A Proposal of Standardised Data Model for Cloud Manufacturing Collaborative Networks

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Abstract. The growing amount of data to be handled by collaborative networks raises the need of introducing innovative solutions to fulfil the lack of affordable tools, especially for Small and Medium-Sized Enterprises, to manage and exchange data. The European H2020 Project Cloud Collaborative Manufacturing Networks develops and offers a structured data model, called Standardised Tables, as an organised framework to jointly work with existing databases to manage big data collected from different industries belonging to the CNs. The information of the Standardised Tables will be mainly used with optimisation and collaboration purposes. The paper describes an application of the Standardised Tables in one of the pilots of the aforementioned project, the automotive industry pilot, for solving the collaborative problem of a Materials Requirement Plan.

Keywords: standardised data model, management information systems, manufacturing, data handling, modelling, cloud, collaborative networks

1 Introduction

Collaborative approaches have been spreading over the last years due to the advantages associated with the enterprises that take part in collaborative networks (CN). Different areas of research have been studied, such as collaborative planning, performance measurement, strategies alignment, partners' selection, interoperability, data sharing [1]. Current globalised market environments involve open data movement contributing to the wide availability of such data. Nevertheless, earlier approaches to collaborative networking are constrained by the scarcity of data and technologies to deal with the fast evolving scenarios, in terms of data (data exchange/change, and data management). Big data focuses on processing and analysing large data repositories that with the conventional tools of analytical databases will be very difficult to treat. Large data repositories are fed by Radio Frequency IDentification, (RFID) sensors and other Internet of Things (IoT) devices that generate data, faster than people do. To this regard, big data requires smart technologies to efficiently process large quantities of data within a tolerable amount of time. Technologies being applied to big data include, amongst others, manufacturing execution system (MES), business intelligent systems (BI) or cloud computing platforms, allowing to process big data or repositories based on distributed, cloud and open source systems [2]. In terms of MES, some authors fulfilled a fundamental need of designing data model for MES [3] [4], which are based on entities relationship models [5]–[7]. These data models are considered to compose the standardised data model for cloud manufacturing collaborative networks.

The main drawback of acquiring technologies for handling big data in CNs, formed by small and medium enterprises (SMEs), is the lack of affordable tools. To achieve the advantages offered from cloud computing capabilities (complex event processing, collaboration technologies, big data management and knowledge processing) enterprises need to start the process of ICT transformation to fulfil the requirements for business innovation and turn technology into competitive advantage. Adopting technologies to deal with collaborative relationships within networked enterprises and adopting future Internet technologies such as cloud computing and data analytics are core competences researchers must deal with in order to support the enterprises technology change.

In this regard, the European H2020 Project Cloud Collaborative Manufacturing Networks (C2NET) develops methods and tools to collect data from real-world and virtualise resources, to collaborate in this data rich world. Addressing data acquisition from different sources interconnected to the C2NET platform and its cloud. Taking into account the diversity and heterogeneity of data resources in CN a proposal of Standardised Data Model is presented to jointly work with existing databases to manage big data collected from different industries belonging to the CN.

In this regard, this paper is structured as follows: Section 2 presents a brief overview of the C2NET project in which the paper is contextualised; in Section 3 the methodology followed in C2NET project to create the standardised data model is presented; in Section 4 the skeleton of the standardised data model is presented with the Standardised Tables (STables) created; Section 5 presents the application of the STables in one of the pilots in the C2NET project, the automotive industry pilot; finally, in Section 6 the conclusions and future research lines are addressed.

2 C2NET Overview

Cloud Collaborative Manufacturing Networks project (C2NET) [8] [9], will build a Cloud Architecture to support SMEs with affordable tools to help them to overcome the barriers appearing when they are willing to participate in a CN. C2NET Project generates a Cloud Architecture composed by [10]: (i) The Data Collection Framework (C2NET DCF) to provide continuous data collection from supply network resources; (ii) The Optimiser (C2NET OPT) to support SMEs belonging to the CN in the optimisation of collaborative manufacturing and logistics assets. C2NET OPT contains a repository of algorithms that compute and optimise different set of individual or collaborative plans related to replenishment, production and delivery; (iii) The Collaboration Tools (C2NET COT), a set of tools in charge of managing the agility of the collaborative processes; and (iv) The Cloud Platform (C2NET CPL) to integrate the data collection module, the optimisers and the collaborative tools in the cloud and allow the access to process collaboration and optimisation resources to all CN partners.

This paper presents part of the results obtained in C2NET project and provides the standardised data model of the C2NET database for gathering structured information in the C2NET DCF. The stored data will be used by: (i) the C2NET OPT as input of the optimisation algorithms designed in the scope of automatically solving replenishment, production, and delivery plans; (ii) the C2NET COT as an input for collaboration workflows, and monitoring of the optimised plans.

The validation of C2NET project is performed through the implementation of the results in four pilots representing the automotive industry, dermo-cosmetics, metalworking SMEs and OEM equipment manufacturer.

3 Data Base Requirement Analysis

The design of C2NET database raises from the need to define standardised terminologies to manage information in multiple locations and with multiple conceptual areas. A common and structured terminology is created in form of Standardised Tables (STables) to have a shared understanding of all the different needs in terms of collaboration and optimisation, for supporting the definition and calculation of replenishment, manufacturing and delivery plans. Namely, C2NET software developers can develop all kinds of functions for collaboration and optimisation planning, on the basis of the database system. In order to build the C2NET database and STables, two approaches have been considered:

The generic approach: A set of generic problems have been identified from the literature, which were classified using the Supply Chain Operations Reference (SCOR) [11]in Source (S), Make (M) and Deliver (D) plans, and combinations SM, MD and SMD. Each plan type classifies the plan subtypes (see figure 1). Around half thousand potential plans were identified in the literature, among which 101 were thoroughly analysed. A detailed analysis has been performed for each of the Literature Plans, regarding the modelling approach, the solution approach, the planning horizon and period, the collaboration level, the algorithm proposed, and the input data, objectives, and output data associated to the algorithm.

The Pilots approach: Some of the generic problems identified in the literature can solve the Pilot problems, while others not. For that reason, the Pilots approach has allowed to identify the Pilot Plans. The input received from the Pilots has allowed identifying problems that include new restrictions to solve the problems that in the generic algorithms have not been considered. Moreover, from the Pilot Plans, a set of input data, objectives and output data have been identified; considering a widespread number of scenarios for building the C2NET database. In this approach, the data that the pilots can provide has been checked, due to sometimes the enterprises do not have available the data required by the algorithms. In this regard, the algorithms must be adapted to the input data that enterprises can provide.

The STables have been built based on the homogenised categories, created to develop a common terminology in C2NET.

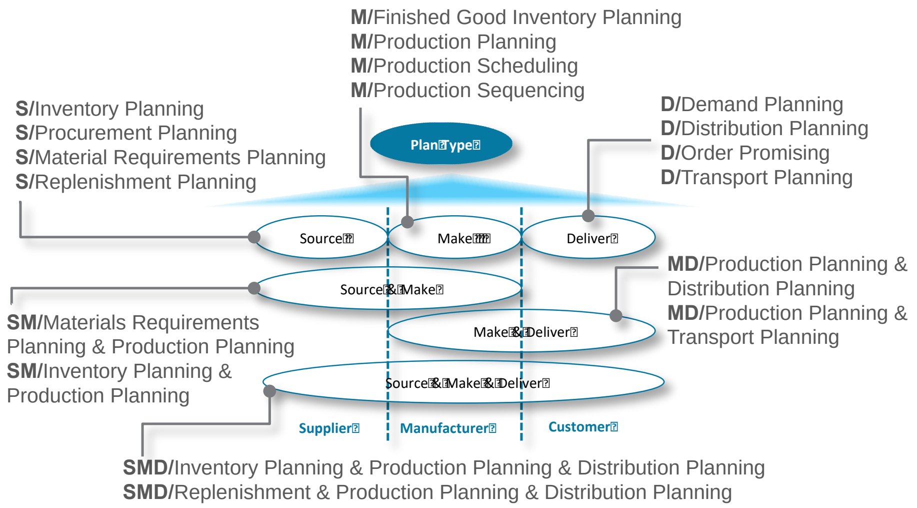

Fig. 1. Plan Types and Plan Subtypes [12][13][14]

4 Data Model: Standardised Tables

The input data, objectives and output data derived from the algorithms reviewed (generic problems) and from the Pilots problems have allowed the completion and refinement of the STables data, according to the needs of the domain modules C2NET DCF, C2NET OPT and C2NET COT. In this regard, STables are built to provide in a structured and standardised way the C2NET data needed.

The STables meta-structure is currently composed by 67 STables (a brief description of each STable is shown in Table 1). The STables are classified into two types: (i) One-dimensional STables which are the master data representing the main entities of C2NET, e.g. the STable *Machine*. This means that the table of Machine will only contain data related to Machine; and (ii) Combined Stables, contains the relations of one or several one dimensional STables; e.g. the STable *Machine_Tool* contains data related to a unique set of machine and tool. This STable contains the field *Setuptime* that is the time needed to setup a specific tool in a specific machine. Each STable contains four fields: (i) fieldname, designation of the field (data) with which the data is identified and/or known; (ii) fieldType, category of the data (string, integer, real, floating-point real number, date, boolean etc.); (iii) fieldUnit, magnitude of the data (length in meters, mass in kilograms, time in hours, etc.); and (iv) fieldDescription, characterisation of the data representing its meaning.

Table1. The Stables of C2NET

STable	Definition
Container	Containers hold Parts for delivery, supply, storage or transport
Customer	Customers buy Parts to the Company
Customer_Order	Associates an Order with a Customer
Customer_Part	Associates a Part with a Customer (parts purchased by the customer to the company)
Customer_Site	Associates a Customer with a Site
Customer_TimeFrame	Associates a TimeFrame with a Customer (available timeslots for supplying parts to the customer)
Labour	Type of Labour of the company
Labour_Period	Associates a Period with a Labour (the number of labours can vary along periods)
Machine	Machines of the company
Machine_Container	Associates a Container with a Machine (the machine needs a number of empty containers to work)
Machine_Labour	Associates a Labour (type of) with a Machine (the machine needs the labour to work)
Machine_Period	Associates a Period with a Machine (the machine can be available or not in such period, or other status)
Machine_Site	Indicates the Site in which the Machine is
Machine_Tool	Associates a Tool with a Machine (the machine needs the tool to work)
Machine_Tool_Labour	Associates a Tool and a Labour (type of) with a Machine (machine needs the tool to work, the tool needs the labour to be setup
Machine_Tool_Period	Associates a Tool with a Machine in each period (the machine and tool can be available or not in such period)
Machine_Tool_Tool	Associates two Tools with a Machine (indicates some characteristics when a tool is setup in the machine having another tool)
Operation	An Operation is a generic phase for changing a thing from one state to another state
Operation_Labour	Associates a Labour (type of) with an Operation (the operation needs the labour to be performed)
Operation_Machine	Associates an Operation with a Machine (the operation needs the machine to be performed)
Operation_Operation	Relate 2 Operations (for establishing sequences)
Operation_Part	Associates a Part with an Operation (the operation needs the part to be performed or generates the part)
Operation_Tool	Associates an Operation with a Tool (the operation needs the tool to be performed)
Order	Generic Order (from a Customer to the Company, or from the Company to a Supplier)
Order_Part	Associates an Order with a Part (the part should be delivered in such order)
Order_Part_Site	Associates an Order of the part with a Site (the part of the order should be delivered in such site)
Order_Period	Associates a Order with a Period
Order_Site	Associates an Order with a Site (the order should be delivered in such site)
Part	Generic Part (raw material, component, final product; purchased or sold by the Company)
Part_Container	Associates a Part with a container (the part needs the container to be stored o transported)
Part_Container_Customer	Associates a Part with a container of a customer (the part of a customer needs the container to be stored o transported)
Part_Container_Machine	Associates a Part with a Container and a Machine. Modelling the picking activity whom load and cost depend on the container (unit, pack, factory box, distribution box, pallet) and the machine used to make the picking activity of the part in the container
Part_Container_Supplier	Associates a Part with a container of a supplier (the part of a customer needs the container to be stored o transported)
Part_Container_Period	Associates a Part with a Customer in a Period (information on such part in the customer in that period)
Part_Machine	Associates a Part with a Machine (the machine produces the part) [a more detailed modelling can be defined using Operation]
Part_Part	Bill of Materials (amount of a part for obtaining one unit of another part)
Part_PartGroup	Associates a Part with a PartGroup (group to which the part belongs)
Part_Period	Associates a Period with a Part (information of the part in such period)
Part_Site	Associates a Part with a Site (the site in which the part is)
Part_Supplier_Period	Associates a Part with a Supplier in a Period (information on such part in the supplier in that period)
Part_Tool	Associates a Part with a Tool (the part needs the tool to be produced)
Part_Vehicle	Associates a Part with a Vehicle (the part needs the vehicle to be transported)
Part_Warehouse	Associates a Part with a Warehouse (the part needs the warehouse to be stored)
PartGroup	Group of Parts
Period	Specifies periods of time (hours, days, week, months, ...)
Person	An individual employee
Person_Labour	Associates a Person with a Labour (a worker able to perform certain type of labour)
Person_Period	Associates a Person with a Period (availability of the worker in such a period)
Route	Generic route
Route_Site_Site	Associates a pair of Sites with a Route (for creating a complete route from the initial site to the end site)
Route_Vehicle	Associates a Vehicle with a Route
Site	Specifies a Site (a location, for a factory, distribution centre, customer, supplier, etc.)
Site_Site	Associates a Site with another Site (information between both Sites)
Site_Site_Vehicle	Associates a Site with another Site and a Vehicle (information between both Sites using the Vehicle)
Supplier	Suppliers deliver Parts to the Company
Supplier_Order	Associates an Order with a Supplier
Supplier_Part	Associates a Part with a Supplier (parts purchased by the company to the supplier)
Supplier_Site	Associates a Supplier with a Site
Supplier_TimeFrame	Associates a TimeFrame with a Supplier (available timeslots for receiving part from the supplier)
TimeFrame	Generic timeframe
Tool	Tools of the company
Tool_Labour	Associates a Labour (type of) with a Tool (the tool needs the labour to setup)
Tool_Period	Associates a Period with a Tool (the tool can be available or not in such period, or other status)
Vehicle	Vehicles of the company
Vehicle_Period	Associates a Vehicle with the period (the vehicle can be available or not in such period, or other status)
Warehouse	Warehouses of the company
Warehouse_Site	Associates a Warehouse with a Site

5 Application Example of C2NET Standardised Data Model

The application is performed in the automotive pilot of C2NET that is specifically for solving the collaborative problem of a Materials Requirement Plan (MRP) between the First Tier and the Second Tier suppliers of an automotive enterprise. The structure of the STables and Fields required for solving the collaborative MRP are presented in Figure 2.

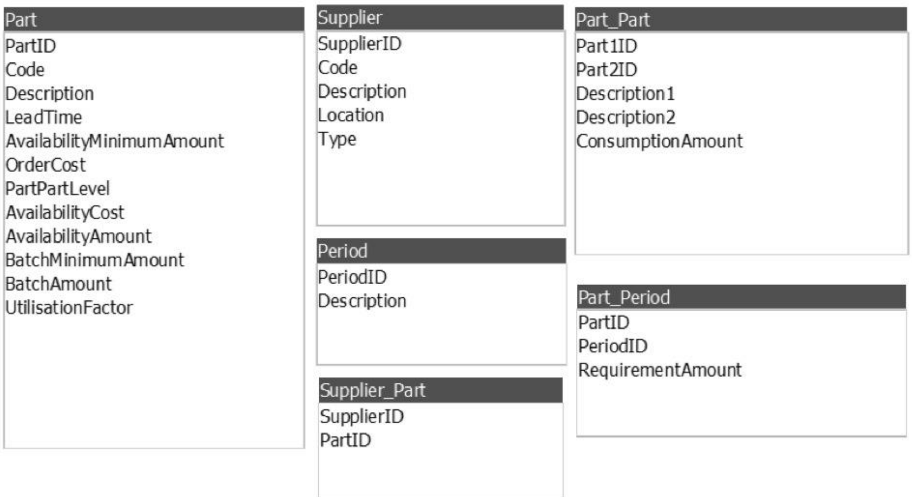

Fig. 2. Data structure required to solve the collaborative MRP.

Table 2 shows the description of each of the fields required for solving the collaborative MRP as an illustrative example of the input data sets needed and how they are structured.

Table 2. Description of each of the fields

STable.Field	Description
Part.PartID	C2NET unique identifier (autonumeric) for a part (product, raw material, component…)
Part.Code	Company unique identifier for a part
Part.Description	Company description of a part
Part.LeadTime	Supply time of the raw material/component from the supplier to the manufacturer or delivery time of the product from the manufacturer to its customer
Part.AvailabilityMinimumAmount	Minimum inventory of parts, e.g. safety stock
Part.OrderCost	Cost of order release
Part.PartPartLevel	0: product; 1: subassembly; 2: semi-finished; 3: standard; 4: raw material
Part.AvailabilityCost	Inventory cost per unit of the part
Part.AvailabilityAmount	Current amount of parts available in the inventory
Part.BatchMinimumAmount	Minimum lotsize of parts
Part.BatchAmount	Lotsize of parts taken
Part.UtilisationFactor	Percentage of parts with the required quality (e.g. 85% of the produced parts are within the quality boundaries, the other 15% remaining parts are scrap). The value is given

STable.Field	Description
	in base 1.
Period.PeriodID	C2NET unique identifier (autonumeric) for a period (hour, day, week, month…)
Period.Description	Company description for the period
Supplier. SupplierID	C2NET unique identifier (autonumeric) for a supplier
Supplier.Code	Company unique identifier for a supplier
Supplier.Description	Company description of a supplier
Supplier.Location	Location of a supplier (e.g. address)
Supplier.Type	Types of suppliers e.g. potential suppliers, current suppliers…
Part_Part.Part1ID	C2NET unique identifier (autonumeric) for a Part1 that is the parent item of Part2
Part_Part.Part2ID	C2NET unique identifier (autonumeric) for Part2 that is the child itemof Part1
Part_Part.ConsumptionAmount	Amount of a Part2ID consumed to create one unit of Part1ID
Part_Period.Part	C2NET unique identifier (autonumeric) for a part
Part_Period.Period	C2NET unique identifier (autonumeric) for a period
Part_Period.RequirementAmount	Demand of a part in a period
Supplier_Part.Supplier	C2NET unique identifier (autonumeric) for a supplier
Supplier_Part.Part	C2NET unique identifier (autonumeric) for a part

6 Conclusions and Future Work

The growing amount of data to be handled by CNs, raises the need of introducing innovative solutions to fulfil the lack of affordable tools, especially for SMEs, to manage and exchange data. Considering that there is a need to better understand the potential for value creation through collaborative approaches, this paper presents a standardised data model for manufacturing CN, where organisational data exchange can be highly improved, from the proposed generic and adaptable standardised data model, playing an important role when data sharing and management is carried out in manufacturing CNs.

The STables were defined with the aim of creating a common terminology of C2NET data from the input data, objectives and output data extracted from the generic problems (literature algorithms) and the Pilot problems (developed algorithms).

The process of defining STables is not considered as completely finished, on the contrary, it is under continuous development. The generation of STables depends on (i) the results obtained in the work developed in C2NET project (ii) the new requirements appearing in the implementation and validation of C2NET project, and (iii) further needs that could emerge a posteriori in the exploitation phase, when C2NET project finishes, and when C2NET is implemented in other industrial sectors and contexts.

Acknowledgments. The research leading to these results is in the frame of the "Cloud Collaborative Manufacturing Networks" (C2NET) project, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 636909.

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