Towards a Meta-Model for Networked Enterprise

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Abstract. To deal with challenges as globalization and fast-changing environments, enterprises are progressively collaborating with others and becoming a Networked Enterprise (NE). In this context, Enterprise Interoperability (EI) is a crucial requirement that needs to be verified by enterprises when starting a relationship to avoid interoperability problems. The concepts of NE and EI are not easy to understand due the variety of interpretations that exist in the literature. Having a clear and shared understanding of the NE and the different interoperations between partners is a necessity to manage the interoperability development. In order to reach such an objective, this research work defines a meta-model for NE based on a systemic approach. Concepts related to EI are taken into account to highlight the importance of this ability (i.e. Interoperability), seen as a requirement, within a system to attain its targeted goals. Finally, a real case study is proposed to validate the defined meta-model.

Keywords: Networked Enterprise, Enterprise Interoperability, Meta-Model, Systemic approach.

1 Introduction

Contemporary enterprises face a variety of challenges in the increasingly dynamic socio-economic environment where they evolve. Challenges such as globalization, novel technologies, financial crisis, the need for cost reduction and new markets are change-drivers that require transformation within companies and their environments. These challenges can be illustrated by the growing number of start-ups around the world; the rapid evolution of information and communication technologies (ICT) that offers, paradoxically, opportunities (e.g. ease the long-distance communications) and threats (e.g. incompatibilities between communication protocols); the boost of customized products demand, etc. In order to deal with these challenges, enterprises are progressively collaborating with each other and participating to a so-called

Networked Enterprise (NE) [1], [2], [3], [4], [5]. The concept of NE is commonly confused with Collaborative Network [6], Enterprise Networks [7], [8] and Value Network [9], [10]. In the NE context, interoperability [11], [12], [13], is a crucial requirement having to be verified by enterprises when starting a relationship with others to attain shared goals [14], [15]. As soon as this requirement is not achieved when systems or system's elements need to operate together, interoperability becomes a problem that must be solved [16]. Many research works were proposed in the literature to study Enterprise Interoperability (EI) and propose related frameworks such as: the Athena Interoperability Framework (AIF) [17], the IDEAS Interoperability Framework [12], the Framework for Enterprise Interoperability (FEI) [18], [19], the Classification Framework for Interoperability of Enterprise applications [20], the Ontology of Enterprise Interoperability (OoEI) [16], [21] etc. Among these, the particularity of the OoEI is its basis on the other cited researches and its unicity in defining the EI concepts in a systemic approach [22]. Having a systemic view is very important and widely used in Enterprise Modelling (EM) [23] because it provides a component-oriented view, which reflects closely the reality of enterprise functioning. According to Giachetti [24], an enterprise is *a complex, socio-technical system that comprises interdependent resources of people, information, and technology that must interact with each other and their environment in support of a common mission*. As part of a network, an enterprise can also be seen as part (i.e. System element or component) of a more complex system: the network. Having a clear and shared understanding of the NE and the different interoperations between partners is a necessity to manage the interoperability development, including the detection and prediction of problems at the early stage. Thus, the following research question is raised: *How can we establish a common and clear understanding of the NE and its interoperations?* To answer this question, an analysis of the different perspectives of both concepts (i.e. NE and EI), as well as, the representation of the relations between them are required. This raises a new research question: *How can we design the interoperability in the context of Networked Enterprise?*

The main objective of this work is to develop a common understanding of the Networked Enterprise domain and the interoperability issues involved in the design of such network. This is tackled through the proposition of a meta-model for Networked Enterprise (NE), that we call the "Networked Enterprise Meta-MOdel" (NEMO). This meta-model is defined based on the Design-Science Research (DSR) methodology [25], [26] and uses a systemic approach to describe the NE elements. The identification of the NE elements and characteristics are based on the definitions and interpretations proposed in the literature [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]. Concepts related to the interoperability domain are mainly taken into account based on the OoEI [16], [21].

The reminder of this paper is as follow – Section 2 gives an overview of the research methodology applied for this research. Section 3 presents the relevant related work. This is followed by Section 4 where the NEMO is proposed. Section 5 illustrates a real case study based on an active NE in the field of marketing and communication in Luxembourg. The conclusion and future work are brought forward in Section 6.

2 Research Methodology

In order to answer the research question and to achieve the research objective, this work is based on a simplification of the design-science research (DSR) as proposed by [25], [26]. The methodology applied is divided according to the two processes (*Build* and *Evaluate*) and the research outcome [27]. The *Build* process is composed by two stages: The *conceptual definition* where we proceed with the literature study on Networked Enterprise interpretations together with Enterprise Interoperability concepts. Also, at this stage, the identification and definition of the concepts that are presented in section 3 are performed. The second stage is the *construction* of the meta-model presented in Section 4. An analysis of the relation between NE and EI concepts is required in this stage to understand the proposed meta-model. The *Evaluate* process is done based on the observational case study. This is illustrated through a real case study in section 5.

3 Conceptual Definition - Related work and Positioning

This section presents some of the different definitions and interpretations that have been found in the literature about Networked Enterprise. This will allow the identification of the main properties that need to be considered in this domain and propose a general definition that can serve as a consensus and be used in different contexts. The ability to interoperate, as a key factor within the NE, is also studied through the OoEI and the interoperability requirements that should be satisfied to reach the objectives of the network. The concepts identified in the following subsections are then used to describe interoperability and related properties in the proposed meta-model.

3.1 Networked Enterprise

The notion of "Networked Enterprise" is ubiquitous, but hard to understand due the variety of definitions and interpretations. In [1], NE is defined as *"any coordinated undertaking that involves at least two autonomous parties that interact using information and communication technology (ICT)"*. NE is also considered as *"loosely coupled, self-organizing network of enterprises that combine their output to provide products and services offerings to the market. Partners in the networked enterprise may operate independently through market mechanisms or cooperatively through agreements and contracts"* [2]. In [5], the authors define NE as "*linked companies that collaboratively aim at enabling or implementing the collective Business Model by means of offering service and product and/or sharing resources and competencies*". In [6], the expression "collaborative network" is used to define *"a network consisting of a variety of entities (e.g. organizations and people) that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals, but that collaborate to better achieve common or compatible goals, thus jointly generating value, and whose interactions*

are supported by computer network". In [7], the authors use the term "enterprise network" to define "*two or more participating enterprises are engaged in the supply and receipt of goods or services on a regular and on-going basis. Within enterprise networks, partners rely on each other and the supply of goods (or services) will be constrained by the associated logistics, manufacturing commitments and the operating dynamics of the participating enterprises"*. In [10], the author use the term "Value Network" to define *"a dynamic network of actors working together to generate customer value and network value by means of a specific service offering, in which tangible and intangible value is exchanged between the actors involved"*.

Although, these definitions are based on different context and have different point of views (e.g. technological, manufacturing, industrial, etc.), we can notice that some similar characteristics are considered among these work, such as: the necessity of a NE to be composed by **at least two autonomous** enterprises and the **ability to collaborate** to achieve a **shared objective**.

When adopting a systemic view and being inspired by these common characteristics, we define a **Networked Enterprise** as: *"a system composed of at least two autonomous systems (enterprises) that collaborate during a period of time to reach a shared objective"*.

3.2 The Ontology of Enterprise Interoperability

In the past years, researchers and practitioners have proposed numerous definitions for interoperability [11], [12], [13], [17], [18], [19], [28]. In this research work, we consider a general systemic approach of interoperability, where interoperability is first viewed as a problem to solve: *An interoperability problem appears when two or more incompatible systems are put in relation* [29]. Then, when taking the view of interoperability as a goal to reach, we can also write: *Interoperable systems operate together in a coherent manner, removing or avoiding the apparition of related problems* [30]. To have a clear understanding about the Enterprise Interoperability, we need to study the core concepts and elements of the EI and the operational entities where interoperations take place within an enterprise. These are mainly defined by the OoEI, where interoperability is seen as a problem caused when incompatible systems are put in relation. Its main purposes are to have a common understanding about interoperability and to diagnose *a priori* and *a posteriori* [31] interoperability problems and propose solutions. The EI problems and solutions concepts are related to the three Interoperability dimensions, as defined in the FEI [18], [19]. These are: *Interoperability aspects* (conceptual, organizational and technical), *Interoperability concerns* (business, process, service, and data) and *Interoperability approaches* (integrated, unified and federated). The OoEI includes a systemic model, having a systemic core centered on the notion of the system and its properties, and a decisional model that constitutes the basis to build a decision-support system for EI.

Aligned with the systemic approach used by the OoEI, an enterprise can be decomposed into three main sub-systems [32]: *an operating or physical system*; *a decisional or pilot system*; and *an information system*. In [33], the authors used the

GRAI Integrated Methodology [34] to represent the enterprise sub-systems as depicted in Fig.1.

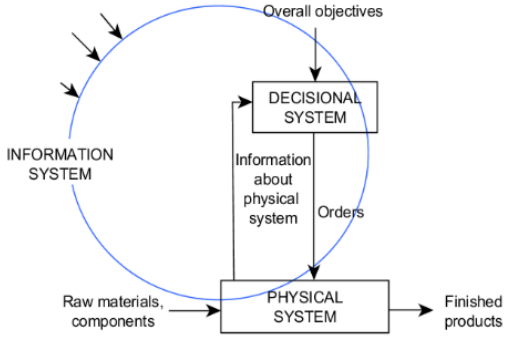

Fig. 1. The three subsystems from an enterprise [34]

In the Fig. 1, the decisional system ensures the overall objectives of the enterprise taking them as inputs to send orders to the physical system. Furthermore, to determine how to control the operating system in order to successfully achieve the system goals and objectives, the pilot system communicates with the environment relating to the system's goals, accepting orders, making commitments and exchanging any other information with the environment that is necessary. The decisional system relies on models of the physical system to make its decisions. However, for these models to reflect reality to a sufficient degree, the decisional system must receive information, or feedback, from the physical system.

As the main objective of this research is to define a meta-model for NE while taking into account the different interoperations between stakeholders, the OoEI and the Enterprise-as-Systems concepts seems to be perfect candidates to be considered in the development of the proposed meta-model since they are grounded in systemics and have a problem-solving perspective.

3.3 Interoperability Requirements

Interoperability is a crucial requirement having to be verified by systems when being in relationship with other systems in order to assume a common mission [15]; where systems are considered as enterprises or parts of enterprises that need to interact in a collaborative and common process with other enterprises or part of enterprises to achieve a common goal [15]. Considering this perspective, the authors in [14] proposed an approach based on the requirement engineering [35], [36] that can be used to describe and structure interoperability requirements that are related to any interoperability problem that may obstruct a collaborative process. The definition proposed is the following: "*an Interoperability Requirement is a statement that specifies a function, ability or characteristic, related to the capacity of a partner to ensure its partnership regarding compatibility, interoperation, autonomy, and reversibility, which it must satisfy''* [14]. In [21], a list of 48 best practices, which can be understood as requirements, were proposed. These best practices describe the

"what to do" in broad terms so that enterprises are left great leeway in creatively implementing the "how to do it".

As soon as these interoperability requirements are not fulfilled, interoperability becomes a problem that needs to be solved. To deal with that, evaluations can be performed to assess the strengths and weaknesses of the considered system. Numerous assessment methods were proposed in the literature such as: the Compatibility Matrix [37], the formal metrics to evaluate the semantic interoperability between systems [38], the Interoperability Score [39] and several maturity models [31], [40], [41], [42], [43]. This stays out of the scope for this paper and will be investigated in future work.

The interoperability requirements are fundamental assets to support the management of the interoperability development as they can be used as indications to identify interoperability problems. Hence, the interoperability requirements and related concepts will be also considered in the design of the proposed meta-model.

4 Construction stage - The Networked Enterprise Meta- Model

In this section we define relevant concepts and definitions used to build the "Networked Enterprise Meta-Model" (NEMO).

Based on related work, we have defined a networked enterprise as: "a system composed of at least two autonomous systems (enterprises) that collaborate during a period of time to reach a shared objective". (C.f. section 3.1).

In this context, the **Objective** represents the system's goal (NE goal) at a given time [16]. This Objective should be compatible with the objectives of the **Enterprise members** that compose the NE and their businesses. This Objective can be described as a *short-term objective*, where there is a temporary alliance to seize a particular business opportunity or *long-term objective*, where enterprises have a stable collaboration that is not limited by only one business opportunity. The objective of the NE should also be aligned with its **Function** (i.e. Business), which represents the set of actions that the system can execute in its environment, to achieve its objectives [16]. Based on that, the NE can have different organizations, called also **Classification** [6], [7] [44], [45], [46], [47].

A Networked Enterprise has its **Lifecycle** representing the different phases that a given networked enterprise may pass through. We define five stages based on [6], [48]: (a) *Creation* is the stage when the networked enterprise is started. It includes the strategic planning, the recruiting, the organizational structure constitution and the setting up; (b) *Operation* is the operating stage of the networked enterprise; (c) *Evolution* is the stage when small changes in membership, roles and work methods happen; (d) *Transformation* is the stage when significant changes in objectives, principles and membership happen, leading to a new form of organization; (e) *Decomposition* is the stage when the networked enterprise ceases to exist.

To be part of the NE there are defined **Requirements** specifying the ability or characteristic that must be satisfied in a given context [35], [36] to avoid problems, mainly the ones related to interoperability. The **Interoperability Requirements**

concept adopted here refers to the ability of partners to ensure the compatibility, interoperation, autonomy and reversibility requirements of a NE [14]. Where a compatibility requirement specifies a function considered to be invariable throughout the collaboration and related to interoperability barriers for each interoperability concern. An interoperation requirement specifies a function considered to be variable during the collaboration, related to the performance of the interaction. An autonomy requirement specifies a function related to the capacity of partners to perform their governance and maintain their operational capacity during collaboration. A reversibility requirement specifies a function related to the capacity of a partner to go back to its original state after collaboration. These requirements are also related to the life cycle stages i.e. each stage has its requirements that need to be fulfilled. The compatibility requirements are mainly related to the creation stage of a NE. The autonomy and interoperation requirements are related to the operation stage. The reversibility requirements are essentially related to the decomposition stage. Fig.2 illustrates an overview of the NEMO model taking into account the concepts defined above.

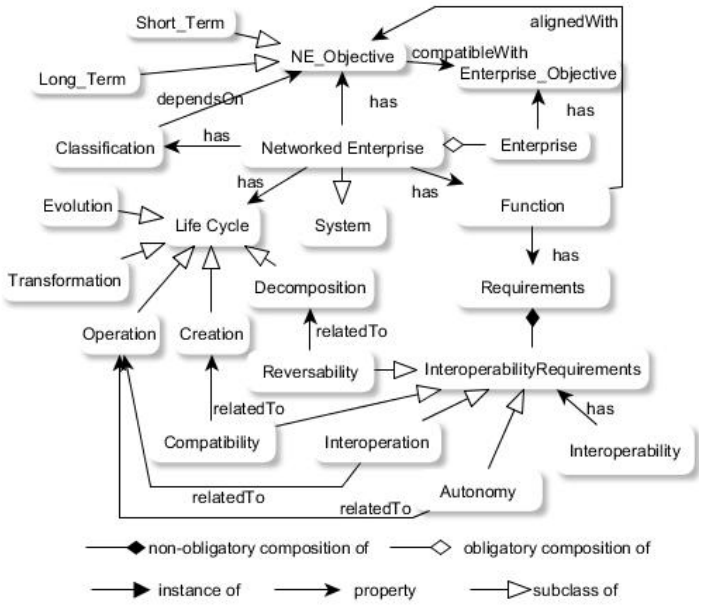

Fig. 2. The NEMO meta-model.

The meta-model gives an extensive view of a Networked Enterprise and its constituents. However it is not enough to realize an accurate characterization of the EI domain because it represents interoperability only as a requirement of a system's function but, as mentioned before, as soon as this requirement is not achieved, interoperability becomes a problem that must be solved. Hence, we combine the OoEI elements because it also considers interoperability from a problem-solving perspective. Therefore, we adopt the following concepts: *EnterpriseInteroperability***,**

EnterpriseInteropDimensions, InteroperabilityAspect, InteroperabilityConcern, InteroperabilityApproach, InteroperabilityBarrier, Problem, ExistenceCondition, Incompatibility, and *Solution.*

Solution uses interoperability approaches to remove interoperability barriers and solve problems. Fig. 3 shows the OoEI concepts (identified by the prefix "*OoEI:"*, and the grey color) integrated into the NEMO (elements in white color). Based on the proposed meta-model, we can clearly see both views of the interoperability concept: the interoperability as a requirement between systems willing to collaborate and as a problem when the requirement is not fulfilled.

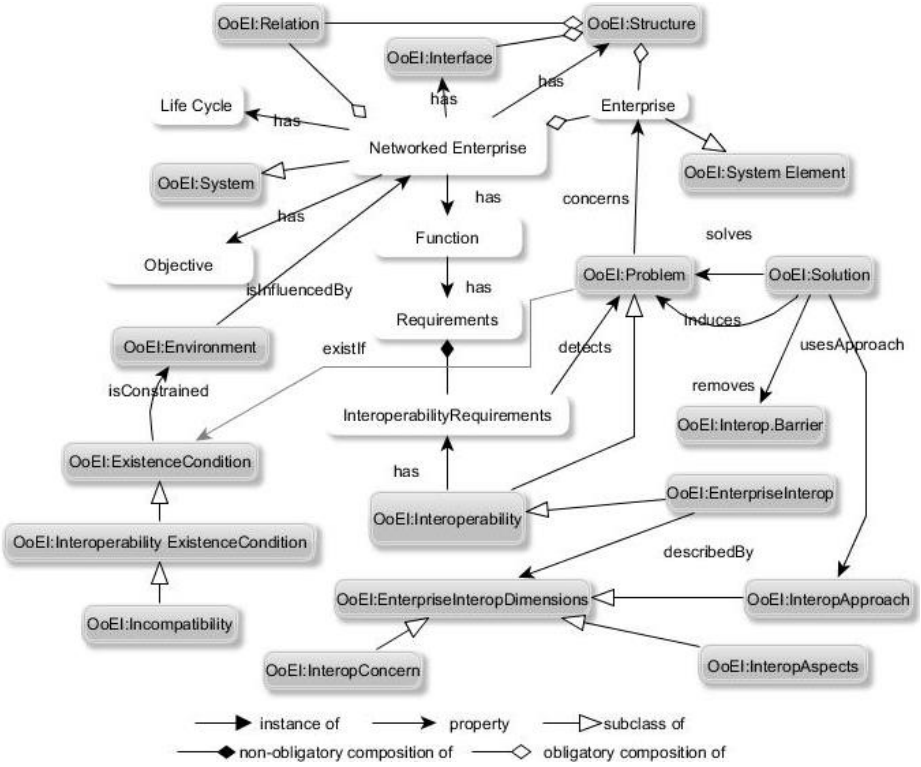

Fig. 3. The NEMO meta-model integrating the OoEI concepts (grey colored).

Considering the Enterprise as System concepts [33] (c.f. section 3.2), Fig.4 shows the integration of these systemic concepts (identified by the prefix "*OoEI:"*, and colored in grey) in the NEMO meta-model (elements in white color).

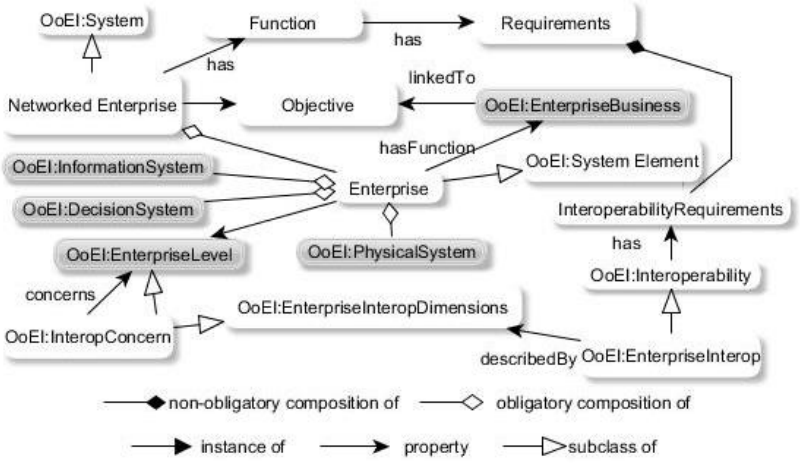

Fig. 4. NEMO meta-model with the Enterprise as System concepts (grey colored).

The *PhysicalSystem* is concerned with the interoperation of physical facilities. The *DecisionSystem* is mainly concerned with operational, administrative and strategic decisions; and the *InformationSystem*'s interoperability concerns the exchange of information between two systems [33]. The *EnterpriseBusiness* denotes the enterprise function such as delivery of products and services to customers. *EnterpriseLevel* represents the layers of enterprise in general. Thus, the four interoperability concerns are also subclasses of this concept. These enterprise-as-systems concepts facilitate analyses on specific systems without influencing the network as a whole.

5 Evaluation using a Case Study

As part of the research approach, this section illustrates the evaluation of the proposed meta- model using a real case study based on The Factory Group (TFG) [49], an active NE in the field of marketing and communication in Luxembourg. TFG brings together independent companies linked by their capital structure or by joint venture agreement. This NE is composed of five distinct enterprises:

1. Concept Factory [50]: Full-service communications consulting agency.
2. Interact [51]: Provider for multimedia information technology services.
3. Exxus [52]: Innovation and strategy consulting agency.
4. Sustain [53]: Service provider for sustainable development projects and corporate social responsibility.
5. Quest [54]: Market Research Company.

It is worth noting that, for some reasons (that stays confidential), Quest has the intent to leave the NE; consequently, we do not consider this company in this analysis. The information used to define the scenario were gathered through interviews and analysis of provided documents by the different enterprises. The selected interviewees are members of the board of directors of each considered enterprise. First of all, we have

modelled the TFG using only the NE concepts identified (c.f. section 4), as illustrated in Fig. 5.

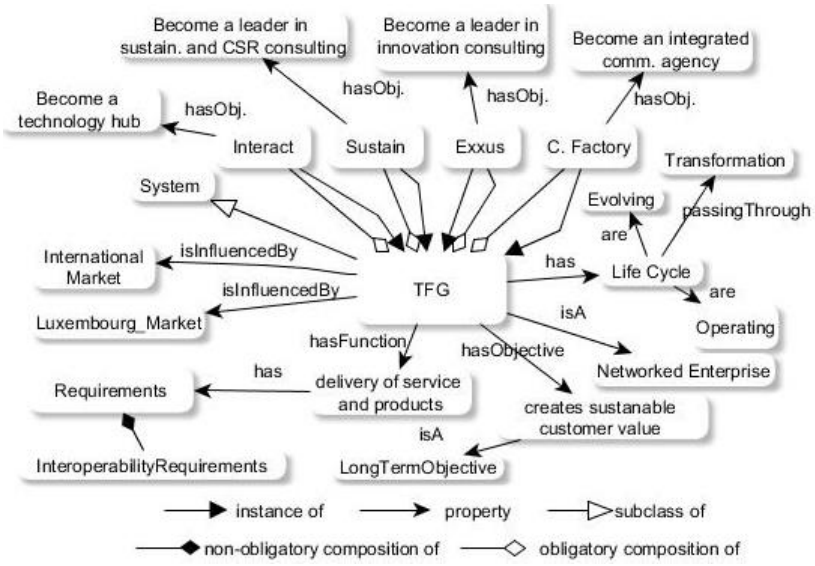

Fig. 5. TFG representation using NE concepts.

Considering the gathered information, the TFG *is composed of* Exxus, Sustain, Concept Factory and Interact. Where the four enterprises collaborate to achieve the TFG goals but remain autonomous to operate and pursue their individual goals. The individual objectives of each enterprise are the following: Exxus *has the objective* to become a leader in innovation consulting, Sustain *has the objective* to become a leader in sustainability and corporate social responsibility (CSR) consulting, Interact *has the objective* to become a technological hub and the Concept Factory *has the objective* to become an integrated communication agency, offering both digital and printed products. The NE as a whole *has the objective* of "creates sustainable customer value". To achieve this goal, the NE *has* functions related to their domain of activity (marketing and communication), for example TFG *has the function* of delivery services and products to its customers. The TFG is located in Luxembourg, and the majority of its clients are from Luxembourg, however, the number of international clients, in the past few years, is increasing. Hence, the TFG *is influenced by* the Luxembourgish and International markets. The TFG is *passing through* three stages in its life cycle. While the group is operating, small changes in the work methods are happening constantly (i.e. they are evolving). TFG are also going through a transformation changing some fundamental principles and roles. For example, Interact are becoming an IT specialized agency rather than a digital marketing agency. In order to provide sustainable products and services, the group has the interest to stay together for a long period of time. Thus, the objective identified hereinabove can be classified as a long-term objective. In order to execute functions to achieve its

objectives, a given number of requirements need to be achieved (i.e. each function *has* its requirements). These requirements are *composed of* interoperability requirements.

Even though the NE elements are well described and consider some concepts related to interoperability, using only the NE concepts to model TFG does not allow to represent the importance of the interoperability concept and its properties. For instance, it is not possible to represent an interoperability problem, its existence condition (i.e. why this problems is happening) and which enterprise level (i.e. business, process, service and data) it is affecting. Without these concepts, it may become difficult to identify the cause and location of the problem, which makes the selection of an appropriate solution rapidly harder. Further, it is important to represent the enterprise interoperability dimension (i.e. Interoperability aspects, concerns and approaches) and the interoperability barrier concept. These four concepts (c.f. section 3.2) describe the main interoperability elements related to an enterprise. As mentioned before (c.f. section 4), to fill this gap related to the interoperability representation, we use OoEI elements. Considering the different concepts that need to be taken into account in the OoEI and in the NE context, we have designed the TFG using NEMO, as depicted by Fig.6. The specific OoEI elements are colored in grey.

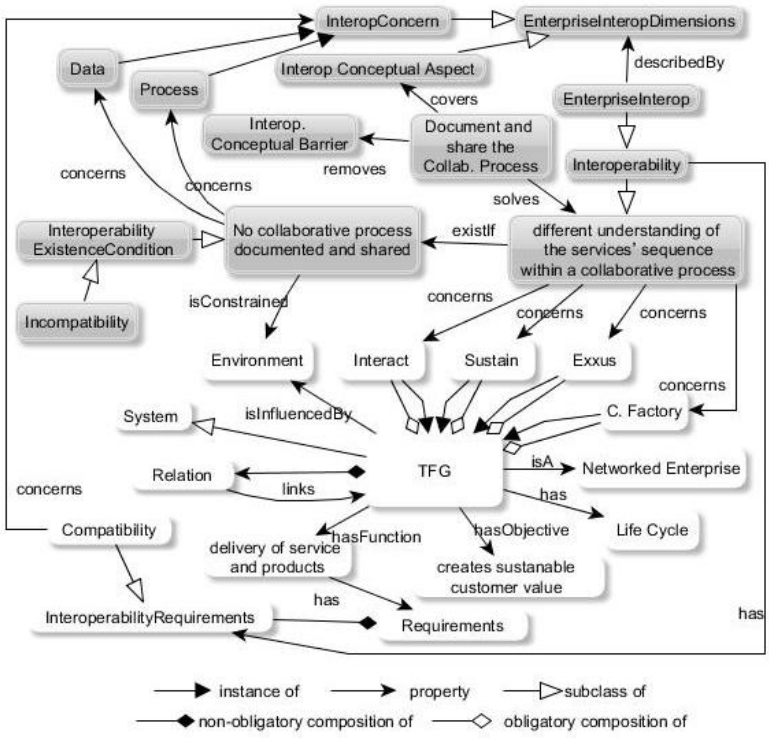

Fig. 6. The Factory Group using the NEMO meta-model.

In Fig. 6, we illustrate the following interoperability problem: "*the different understanding of the services' sequence within collaborative processes*". This problem *concerns* all partners within the NE. A potential cause (*Existence Condition*) of this incompatibility is the fact that there is no collaborative processes documented or shared within the TFG. Consequently, information is not clear to all employees. This incompatibility *is concerned* with the data and process concerns and the conceptual aspect of an enterprise. This problem is considered as a *conceptual barrier*, because it is concerned with semantics and syntactic problems in the process and data levels of the NE. A potential solution to *solve* this problem is to document and share the TFG collaborative processes within the NE.

Applying the NEMO has allowed us to identify and relate the main elements of The Factory Group. Having this real use case was useful to validate the NEMO meta-model.

6 Conclusion and Future Work

In this paper, we have defined the Networked Enterprise Meta-Model (NEMO). Prior to that, an investigation about the different definitions and interpretations about Networked Enterprise (NE) has been done to identify the core concepts related to this domain and propose a systemic definition of NE. The proposed meta-model aims at providing a common understanding of the NE domain. Within this context, interoperability is a key factor to seize business opportunities. Thus, concepts from EI related work was considered.

A real case study of an active NE in Luxembourg has been studied to validate the proposed meta-model, by illustrating the main NE concepts and the different interoperations between them.

As future work, we intend to extend the NEMO meta-model to build a Framework for Networked Enterprise Interoperability using enterprise modelling approaches such as UEML [55], CIMOSA [56], etc. This framework will be completed by an interoperability assessment method based on formal metrics and maturity levels which will tackle the interoperability potential of each member of a NE and the compatibility between them. This will serve as basis to the development of a decision-support system for preventing and solving enterprise Interoperability problems in the Networked Enterprise context.

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