al.,* 2003).

Enterprise Interoperability. Interoperability is an essential problem of sharing information and exchanging services. It goes far beyond the simple technical problems of computer hardware and software, but encompasses the broad but precise identification of barriers not only concerning data and service but also process and business as well

(Chen *et al.,* 2006). Different European actions have been carried out in order to support research activities enabling enterprises to seamlessly interoperate: ATHENA FP6-IST 507849; INTEROP-NoE FP6-IST 508011

Event Driven Architecture (EDA). EDA is in charge of managing event exchanges between processes, people and machines, filtering and applying business rules to detect relevant events or combinations of events. For example, two events, which are not seen as risks or opportunities when viewed separately, may have a different meaning if they are considered together (and so they create a complex event); this is called Complex Event Processing (CEP) (Marterer *et al.,* 2012).

Everything as a Service (EaaS). Provides an increasing number of services through Internet under the Cloud Computing paradigm instead of providing them locally (Lenk *et al.*, 2009). The "everything" term comprises from infrastructure, middleware and platforms, software and compound applications (for different domains) human intelligence, and any combination of them. EaaS is focused on making cloud-based services, both creating new services or adapting previous ones to the cloud paradigm in such way they take as much advantage as possible of the whole potential provided by Cloud Computing.

Internet of Everything (IoE). brings together people, process, data, and things to make networked connections more relevant and valuable, turning information into actions that create new capabilities, richer experiences, and business opportunities (Cisco, 2013). Five key factors are considered in IoE: (i) assets utilization through reduced costs and more effective decision making, (ii) employee productivity empowering people and increase efficiency, (iii) supply chain and logistics, eliminating waste and idle times, (iv) know customer experience and build better relationships, and (v) innovation, to create and expand new markets and services, including product-services concept (FInES, 2013).

Manufacturing Processes Management. Globalisation of businesses has increased enterprises competition. As a consequence companies have to deal with rapid changes in their business or face extinction (Banerjee, 2000). In order to face up to these new requirements, companies seek to redefine and improve various aspects of their manufacturing process management (MPM). MES provides shop floor control and simultaneously manufacturing feedback (Garetti *et al.*, 2007). Therefore, MPM is a strategy that supports formal communication between engineering and production (Fortin *et al.,* 2007).

Manufacturing Processes Optimization. Research in optimization techniques has been a very active field in the last decades. One of the most successful application areas has been the planning and scheduling of operational manufacturing processes, trying to optimize cost, resource allocation, delivery time, etc. Different mathematical programming approaches in a deterministic context are proposed in the literature (Alemany *et al.,* 2010). Intelligent modelling and heuristic modelling approaches have also been proposed as bridging techniques between the problems that theoretical optimization techniques can handle and real world problems. Hernandez *et al.* (2014) developed multi-agent negotiation based algorithms. Moreover, fuzzy mathematical programming models (Mula *et al.* 2010a) have been developed for production planning problems under uncertainty. Identify the appropriate technique for the different optimisation process is a controversial discussion and is the source of much research. Real-life enterprise optimization problems, as for example planning and scheduling, often need both linear and non-linear constraints and may involve hundreds/ thousands of (real/integer/binary) variables and constraints, and are difficult to tackle with genetic algorithms-like techniques.

Mobile Computing. With the emergence of mobile computing and the rapid developments on mobile devices and communication technologies, the possibility of providing information to users when and where is needed is now possible. Mobile computing poses a series of unique challenges for the development of mobile information systems (Satyanarayanan, 1996) where personalized information is shown to people with different necessities and profiles.

Ontologies. Refers to an explicit and formal specification of a shared conceptualization (Gruber, 1993). An Ontology represents knowledge of some domain of interest as a set of concepts, their definitions and their inter-relationships; it is shareable and can be understood by a computer. Sharing common understanding of the structure of information among people or software agents is one of the more common goals in developing ontologies, as well as, making explicit domain assumptions in order to change these assumptions easily if the knowledge about the domain changes. Different ontologies have been developed since then that uses specific ontology languages (e.g. OWL, CGs, OIL, and DAML) and editor (e.g. Protégé).

Open Source Technologies/Software (OSS). The term is traced back to the 1950s and 1960s, but it was Richard Stallman, who founded the Free Software Foundation that provided the conceptual foundation for open source software. The OSS development approach has become a remarkable option to consider for cost-efficient, high quality software development. Utilizing OSS (Merilinna and Matinlassi, 2006) has allowed its utilization as part of an in-house software application. Main benefits for adopting OSS are (Dixon, 2004): easy adoption, lower cost, motivation, control and flexibility. Some of the main institutions on the OSS are: The Free Software Foundation (FSF), The Open Source Initiative (OSI), and Open Source Development Labs (ODSL). The Computational Infrastructure for Operations Research (COIN-OR) project is an initiative to spur the development of open-source software for the operations research community.

Orchestration / Choreography of Workflows. Orchestration (i) refers to an executable business process and (ii) represents the service composition from one partner's perspective in the case of a collaborative process (Peltz, 2003). Choreography refers to a viewpoint of the services composition where the interactions between the services involved into collaborative processes are seen from a global perspective (Barros *et al.* 2005). Choreography is used to execute several business processes. Various languages have emerged in the last years in order to model the services choreography: (i) Interaction modelling: the logic of the choreography is specified as a workflow where the activities represent the messages exchanged between the parties, e.g. WS-CDL (Barros *et al.* 2005) and (ii) Interconnected interfaces modelling: the logic of the choreography is shared across the parties through their roles, which are connected using message flows, channels or equivalent concepts, e.g. BPMN 2.0 (OMG, 2015).

3. Cloud Collaborative Manufacturing Networks: C2NET Project

3.1. Objective

Currently, the European SMEs do not have access to advanced management systems and collaborative tools because of their limited resources (European Commission 2005). Value chains formed by SMEs are distributed and dependent on information and complex materials flows that require new approaches to reduce the complexity of manufacturing management systems. In this context, ubiquitous tools are needed to support collaboration between different entities in the value chain and offer advanced algorithms to achieve global and local optimization of manufacturing processes and respond more quickly and efficiently unforeseen changes. The main objective of C2NET is building a new architecture in the cloud to provide SMEs, affordable tools (in terms of cost and ease of use) to help overcome the current economic crisis, improving competitiveness in the economy world.

Therefore, C2NET objective is based on the creation of cloud tools to support optimization of manufacturing networks composed mainly of SMEs and their logistic assets through demand management, production and supply plans, considering the Collaborative Network perspective.

3.2. Expected Results

The C2NET Project will generate a Cloud Architecture composed by the Cloud Platform (C2NET CPL), the Data Collection Framework (C2NET DCF), the Optimizer (C2NET OPT) and the Collaboration Tools (C2NET COT) (see Figure 1).

The Data Collection Framework (C2NET DCF) to provide software components and hardware devices for IoT-based continuous data collection from supply network resources. This supports the collaborative manufacturing functionality while taking advantage of Cloud environments, which can enable solutions that are highly scalable, available and fault-tolerant.

The Optimizer (C2NET OPT) to support manufacturing networks in the optimization of manufacturing and logistics assets by the collaborative computation of production plans, replenishment plans and delivery plans in order to achieve shorter delivery times, better speed and consistency of schedules, higher use of productive resources and energy savings.

The Collaboration Tools (C2NET COT) for providing the Collaborative Manufacturing Network Platform with a set of tools in charge of managing the agility of the collaborative processes (Lauras *et al.*,. 2015).

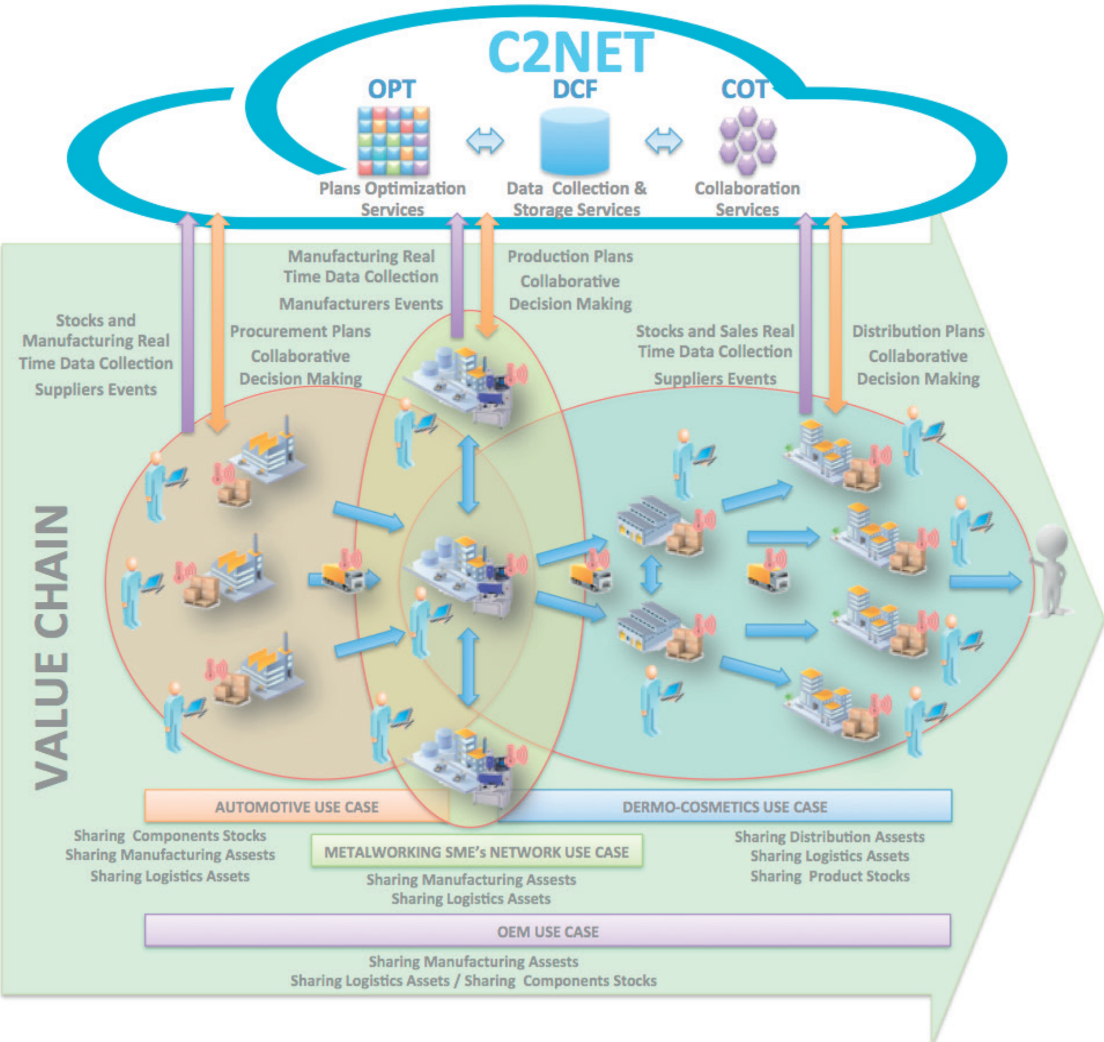

Figure 1. Overview of C2NET Cloud Architecture.

The Cloud Platform (C2NET CPL) to integrate the data module, the optimizers and the collaborative tools in the cloud and allow the access to process optimization resources to all the participants in the value chain to support their decisions and process enhancement. It will provide the base for the integration of the different modules for generating a collaborative working environment for manufacturing network partners.

3.3. Expected Impacts

Among the major challenges that manufacturing companies face today are the growing complexity of their processes and supply networks, cost pressures, growing user and customer expectations for quality, speed, and custom products, and worker safety and assistance. Manufacturing is evolving from being perceived as a production-centred operation to a human-centred business with a greater emphasis on workers, suppliers and customers being in-the-loop (ActionPlanT, 2014).

Manufacturing networks performance can be significantly improved through more harmonious and equitable peer-to-peer inter-enterprise relationships, conforming a collaborative decision making model and providing major benefits mainly in terms of:

- Enhanced overall competitiveness, innovation and adaptability in today and tomorrow's enterprise partnership scenario.

- Cross-country and inter-enterprise interchanges, building networked enterprises that are supported by stable relationship schemas and modern co-operation & co-ordination business paradigms.

- Cost reduction, through overall optimisation and elimination of inefficiencies of processes, stocks, flows, plans, etc.
- Companies' human resources improved quality of work and skills, through improved knowledge management and dissemination, better understanding of dynamics and flows, and clearer definition of roles and responsibilities.
- End consumers' advantages, mainly in terms of diminishment of products time-to-market and costs.
- SMEs empowerment and enhanced accessibility to networked enterprises.
- Optimisation of materials, wastes and energy consumption based on more rational and homogeneous production and supply plans, stocks and workforce balance.

The European industry needs advanced methods and tools to address economic and risk assessments in order to support complex decision-making as the management of co-evolution of products-services and the related production systems, the evaluation of alternative configurations of the network of actors involved in the global supply chain, or integration of new technologies in the factory. Best-in-Class companies versus Others are up to 1.78 times as likely to have ability to analyse current level of supply chain risk exposure to have online visibility into supply chain disruptions and to have online trading partner collaboration and enablement.

4. Collaborative Plans Optimization

C2NET Optimizer **(C2NET OPT)** supports manufacturing networks in the optimization of manufacturing and logistics assets by the collaborative computation of production plans, replenishment plans and delivery plans in order to achieve shorter delivery times, better speed and consistency of schedules, higher use of productive resources and energy savings.

The main objective of C2NET is to develop tools to support manufacturing networks in the optimization of manufacturing and logistics assets by the collaborative computation of production plans, replenishment plans and delivery plans in order to achieve shorter delivery times, better speed and consistency of schedules, higher use of productive resources and energy savings.

C2NET OPT will incorporate a set of highly specialized optimization algorithms to be applied depending on the characteristics of each unexpected event, e.g., lack of products at a point of sale, a machine breakdown or a delay on a component arrival. Using these algorithms together with some business rules agreed between the companies in the supply chain (C2NET will incorporate a business rules engine), C2NET Optimizer will provide a new production plan whose main objective will be to optimize the available capacity of manufacturing assets.

In order to design the C2NET OPT four steps are identified: (i) the creation of a taxonomy to classify the collaborative plans, (ii) the selection of collaborative plans to specify and develop optimization and simulation algorithms, (iii) the validation of optimization and simulation algorithms developed and (iv) the computational implementation of the algorithms. This steps are outlined next.

The creation of a taxonomy of optimization and simulation solutions for Manufacturing and Logistics Processes is provided from the (i) analysis of the collaborative manufacturing and logistics processes identified in each of the industrial Pilots, and (ii) review of current SoA of optimization algorithms and simulation procedures used to solve related manufacturing processes problems, especially in the frame of collaborative processes, considering Source (S), Make (M) and Delivery (D) Plans and their combination (e.g. Source & Make, Make & Delivery and Source & Make & Delivery). As a result of this activity it will have a deep understanding of the different optimization and simulation approaches existing in the literature and existing tools as the main input to address the development of new optimization and simulation algorithms to support collaborative manufacturing and logistics processes optimization.

Collaborative problems are selected from industrial scenarios and their requirements analysis in order to specify and develop optimization and simulation algorithms for Collaborative Manufacturing and Logistics Processes (CMLP). Taking into account the taxonomy created and the existing optimization and simulation tools, the specification and development of new optimization and simulation algorithms and the adaptation of existing algorithms for supporting collaboration between enterprises will be made. The proposed algorithms will be classified concerning its calculation mechanism, which is related with the calculation time and the proximity to the optimum:

Optimiser Algorithms (OA) employ a technique that ensures to find the optimum solution. These algorithms use to be the slowest ones and, for some kind of problems, the needed time to find the optimum is unacceptable. Some examples of OA are: Branch and Bound (Land and Doig, 1960), Dynamic Programming (Giegerich *et al.,* 2004), Lomnicki (Lomnicki, 1965) or Simplex (Dantzig *et al.,*1955).

Heuristic Algorithms (AH) employ a practical methodology not guaranteed to be optimal or perfect, but sufficient for the immediate goals. Heuristic algorithms use to be the quickest ones and normally find one solution (it can not ensure optimum). Some examples of AH are: Decomposition & Aggregation (Pervozvanskii and Gaitsgori, 2013), Greedy (Luke, 2013), Minimum Spanning Tree (Horowitz and Sahni, 1978), Nearest Neighbour (Cover and Hart, 1967) or Lagrangian (Hestenes, 1969).

Metaheuristic Algorithms (AM) consist of higher-level procedures designed to find, generate, or select a heuristic (partial search algorithm) that may provide a sufficiently good solution. Meta-heuristic algorithms use to implement random search and can find several solutions (it can not ensure optimum) using a search strategy which needs a stop rule (it can be time). Some examples of AM are: Colony Optimization, Evolutionary Computation, Genetic Algorithm, Iterated Local Search, Neural Networks, Scatter search, Simulated Annealing, Tabu Search, Variable Neighbourhood Search (Luke, 2013).

Matheuristic Algorithms (AA): is an optimisation algorithm made by the interoperation of metaheuristics and optimiser techniques. Matheuristic can find optimum solutions faster than some optimiser techniques. Some examples of AA are: Cross-Entropy Progressive Hedging (Rubinstein, 2001), Hybrid Reactive GRASP (Feo and Resende, 1989) or Steiner Tree (Garey and Johnson, 1977).

The optimization and simulation algorithms developed will be validated for CMLP, running test suites of on the industrial Pilots. A collection of real collaborative processes instances with their solutions representing production, replenishment and delivery plans will be prepared as a key input to validate the algorithms.

After the validation, the optimization and simulation algorithms developed will be implemented in the “Processes Optimization of Manufacturing Assets” (POMA) bricks, which will be integrated within the C2NET Cloud Architecture. The optimization and simulations algorithms to solve collaborative production, replenishment and delivery plans will be offered in an Optimization as a Service mode to the firms collaborating in a manufacturing network. POMA bricks will include tools to collaboratively calculate production plans (amount of items to be produced), replenishment plans (amount of items to be ordered) and delivery plans (amount of items to be ordered) per periods of a horizon to every actor of the supply chain involved in the collaboration, from a holistic point of view to reach global optimization of manufacturing and logistics assets. POMA bricks will be also validated with the industrial Pilots.

5. Conclusions

The C2NET project provides a scalable real-time architecture and a cloud platform that will gather different software to support the different network enterprises to: (i) manage the complexity and data security of all the network enterprises; (ii) store and share product data, processes and logistics; (iii) optimize manufacturing assets through collaborative computing production plans; (iv) optimizing logistics assets through efficient delivery plans, and (v) Make the complete set information of the network is available on any mobile device (PC, tablets, smartphones...) to support decision makers in the tasks of control and visualization, so that they can share the necessary information and data to efficiently collaborate.

Future research lines led to implement the steps described, with regards the optimizer (C2NET OPT) and propose a wide variety of optimization and simulation algorithms. Optimisation algorithms will not only be focused on the local scope of enterprises, but also will to support the network enterprises on computing from a collaborative and automated way the plans performed in the value chain, including source, make and delivery plans.

Collaborative planning, besides being supported by the C2NET OPT module, will be assisted by the proposals developed in the collaboration module, C2NET COT. The tasks of supervision, detection, adaptation and assessment, developed in C2NET COT will facilitate the coordination between the network partners.

Each of the C2NET modules will be supported by the cloud platform (C2NET CPL). The cloud collaborative platform will allow SMEs, with less accessible capabilities and resources, to have access to sophisticated tools in order to deal with collaboration and facilitate the collaborative decision-making performed at both, enterprises and network level.

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