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An approach for interoperability assessment in networked enterprises

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Abstract: Nowadays, enterprises are progressively collaborating with each other and participating in Networked Enterprises (NE) for dealing with challenges such as globalisation, new technologies, and financial crisis. In some cases, these enterprises have to plan coherent transformations to develop and implement effective interoperations, while working uninterruptedly. Interoperability, in this context, is a crucial requirement allowing the proper collaboration between members of a network. As soon as it is not achieved; Enterprise Interoperability (EI) becomes a problem that needs to be solved. With the intent to avoid EI problems, enterprises can benefit from the use of assessment approaches, allowing the measurement of strengths and weaknesses regarding interoperability. However, the proposed approaches in the literature have limitations such: (a) covering only one application context (b) focusing on specific areas of interoperability and (c) not representing the interdependencies of such areas. Hence, the objective of this research is to propose a new assessment approach covering the different areas of interoperability and its relationships for providing guidance regarding EI transformations within a NE.

Keywords: Enterprise networks design and implementation, Enterprise Systems, Systems Interoperability, Interoperability Requirements, Interoperability Assessment, Decision Support Systems.

1. INTRODUCTION

In the current fast-changing environment, enterprises need to remain competitive and to survive disruptive changes. Thus, they are shifting their boundaries and collaborating with other companies. Within this context, enterprises need, sometimes, to participate and be part of a so-called Networked Enterprise (NE) (Camarinha-Matos et al. 2009), (Li et al. 2010). A major issue in global collaboration and cooperation faced by the NE is the development of interoperability (Guédria et al. 2013). Enterprise Interoperability (EI) refers to the “ability of interaction” between enterprises (Chen et al. 2006). In other words, it provides two or more business entities with the ability to exchange or share information and to use a functionality of one another in a distributed and heterogeneous environment (Vernadat 2007). To describe the EI domain, we use the Ontology of Enterprise Interoperability (OoEI) (Naudet et al. 2009). It adopts a systemic approach, where interoperability is first viewed as a requirement inside a system (e.g. an information system, an enterprise or a NE itself), which maturity depends on the interactions or composition among its components. As soon as this ability is not achieved, interoperability becomes a problem that must be solved.

In certain cases, when a NE encounters EI problems, enterprises should plan coherent transformations (Rouse 2005) of their enterprise models, for increasing its interoperability, while working seamlessly. These transformations are stages which an enterprise should follow to achieved their targeted objectives, as well as the goals of the NE in which it participates. However, most of the

initiatives taken to deal with Enterprise Transformation (ET) planning have been mainly motivated by the need to better manage transformation from a general viewpoint, and no provision has been made to convey any information or guidance to interoperability issues. Thus, we raise the following question: “*How to support an enterprise to plan interoperability transformations in the NE context?*”

Being able to predict EI problems before they occur and identify related EI solutions, allows enterprises to properly decide and plan EI transformations. Thus, companies could benefit from the use of interoperability assessment approaches. They are sets of measurements that highlights the enterprise strengths and weaknesses regarding interoperability. To our best knowledge, despite the variety of the approaches proposed in the literature (Panetto 2007) (Ford 2008) (Guédria et al. 2013) (Leal et al. 2016b), none of them addresses at the same time the various areas of interoperability (AoI) and the different assessment contexts of application (Chen et al. 2006), (Guédria et al. 2013). Another limitation faced by the existing approaches is that they are not defining AoI interdependencies, what might hinder the decisions to make when planning EI transformations. Thus, the following question is raised: “*How can we diagnose the interoperability coherently within a NE, when dealing with different contexts and interoperability areas?*”

As a result of the interoperability diagnosis, a set of problems is identified. The enterprise can choose to deal with the totality of the problems or select some of them. It depends on the set of the transformations that will result to solve these

problems. This raises the following question: “How to select transformations to put in place for solving EI problems in NE?” This last question is out of the scope of this work, and we keep them for future work.

This research aims at addressing the EI Transformation (EIT) by providing a new approach for assessing EI and providing EIT guidance within a NE. The rest of the paper is organised as follow – Section 2 gives an overview of the relevant related work. Section 3 presents the proposed artefacts that support the proposed approach. It is followed by the proposed approach and its main stages in Section 4. Section 5 brings forward conclusions and perspectives.

2. RELATED WORKS

To support enterprises to better collaborate within a NE, the interoperability between their systems requires being assessed and continuously improved. An enterprise knowing their strengths and weakness regarding interoperability should plan coherent transformations (Rouse 2005), (Nightingale 2009), (Lahrman et al. 2012) of their technical and organisational models while working seamlessly. Such transformations aim at improving the EI and consequently at reducing the negatives impacts caused by interoperability problems. A variety of approaches for assessing and identifying interoperability problems can be found in the literature. Many of them are defining a maturity model (e.g. the Levels of Information System Interoperability (LISI) (DoD 1998) and the Maturity Model for Enterprise Interoperability (MMEI) (Guédria et al. 2013) which consists of a framework that describes the stages through which systems should evolve. Besides the maturity models, there are other approaches such as the formal measures for semantic interoperability proposed by (Yahia et al. 2012) and the i-Score proposed by (Ford 2008) that are not defining levels of maturity but rather characterising the interoperability by attributing numeric or linguistics values. Based on surveys and comparison analysis such as (Panetto 2007), (Ford 2008), (Guédria et al. 2013), (Leal et al. 2016b) we identified relevant aspects to be considered when assessing interoperability for planning transformations within a NE. These aspects and the limitations faced by the existing approaches are described in the following sections.

2.1 The context of application

The application context is related to the “When” and “Where” the assessment is performed. In the EI domain, three main contexts exist (Chen et al. 2006). Context A: the assessment of the potential interoperability (before any interoperation happens) of an enterprise towards its environment. Context B: The assessment of the potential interoperability between two known partners for identifying potential EI problems. Context C: the assessment of the performance between known partners regarding the interoperability cost, delay and quality during interoperations. The latter is out of the scope of this work, as we intent to prevent EI problems before they occur.

Regarding this aspect, the majority of the existing approaches are dealing with a specific context. This fact is not seen as a limitation when enterprises need to assess interoperability in specific situations. However, when considering the different life-cycle phases of an NE (Camarinha-Matos et al. 2009) the application of different approaches may hinder the *as-is* and *to-be* design and the interoperability maturity determination as they use different metrics and viewpoints (Leal et al. 2016b). Table 1 presents some of the main approaches dealing with interoperability and their application context.

Table 1. Approaches context of application and metrics. Adapted from (Leal et al. 2016b)

Approach	Context	Metrics
LISI	B	Level 0 to 4
MMEI	A	Level 0 to 4
i-Score	B	Numeric value from 0 to 1
Yahia et al. 2012	B	Ratio (%) between an expected and a real state.

2.2 The areas of interoperability

The concept of “areas of interoperability” concerns to the “What” is being assessed. The AoI is direct related to the problem space defined by the Framework of Enterprise Interoperability (FEI) (Chen et al. 2006), (ISO/TC 184/SC 5 2011). The problem space is represented by two dimensions: the EI concerns (Business, Process, Service and Data) and the Interoperability barriers (Conceptual, Technological and Organisational). The intersection of these dimensions constitutes 12 sub-domains i.e. the AoI. These areas contain the criteria that an EI concern should meet to prevent interoperability barriers.

Regarding this aspect, the majority of the existing approaches are not dedicated to the whole problem space; they focus on specific AoI. We argue that the use of multiple approaches might not provide a complete assessment and also might cause redundancy and confusion if they are assessing the same AoI but in a different manner. Based on the cited surveys, the MMEI is the only approach proposed to cover the four concerns and three barriers. However, MMEI cannot guarantee that two enterprises having the same maturity levels can interoperate without problems (related to the Context B). For example, if two enterprises have the conceptual maturity level 2, it means that both are using enterprise modelling standards, but if the used standards are incompatible, the interoperability between the two enterprises will be troublesome.

2.3 Other relevant aspects and considerations

During the ET process (Nightingale 2009), (Lahrman et al. 2012) decisions are made. We argue that while planning transformations, decision makers should take into account the potential impacts that their decisions can cause on different levels of an enterprise or a NE. Considering the EI transformation, this can be linked to the statement proposed on (Naudet et al. 2009) that a solution solves but also induces problems. Thus, the relationships and influences between the

different AoI are relevant aspects to be considered. However, to our best knowledge, no EI assessment approach defines the AoI interdependencies. Furthermore, the majority of the studied assessment approaches are only performed manually, which is difficult and very expensive. Therefore, the implementation of automated tools for supporting an assessment is advised (Krivograd et al. 2012). To cope with that, the use of decision support systems (DSS) (Phillips-Wren et al. 2011) could increase the rapidity of the assessment and transformation planning by automating (entirely or partially) their processes.

To answer the raised questions in Section 1 and to reduce the limitations found in the literature, we intend to propose a new NE interoperability assessment approach which is detailed in the following sections.

3. APPROACH ARTEFACTS

The proposed approach is supported by four main artefacts that we define in this section. The artefacts are based on a simplified view of the design science research (DSR) (Hevner et al. 2004), (Winter 2008). We chose this methodology as it aims at providing a valuable artefact (e.g. a model or a tool) to solve a particular problem. The methodology follows two general processes. The Build process is composed of two stages: The conceptual definition where we proceed with the literature study to scope the research work and to define the related problems based on the literature limitations. The second stage is the construction of the artefacts intended to contribute to reducing the identified limitations. The Evaluate process aims at validating the proposed artefacts by applying a case study.

The first artefact is the Networked Enterprise Meta-Model (NEMO) which is proposed for dealing with the lack of common understanding of the NE concept and the different interoperation within such network. NEMO is based on the various NE definitions and uses the FEI and the OoEI as reference models to describe the EI dimensions. Finally, data from a real NE were collected to enrich the proposed MetaModel. The usefulness of NEMO is that we can use it for designing the *as-is* and *to-be* situation of a NE considering the relationships of their subsystems while highlighting the EI requirements that should be met for reducing EI problems. It is worth noting that the NEMO is under improvement and its first version was published on (Leal et al. 2016a) where a case study was used to validate it.

The second artefact is the EIT MetaModel (EITMO) which is proposed for covering the lack of formalisation of the relationships between the areas of interoperability. This model aims at contextualising the decision-making process of an EIT regarding cross-cutting AoI relationships. It is worth noting that EITMO is still in construction. A first attempt to define the concepts and relationships of the model is illustrated in Fig. 1. It is defined based on the Enterprise Architecture decision rationales proposed by (Plataniotis et al. 2014) and the decisional model included on OoEI. The application of the model in a case study and the AoI relationships definition will be done in future work.

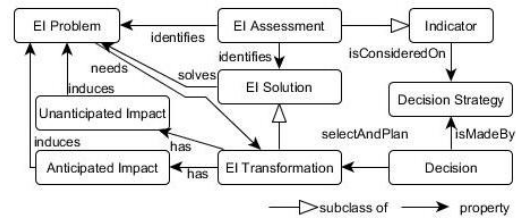


Fig. 1. Overview of the EI Transformations concepts

The third artefact is the extension of the MMEI for covering the application context B i.e. the assessment of the potential interoperability between two known partners. Thus, in (Leal et al. 2016c) we proposed to combine formal measures to enhance the interoperability maturity assessment dealing with the semantic relationships between two systems. However, it can be only applied when companies are using the same enterprise modelling standards. The proposed measures need further refinement and application on more cases study to validate its pertinence. Besides the extension to the context B, we also intend to enhance the current MMEI version with the AoI interdependencies that will be formalised by the EITMO.

The fourth and last artefact is a DSS for partially automate the EI assessment process. Its main objective is to support an enterprise to plan EIT based on the EI assessment. The DSS will have the previously three proposed artefacts as inputs. This artefact is under development (i.e. Build process). The structure of this tool has three layers: (a) the presentation layer (i.e. user interfaces). (b) The Data Storage layer. (c) The Processing layer (i.e. tool components that are required for the determination of the EI maturity). The DSS will recommend actions based on knowledge that has been stored using the OoEI and logic rules.

4. PROPOSED APPROACH

In this section, we present the proposed assessment approach. It is based mainly on the MMEI methodology and on the ET roadmap proposed by (Nightingale 2009). The originality of the approach is the guidance provided during the EIT process from the scope definition to the decision support, passing through the EI Problem/Solution identification. We argue that our most significant contribution to the EI assessment domain will be the formalisation of the interdependencies between AoI.

The approach is divided into four stages which is depicted in Fig. 2 and described in the following sections.

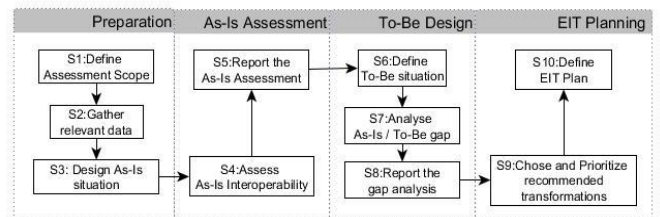


Fig. 2. A simplified view of the proposed approach.

4.1 The preparation

The first stage is divided into three steps. The first one (S1) concerns to the assessment scope definition i.e. the purpose, application context and the AoI to be assessed are defined. The responsible for this step are the decision makers and stakeholders who are familiar with the NE business or a part of it. They should scope the assessment based on their previously experience and the NE objectives. To have an overall view of the scope, NEMO could be used to represent the NE objectives and the associated EI requirements. The EITMO could be used to identify the AoI that may be involved in the assessment scope. Further, the second step (S2) address to the data gathering regarding the defined assessment scope. The data collection can be done through interviews, workshops and online surveys. The questionnaires should be based on the concerned AoI criteria and the best practices described on MMEI. The proposed DSS will support this stage by providing user interfaces to both assessors and stakeholders in case of online survey adoption. Otherwise, if data is collected through interviews and workshops, assessors can enter the data manually into the DSS. The third step (S3) regards to the *as-is* design based on the analysis of the gathered information. In this step, NEMO could be used to model the NE elements and represent the existing interoperations.

4.2 The assessment

Having defined the assessment scope and gathered the relevant data, we move forward to stage 2 which is the *as-is* assessment. This stage is divided into two steps: In the first one (S4), a first evaluation is performed to evaluate the EI maturity of the concerned enterprises within the network (Context A). It is done based on the current version of MMEI (Guédria et al. 2013). This assessment allows the assessor to identify the list of AoI requirements that a given enterprise is fulfilling. Further, an assessment comparing the AoI requirement of two specific enterprises is done (Context B). This second assessment aims at identifying the potential EI problems and related EI solutions. The proposed DSS will be used to run the algorithm to determine the enterprise's maturity. Because of space constraints, please refer to (Guédria et al. 2013) for a detailed view of MMEI measures and algorithm regarding the context A. As mentioned in section 3, measures regarding context B are still under development and aren't presented in this paper. The next step (S5) concerns to the assessment report generation. It will be done automatically by the proposed DSS and validated by the assessor (or lead assessor if there are multiple assessors). The report provides to the decision makers an overview of the *as-is* of the concerned enterprises and the potential solutions as well as their positive and negative impacts to solve the identified problems.

4.3 The to-be design

Furthermore, the third stage concerns to the "To-Be" Design. It is divided into three steps. In the first one (S6) decision

makers should design the *to-be* situation envisioned to reduce the potential EI problems identified in the Assessment stage. To keep coherence and consistency, the enterprise/NE should use NEMO to design the *to-be* situation. After defining the desired state, the step (S7) will be the gap analysis. This analysis aims at identifying the potential transformations and their impacts to reach the defined *to-be* situation. It also highlights the potential EI problems that transformations impacts may cause in the overall enterprise/NE. The gap analysis will be grounded on the MMEI maturity levels, and the relationships between AoI, and it will be performed by the DSS. The step (S8) consists of the *to-be* report which will be generated automatically by the DSS. It contains the identified gaps between the *as-is* and *to-be* situations. The potential EI transformations to be adopted to move from *as-is* to *to-be* and their related impacts are also represented in the report.

4.4 The EIT planning

Finally, the last stage is the EIT Plan. This stage is divided into two steps. First (S9), the decision-makers should prioritise the transformations proposed by the *to-be* report. To do so, they should consider the enterprise/NE objectives and the identified transformation impacts. The last step of this approach (S10) is the definition of the EIT Plan, that is, a report containing the transformations roadmap with the associated information (e.g. delays and employees in charge). This report can be generated by the DSS using the information provided by the decision makers in the previously step. It is worth noting that, the DSS does not select the transformations to be adopted. It only provides the recommendations and it is the responsibility of decision makers to decide and choose the ones that best fits their objectives.

5. CONCLUSION AND PERPECTIVES

In this research, we aim at addressing the NE Interoperability and the associated EIT to deal with potential EI Problems. It is tackled by the proposition of a new EI assessment approach for supporting stakeholders in their understanding, decision making and engineering tasks. In this paper, we have argued that having an approach assessing the potential interoperability of enterprises regarding both their environment and a specific partner is a necessity for having a coherent view of their interoperability strengths and weakness. We also state that knowing the different impacts that an EI problem from a given AoI can cause into another AoI is crucial for planning EI transformations. To support the proposed approach and address our arguments, we proposed four artefacts which are NEMO, EITMO, the MMEI extension and the DSS prototype.

As future work, we intend to endorse our arguments by: (a) formalising the interdependencies between the areas of interoperability trough the proposition of the EITMO; (b) completing the MMEI extension for the assessment context application referred in this paper as context B. Regarding the NEMO artefact, we intend to enhance it using Enterprise Modelling and Enterprise Architecture concepts to better

represent the different enterprise elements (e.g. IT systems, actors and roles). Furthermore, we also intend to complete the DSS development which will be implemented using the JAVA language. Moreover, finally, test and validate the proposed approach and artefacts by using a real case study based on an active NE in the field of marketing and communication in Luxembourg.

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