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A Conceptual Framework for Data Sharing and Exchanging in the Extended Enterprise

Moramay Ramírez-Hernández [1], Yacine Ouzrout [2], Omar López-Ortega [3] and Abdelaziz Bouras [4]
[1,3]CENTRO DE INVESTIGACIÓN EN TECNOLOGÍAS DE INFORMACIÓN Y SISTEMAS
Universidad Autónoma del Estado de Hidalgo
[2,4] INSTITUT UNIVERSITAIRE DE TECHNOLOGIE
Université Lumière Lyon 2
[1,3] MÉXICO - [2,4] FRANCE
[1]moramayrh@hotmail.com, [3]olopez27@prodigy.net.mx, {[2]yacine.ouzrout, [4]abouras}@univ-lyon2.fr

Abstract: - Data sharing and exchanging is a critical factor for theparticipants of an Extended Enterprise to appropriately integrate their information systems along the product life-cycle. The proposed conceptual framework consists in a formalization of the Extended Enterprise based on the relations among data sets regarding Product, Resources,Manufacturing Process and Organizations. The activities for information exchange are finite state machines that relate elements of the mentioned data sets. Such a conceptual model is a framework where standardized technical found in MANDATE, PLIB and STEP resides coherently.

Key-Words: - Extended Enterprise, Data Models, Data Sharing, Conceptual Framework

1 Introduction

Manufacturing Systems enabled by information technologies are taking an outstanding place in global economy. Data regarding product design, manufacturing processes and resources is continuously shared and exchanged among enterprises to elaborate a final product. So, appropriate information technologies are required along the product life-cycle to reduce incompatibility barriers. One approach to increase integration is by means of software interoperability, as reported in [16]. However, standardized data models have been already created and presented as International Standards. This is the preferred approach up to date. Moreover, coherent integration to enhance data exchange in an Extended Enterprise context is still needed, being this framework the main contribution of this paper.

Manufacturing companies are aimed at creating their own Extended Enterprise. "An Extended Enterprise is a venture of enterprises that share capabilities and resources to respond to business opportunities. The cooperation among them is enabled by Information Technologies, so that the participants coordinate and cooperate as a single unit" [6]. Enterprises organize to design products, share resources and capabilities by means of collaborative data exchanging. Each participant specializes on those business processes where it has outstanding experience or talent, so that its competency is shared to other members through an open data repository, where the participant writes its own data and it is also capable of reading data regarding others.

As stated in [1] the effectiveness of the network structure is highly dependent on the use of Information Technology, which makes easier the coordination of interdependencies. A requirement for the proper integration of enterprise is a compatible definition of product and processes [5]. Such a compatible definition implies the agreement among the members of the Extended Enterprise of the terms to be used in the information system, so that no misunderstandings arise.

Therefore, to support the Extended Enterprise, each participant is required to share and exchange its own data, by using open information systems. Of particular importance is the data of those entities that are necessary along the product life-cycle, since its conception until its recycling. As the number of participants of the Extended Enterprise as well as the amount of information being exchanged is high, it is necessary to agree on the semantics and the syntax of the data. Standardized data models presented in STEP [12], MANDATE [11], and PLIB [10] are helpful to overcome this obstacle. At this respect, an effort has been made to ntegrate the PLIB standard with some schemas of the STEP standard [13], where data regarding product identification is integrated with the components that make the product up.

The present paper describes an entity-oriented

analysis of the data that is necessary to exchange, and the actions to exchange data that actually take place. The analysis starts with the creation of a formal Extended Enterprise framework. Upon the construction of this framework, information sharing actions models where created to define the behavior of each participant. Afterwards a case study is presented to exemplify the soundness of the framework. The dynamics of the Extended Enterprise is out of the scope of this paper.

2 Formalization of the Extended Enterprise

In an Extended Enterprise each participant exchanges data in order to synchronize its business processes, either locally or globally. Several proposals have been presented regarding data exchange in specific domains for an Extended Enterprise, see for example [4]. However, it is possible to say that no consensus has been reached regarding a formal structure of the data exchange process. Therefore, our first step consisted in the development of a Framework of Extended Enterprise around three important notions: Data Sets, Information Exchange Actions, and the liaisons among the participants.

2.1 The Extended Enterprise Conceptual Framework

The Extended Enterprise can be formalized as a family of data sets regarding the used Resources, the Product to be manufactured, the Organizations and the Manufacturing processes that take place. Data from these these elements is needed to produce both the final product and the intermediate components. Each of these data sets is called Extended Enterprise Elements Sets or E^3S.

$$E^3S = \{\{E^3S_r\}, \{E^3S_m\}, \{E^3S_p\}, \{E^3S_o\}\} \quad (1)$$

Therefore

$$E^3S_i \subset E^3S \quad (2)$$

Where sub index i may take the following values: r for Resources, m for Manufacturing processes, p for Product, and o for the Organizations.

Moreover, each E^3S_i is also a family of sets that contain the actual data required to define the information system. For example, a given Extended Enterprise can be formed by several *organizations*: a Component Manufacturer, a Main Manufacturer, one of more Warehouses and Clients. However, another Extended Enterprise may be formed by erasing the warehouse for the sake of minimizing storage cost. In both cases, the set E^3S_o must contain families of organizations, which had agreed to cooperate on a long-term basis regardless the actual configuration of the network.

This notion can be generalized to state:

$$E^3S_i = \{\{E^3S_{i1}\}, \{E^3S_{i2}\} \cdots \{E^3S_{in}\}\} \quad (3)$$

$$E^3S_{in} \subset E^3S_i$$

Different relationships exist among the organizations in an Extended Enterprise, as noted in [8]. Also in [2] it is described how the same organizations that had agreed to create a long-term relation via en Extended Enterprise, may arrange themselves in different ways. The interesting point to remark is that for a given set of products, processes, resources and organizations, the *shape* of the Extended Enterprise may be different. That is to say, the same companies, sharing the same resources for a given final product, may vary their form of cooperation, according to the *liaisons* among them. Therefore the number of possible liaisons is obtained by the following equation:

$$L = E^3S_i \times E^3S_i \quad (4)$$

That is to say, the liaison L is a *4-tuple* that relates resources, manufacturing processes, products and organizations:

$$L(E^3S_r, E^3S_m, E^3S_p, E^3S_o)$$

Given set L, there exists a subset S that contains specific liaisons in an Extended Enterprise:

$$S \subset L \quad (5)$$

$$l_i^{i+1} \in S$$

Element $l_i^{i+1} \in S$ is called the *liaison predicate*, that is to say, a sentence that relates an element

$$e_i \in E^3S_i$$

with another element $e^{i+1} \in E^3S_i$. Therefore, the set S contains all the liaisons predicates that conforms the actual shape of the Extended Enterprise.

2.2 The E^3S_i Sets

The information along the product life-cycle may be classified in three standardized groups regarding Product, Manufacturing process and Resources, plus another regarding Organizations (although this last data group is not standardized yet).

Specifically, the *Product* group contains all those entities used to describe product features and constraints. On the other hand, the *Manufacturing Process* group contains entities that are used to define processes, times, management and so on. Our classification defines a third data group regarding the actual manufacturing *Resources*. Finally we define the *Organizations* data group, where data regarding Suppliers, components Manufacturers, Storage Locations and so on, is defined. This approach is similar to the one presented in [15], where a set of all durable resources (employees, equipment, facilities) is called R_f. In our framework each entity e that belongs to one of the three families of sets may be defined according to the next equation:

$$\exists e_i | e_i \in E^3S_{in} \wedge E^3S_{in} \subset E^3S_i \tag{6}$$

For a given Information Exchange Action, one or more elements e_i are requested or given to the information system. The Information Exchange Actions are defined in the next section.

2.3 Information Exchange Actions

The set of all the actual actions that take place when exchanging data is called IEA. This set is defined next:

$$IEA = \{iea_1, iea_2 \cdots iea_k\} \tag{7}$$

The relationships among the previous families of sets are described next. Element $e_i \in E^3S_i$ is the entity actually exchanged during the execution of action $iea_i \in IEA$. Also, in the proposed framework, an element p_a^e relates, for a given $iea_i \in IEA$, an element $e_i \in E^3S_i$.

Each $iea_i \in IEA$ is actually a finite state machine, which initializes when a given organization $o \in E^3S_o$ requests data, and terminates when the data is either donated successfully or not. All the IEA's that take place can be modelled by using Use Cases in order to determine, from a software engineering perspective, the interaction of the organizations with the information system.

2.4 Participants

Two types of participants exist in any Extended Enterprise, according to their role as information processors. They are either Active Participants (AP) or Passive Participants (PP). An Active Participant is any entity that either initiates or responds to Information Exchange Actions (IEA), whereas a Passive Participant only responds to them. Therefore, let P be the family of sets that contains all the Passive Participants and all the Active Participants in an Extended Enterprise:

$$P = \{\{AP\}, \{PP\}\} \tag{8}$$

where

$$AP \subset P$$

$$AP = \{ap_1, ap_2, \cdots, ap_n\}$$

and

$$PP \subset P$$

$$PP = \{pp_1, pp_2, \cdots, pp_m\}$$

From the previous equation two sets are yield. The set AP contains all the Active Participants of an Extended Enterprise, whereas set PP contains all the Passive Participants of an Extended Enterprise. It is important to say that a Participant is actually an element $o \in E^3S_o$, that participates either requesting, donating or receiving data. This classification os important in order to construct the interactions of each participant with the information system.

3 The Data Sets of the Extended Enterprise

The conceptual framework is an abstraction that makes reference to entities as elements of proper subsets, exchanged by information exchange actions. However, to prove the validity of the model it is necessary to expand it and define the concrete elements of it. Specifically, we elaborate on the elements regarding Organizations and Resources. With the example of section (4) the complete framework is used to describe a particular kind of Extended Enterprise.

It is important to remark that most of the elements are already described in the scientific literature, therefore we do not propose an exhaustive description of each particular set. Our main contribution is to present a framework where this vast amount of entities resides harmoniously.

3.1 Resources

In this subsection we propose to integrate the family of sets that define E^3S_r as described next.

Let:

$$E^3S_{r1} \subset E^3S_r = RIS$$

be the Resource Information Set,

$$E^3S_{r2} \subset E^3S_r = MMIS$$

be the Manufacturing Management Information Set, so:

$$E^3S_{r1} = RIS = \{r|r \in RIS \wedge RIS \subseteq E^3S_r\} = \{Resource, ResourceView, ResourceDomain, ResourceType\} \quad (9)$$

The rationale to include this set of entities is found in [7].

$$E^3S_{r2} = MMIS = \{m|m \in MMIS \wedge MMIS \subseteq E^3S_r\} = \{Capacity, Capability, ProcessTime, ProcessCost, ResourceQuantity, ResourceGroup, ResourceProfile\} \quad (10)$$

The totality of elements in the previous set are those of the ISO standard called MANDATE [11], as it contains standardized entities regarding manufacturing management information systems.

3.2 Product

This subsection concerns the integration of the family of sets that define E^3S_p as described next. Let:

$$E^3S_{p1} \subset E^3S_p = DCIS$$

be the Design Constraints Information Set,

$$E^3S_{p2} \subset E^3S_p = CIS$$

be the Component Information Set, so:

$$E^3S_{p1} = DCIS = \{d|d \in DCIS \wedge DCIS \subseteq E^3S_p\} = \{ProductConfiguration, ProductModel, ProductDesign, ProductFile\} \quad (11)$$

These elements are mainly those that represent the basic entities that describe a product, according to the STEP standard [12]for details.

$$E^3S_{p2} = CIS = \{s|s \in CIS \wedge CIS \subseteq E^3S_p\} = \{Component, Supplier, ComponentFamily\} \quad (12)$$

The totality of elements that conform this set are those of the PLIB standard [10], as it contains appropriate entities for the computer-sensible representation and exchange of part library data and its suppliers.

3.3 Manufacturing Process

A proposal to integrate the family of sets that define E^3S_m is described next. Let:

$$E^3S_{m1} \subset E^3S_m = MPIS$$

be the Manufacturing Process Information Set,

$$E^3S_{m2} \subset E^3S_m = RCIS$$

be the Real-life Constraints Information Set, so:

$$E^3S_{m1} = MPIS = \{p|p \in MPIS \wedge MPIS \subseteq E^3S_m\} = \{Operation, Tool, DueDate\} \quad (13)$$

The process planning entities were yield according to a proposal found in [9] and [17].

$$E^3S_{m2} = RCIS = \{rl|rl \in RCIS \wedge RCIS \subseteq E^3S_m\} = \{Time, Cost, DueDate, Worker, Component\} \quad (14)$$

In [3] this last set of entities are described.

3.4 Organizations

Here we propose to integrate the family of sets that define E^3S_o. The formal definitions are made in the same way as in the case of the E^3S_r families, so we only present the actual content of the E^3R_o.

The proposed E^3S_o families are:

$$E^3S_{o1} = PIS = \{r|r \in PIS \wedge R \subseteq E^3S_o\} = \quad (15)$$

$$\{Manufacturing, Assembly, Design\}$$

This family refers to the sets that define design, manufacturing or assembly facilities.

$$E^3S_{o2} = WIS = \{r|r \in PIS \wedge R \subseteq E^3S_o\} = \{Warehouse, StorageCenter\} \quad (16)$$

This family refers to the sets that define facilities to store items.

$$E^3S_{o3} = CIS = \{r|r \in PIS \wedge R \subseteq E^3S_o\} = \{InternalClient, ExternalClient\} \quad (17)$$

This family refers to the sets that define the types of Clients in an Extended Enterprise.

$$E^3S_{04} = DIS = \{r|r \in PIS \wedge R \subseteq E^3S_o\} = \{Retailer, DistributionCenter, Dealer\} \quad (18)$$

This family refers to the sets that define the organizations in charge of distributing the final product to the Clients.

4 The case study

This case study was first presented by Biswas in [14]. The Extended Enterprise consists of import facilities, storage facilities, dealers, bottling plants and industrial customer. The product are cylinders of liquid petroleum gas, and it is transported with trucks or tankers, from one organization to another. The raw material (LPG) is transported with pipelines to the storage facilities. The Extended Enterprise is defined by families of Resources, Organizations and Products:

$$E = \{\{E^3S_r\}, \{E^3S_o\}\ \{E^3S_p\}]$$

Where:

$$E^3S_o = \{\{Plant\}, \{Customer\}, \{Storage\}, \{Distributor\}\}$$

whereas

$$E^3S_o = \{\{Vehicles\}\}$$

and

$$E^3S_p = \{\{Cylinder\}\}$$

Therefore:

$$E^3S_{o1} = Plant = \{BottlingPlant\}$$

$$E^3S_{o2} = Customer = \{IndustrialCustomer, DomesticCustomer\}$$

$$E^3S_{o3} = Storage = \{Warehouse, Port\}$$

$$E^3S_{o4} = Distributor = \{Dealer\}$$

The resources set is:

$$E^3S_{r1} = Vehicles = \{Pipeline, Tanker, Truck\}$$

While the Product set is:

$$E^3S_{p1} = Cylinder = \{IndustrialCylinder, DomesticCylinder\}$$

$$E^3S_{p2} = RawMaterial = \{LPG\}$$

Once the family E^3S_i has been defined, the set L is formed by 2^E. Next, set $S \subset L$ is formed by those *liaison predicates* which actually relate the elements of the Extended Enterprise. For example,

$$l^o_{r1} = connects(Warehouse, Pipeline)$$

is a *liaison predicate*. It means that element *Pipeline* $\in E^3S_{r1}$ *connects* with element *Warehouse* $\in E^3S_{o3}$. The complete set S contains all the actual relations that conform the shape of the Extended Enterprise.

Some of the Information Exchange Actions are modelled as follows:

$$IEA = \{\{iea_1\}, \{iea_2\}\}$$

where iea_1 = *Customer request Product* and iea_2 = *Customer informs Product is received.* As can be noted, the succession of IEA define the actual interaction of a participant, either requesting or giving data.

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