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Methodology for Enterprise Interoperability

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Abstract: This paper aims at presenting a methodology for guiding enterprises to improve interoperability. This methodology consists in (i) a framework of interoperability, which structures specific solutions of interoperability and is composed of *barriers*, *concerns* and *approaches dimensions*; (ii) method to measure interoperability, which takes into consideration interoperability (*maturity*) before and (*operational performances*) during a partnership; and (iii) a structured approach defining the steps of the methodology, from the expression of enterprise's needs to implementation of solutions. The relationship which consistently relates these components is highlighted. It enables establishing interoperability in a step-by-step manner. This paper presents each component of the methodology and shows how it operates.

1. INTRODUCTION

A strong competitive environment characterizes the phenomenon of globalization, which enterprises cope for last twenty years. Therefore, in order to remain perennial, enterprises must have the ability to react to specific requirements of customers, and to take the position on new markets. In this context, the trend for an enterprise is to focus on its core business and to develop partnerships. Then, the competitiveness of an enterprise depends not only on its internal productivity and performance, but also on its ability to set up and carry out a partnership with others. Even if the success of these partnerships is related to the reach of the objectives of enterprises (customer satisfaction, positioning on new market), it is important to keep in mind that this success is also related to the quality of communication and interaction between partners. Existing solutions allowing, mainly, performing enterprise integration are not well adapted to this current context (interdependency of partners, networked manufacturing, no perenniality of the partnership, *etc.*). Thus, the concept of interoperability has emerged and aims at supporting and improving communication and interaction of these partnerships while respecting the constraints imposed by the context in which enterprises evolve. The research work presented in this paper proposes a methodology that could allow enterprises to establish interoperability by following a structured approach. This research was conducted in the frame of two significant European projects dealing with interoperability of enterprise applications, namely ATHENA Integrated Project (Advanced Technology for interoperability of Heterogeneous Enterprise Networks and their Applications, n°507849) and the Network of Excellence INTEROP (INTEROP NoE, n°508011).

The paper is structure in five sections. After brief introduction in section 1, problems and expected research results are presented in section 2. The set of methodology components (framework, structured approach and interoperability measurement method) are outlined in section 4. To illustrate the use of the proposed methodology, a simplified case study is shown in section 5. Section 6 concludes the paper.

2. PROBLEMS AND EXPECTED RESEARCH RESULTS

One of the most important obstacles to an effective implementation of interoperability between enterprises is that, so far, research works dealing with interoperability are usually focused on finding theoretical and/or technical solutions to given specific interoperability problems. These solutions can be effective only if their implementation is ensured into enterprises. Our objective was to provide a generic methodology allowing enterprises identifying their problems in terms of interoperability and selecting solutions adapted to their needs. Using a methodology will avoid hazardous approaches; therefore reduce the time needed to develop interoperability and avoid the implementation of non-adapted solutions to the partnership. Our basic hypothesis is that a structured approach has to allow developing interoperability between enterprises in a more efficient way. More precisely, our proposed methodology must allow establishing interoperability by:

1) Dynamically composing elements of available interoperability solutions and tools according to identified specific requirements; it concerns the development of a framework structuring and identifying aspects to take into account during selection of adapted interoperability solutions according to enterprise needs;

2) Following a structured approach in a step-by step manner in order to guide enterprises during the interoperability solutions selection process, from the expression of their need to the implementation of solutions;

3) Evaluating interoperability degree between enterprises to know their strengths and weaknesses.

3. METHODOLOGY FOR INTEROPERABILITY

3.1 Enterprise interoperability framework

The term 'framework' refers to an organising mechanism to structure concepts or more generally 'things'. Recently several research initiatives on interoperability proposed interoperability frameworks to structure issues and concerns in quite different ways. The European Interoperability Framework in the eGovernment domain (EIF, 2004) defines three types of interoperability: semantic, technical and organisational. A similar approach was also proposed in e-Health interoperability framework (NEHTA, 2006), which identified three layers: organizational, informational and technical interpretabilities. In the manufacturing field, the IDEAS interoperability framework (IDEAS, 2003) defines three main layers - Business, Knowledge and ICT - with two additional vertical dimensions - Semantics and Quality attributes. More recently the ATHENA Interoperability Framework (AIF) proposes to structure interoperability issues and solutions at three levels: conceptual, technical and applicative (ATHENA, 2003). The Interoperability Framework we previously proposed (Chen *et al*., 2006) (INTEROP, 2006) is barrier-driven and takes into account the basic concepts addressed in existing frameworks. Indeed our proposed enterprise interoperability framework defines three basic dimensions: the dimension of interoperability barriers, the dimension of interoperability concerns and the dimension of interoperability approaches.

The **dimension of interoperability barriers** takes into account three categories of interoperability problems which can be considered as following.

- *Conceptual barriers* are related to the problems of syntactic and semantic of information to be exchanged. This category of barriers concerns the modelling at high levels of abstraction as well as modelling at the level of programming.
- *Organisational barriers* are related to the definition of responsibilities and authority so that interoperability can take place under good conditions.
- *Technological barriers* are related to the problem of use of information technologies. This category of barriers concerns the standards that are used to present, store, exchange, process, and communicate data through the use of computers.

The **dimension of interoperability concerns** identifies various levels of enterprise where interoperability takes place. These levels are based on the ATHENA Technical framework: the business level, the processes level the services level and the data level.

- *The business level* refers to working in a harmonise way at the levels of organization and company in spite of for example, the different modes of decision-making, methods of work, legislations, culture of the company and commercial approaches etc. so that business can be developed and shared between companies.
- *The process level* aims at making various processes working together. A process defines a sequence of services (functions) according to a specific need of a considered company. Commonly, in a company, several processes run in interactions (serial or parallel). In the case of a networked enterprise, internal processes of two companies must be connected to create a common process.
- *The service level* is concerned with identifying, composing, and making function together with various applications (designed and implemented independently) by solving the syntactic and semantic differences, as well as finding connections to various heterogeneous databases. The term `service' is not limited to computer-based applications but also concerns functions of the company or the networked enterprises.
- *The data level* refers to making different data models (hierarchical, relational, *etc.*) and different query languages working together. Moreover, their contents are organized according to conceptual schemas (*i.e.* vocabularies and sets of structures of data) that are related to particular applications. The interoperability of data is related to find and share information coming from heterogeneous bases, which can moreover reside on different machines with different operating systems and databases management systems.

The **dimension of interoperability approaches** takes into consideration the three admitted approaches to develop interoperability (ISO, 1999): the *integrated* approach, the *unified* approach and the *federated* approach.

If the need for interoperability comes from a merge between enterprises, the integrated approach seems to be the most adapted. In this case there is a standard format for all partners and all models are developed according to this standard. It implies the format must be as rich as the models of the partners. If the need for interoperability concerns a long term-based collaboration, the unified approach may be chosen. A common meta-model across partners' models provides a mean to establish semantic equivalence. The meta-model is not an executable entity but a neutral model that allows mapping between diverse models. Finally, in terms of a need for interoperability originated from a short-term collaboration project, the federated approach can be implemented. To interoperate, partners must dynamically adapt and accommodate rather than build a predetermined meta-model.

Given all this set of elements, we defined the enterprise interoperability framework using the three above dimensions as illustrated in figure 1.

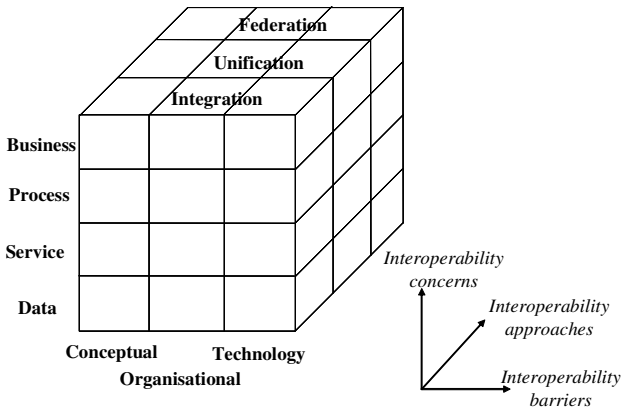

Fig. 1. The three dimensions of the proposed Enterprise Interoperability Framework

Each intersection between an approach, a concern and a barrier represent an interoperability research area. The objective is to capitalise in these spaces (intersections) (1) conceptual solutions - including references models and architecture related to interoperability - design principle(s) and pattern(s) as well as approaches; (2) support software(s) and (3) applicable solutions that would become good re-usable practices. The set of solutions must allow breaking interoperability barriers. A solution is considered as relevant to develop interoperability if it contributes to remove a barrier for a considered intersection of the three dimensions of the Enterprise Interoperability Framework.

3.2 Enterprise interoperability measurement

The fact that interoperability can be improved means that metrics for measuring the degree of interoperability exist. Measuring interoperability allows a company knowing its strengths and weaknesses to interoperate with a third company and to prioritize actions to improve their partnership ability.

Existing approaches to measure interoperability are mainly focused on maturity measure (C4ISR, 1998) (Kasunic *et al.*, 2004). Maturity can be seen as a kind of interoperability potential. The term maturity model was popularized by the SEI (Software Engineering Institute) when they developed the Capability Maturity Model (CMM) in 1986. Five maturity levels have been proposed (CMM, 2004), namely initial, repeatable, defined, managed and optimizing. Several other models have been developed in different disciplines, focusing on different levels of the enterprise, *e.g.* the Service-Oriented Architecture Maturity Model (Bachman, 2005), the Extended Enterprise Architecture Maturity Model (IFEAD, 2004), the NASCIO (NASCIO, 2003) Enterprise Architecture Maturity Model and the Organisational Interoperability Maturity Model (Clark *et al.*, 1999). These models aimed at evaluating processes within organizations and identifying best practices useful in helping them to increase the maturity of their processes.

More focused on interoperability issues, the LISI (Levels of Information Systems Interoperability) proposed a maturity model for measuring interoperability in five levels of maturity: isolated, connected, functional, domain, enterprise (C4ISR, 1998). Several similar approaches have been developed based on LISI, for example the TENA model identifies six levels (isolated, co-habitable, syntax, semantic, seamless, and adaptive). These maturity models for interoperability were mainly developed for the army systems of the US department of defence.

Based on these existing maturity models, ATHENA project elaborated, for manufacturing enterprises, the EIMM (Enterprise Interoperability Maturity Model) to address interoperability issues at all levels of the company (ATHENA, 2005). Defining the EIMM involves two tasks: (i) identifying the main areas of concern on which an enterprise need to work in order to achieve interoperability both internally and externally; (ii) defining the maturity levels that describe the improvement path for each area of concern.

The proposed methodology takes three types of interoperability measurement into consideration: (i) potential measurement; (ii) compatibility measurement and (iii) performance measurement. This allows going far beyond existing approaches that only consider the evaluation of maturity.

The interoperability potential measurement is concerned with the identification of a set of characteristics (maturity) that have impact on interoperability. These measures are performed on one enterprise/system without the necessity to know its interoperation partner. The objective is to evaluate the potentiality of a system to adapt and to accommodate dynamically to overcome possible barriers when interacting with a third partner. For example, an open system has a higher potential of interoperability than a closed system. Our methodology will make use of EIMM (Enterprise Interoperability Maturity Measurement) to measure the interoperability potential of a given company.

The interoperability compatibility measurement has to be performed during the engineering stage *i.e.* when systems need to be re-engineered in order to establish interoperability with a known partner. This measure is performed when the partner/system of the interoperation is known. The measure is done with respect to the identified barriers to interoperability.

Referring to each interoperability concern and interoperability barrier, the objective is to check if there is incompatibility or not. With regards to the interoperability barriers, as examples, the following questions can be asked to know if incompatibility between two systems exists (Daclin *et al.*, 2006).

Conceptual compatibility:

Syntactic: is the information to be exchanged expressed with the same syntax?

Semantic: do the information to be exchanged have the same meaning?

Organisational compatibility:

Persons: are authorities/responsibilities clearly defined at both sides?

Organisation: are the organisation structures compatible?

Technological compatibility:

Platform: are the IT platform technologies compatible?

Communications: do the partners use the same protocols of exchange?

If an incompatibility is detected, the coefficient 1 is assigned to the interoperating level and the barrier that are considered. Conversely, the coefficient 0 will be applied when none incompatibilities is detected. Following this rule, the compatibility matrix, presented figure 2 can be built.

Barriers / Concerns	Conceptual		Organizational		Technology	
	syntactic	*semantic*	*authorities responsibilities*	*organization*	*platform*	*communication*
Business	1	1	0	1	0	0
Processes	1	1	1	1	1	1
Services	1	0	0	0	1	0
Data	0	0	0	1	1	1

Fig. 2. The compatibility measurement matrix

To reach highest degree of compatibility means that all the barriers to interoperability have been removed. The inverse situation means the poorest degree of interoperability. The compatibility measure allows enterprises to know what kinds of barriers there are and what barriers have to be removed so that interoperability can be improved. The more important the number of incompatibilities is, the more important the efforts of the partners to become interoperable should be.

In a similar way, the incompatibility measurement can allow company to prioritize the actions to be taken to improve interoperability. It also allows company to define a migration path to follow in order to remove identified barriers in a progressive way. It is also necessary to work with interoperation partners so that concerted and common actions to remove these barriers are taken at both sides. For measuring the interoperability compatibility, we have developed EIDM (Enterprise Interoperability Degree Measurement) (Daclin *et al*., 2006) (ATHENA, 2007) based on the interoperability framework.

The performance measurement has to be performed during the operational phase, *i.e.* run time, to evaluate the ability of interoperation between two cooperating enterprises. Classical criteria such as cost, delay and quality can be used to measure the performance with respect to barriers and concerns during a basic interoperation cycle (exchange and use of information).

The cost of interoperation represents the cost engaged by the partners to perform interoperability. It is composed of the cost of exchange and the cost of exploitation.

The time of interoperation corresponds to the duration between the date at which information is requested (exchange) and the date at which the requested information is exploitable.

The quality of interoperation takes three kinds of quality into consideration: (1) the quality of exchange, (2) the quality of use and (3) the conformity.

The quality of exchange draws up if the exchange is correctly performed, *i.e.* if information sent to a partner succeeds.

The quality of use represents the number of information received by a partner by comparison with the number of information requested. A higher amount of information received (difficulty to treat all information) or lower amount (shortage of information) to the number of information requested means a deficiency.

The conformity corresponds to the exploitation of the information, *i.e.* if the fact that the information received is directly exploitable or not.

The performance assessment allows partners to know their global degree of performance according to the three criteria time, quality and cost.

The highest degree of performance (none of the three criteria measures differs from the expected results) means that no deficiency appears during the collaboration. The inverse situation (at least one of the three criteria measures differs from the expected results) means that deficiency (ies) exists between partners.

3.3 Structured approach

The structured approach aims at defining the main steps to follow in a sequential way, with the possibility to perform several iterations between the phases. Depending on whether the methodology is being applied to an individual company or a pair of partners, each phase will involve the use of the EIPM (Enterprise Interoperability Potentiality Measurement) or EIDM (Enterprise Interoperability Degree Measurement). Four main steps and activities are identified.

Step 1. Definition of objectives and needs. It aims at defining the performance of interoperability that is targeted, evaluating the feasibility and cost as well as project planning:

(a) Define needs of interoperability for each area of concern defined in the EIPM;

(b) Define needs of interoperability in terms of enterprise level and approach (integrated, unified, and federated) as defined in the EIDM.

Step 2. Analysis of existing system. The main goal of this phase is to identify actors, applications and systems that are involved, and interoperability problems that are encountered:

(a) Analyze the 'as-is situation'; define the 'to-be' situation and the gaps between them;

(b) Identify barriers to interoperability, measure existing interoperability degree using EIDM (compatibility measurement), analyze strong and weak points.

Step 3. Select and combine solutions. It consists in searching and selecting available interoperability solution elements with the support of the interoperability framework:

(a) Provide recommendation in the form of a conceptual solution (*i.e.* standards to be adopted, solutions to use and where to apply them, *etc.*);

(b) Combine and construct a company-specific technical solution that takes the objective and constraints of the company into account.

Step 4. Implementation and test. In this phase, solutions to remove the barriers will be implemented, tested and evaluated:

(a) Implement the technical solutions that have been elaborated during the step 3;

(b) Carry out performance measures and compare the result to the targeted interoperability degree and performance.

The most crucial activity is to identify the barriers to achieve the interoperability degree targeted by the companies. Identifying barriers is only concerned with those 'things' that need to be shared and exchanged between two systems/companies. Interoperability requires a common basis for those elements.

Once the solution(s) implemented, a new measurement needs to be done to verify if barriers are effectively removed using the proposed solution(s). In some cases the interoperability is improved but some incompatibilities still remain. A new iteration is required to adapt the solution or use other solutions until all barriers are completely removed. Performance measures may also be required at the test phase.

This methodology is participative and four groups of actors are defined based on the GRAI methodology:

The project board regroups the top-level management members of the company. They give the objectives of the project;

The synthesis group is composed of the main responsible people of the company. They ensure the follow-up of the project and check the results at various stages;

The specialist group consists in experts in interoperability and methodology. They give advices to the synthesis group, build various models and perform analysis;

The interviewees group is built from company people to be interviewed by specialists. They provide information needed by the other groups.

It is necessary to plan the meetings and tasks to perform. Usually, several iterations are needed to get a validated analysis and good models representing the 'as-is' situation of the company.

The proposed methodology for interoperability, including the set of its components, is represented figure 3.

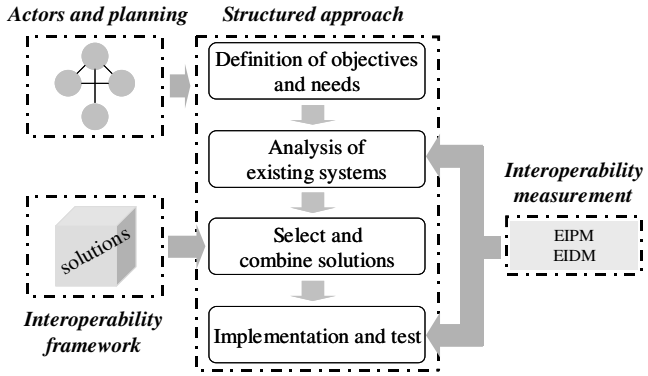

Fig. 3. The structure of the methodology for interoperability

4. APPLICATION OF THE METHODOLOGY

The proposed methodology has been tested and evaluated in the frame of ATHENA integrated project (A8 - SME Interoperability in practice). The case was provided by SAP AG based on a Carrier-Shipper Scenario. The study focuses on the application of EIDM to the scenario, where an SME shipper uses the services of multiple larger carriers. It aims at showing how we identify interoperability barriers, classify interoperability barriers in a coherent framework, classify interoperability solutions in the same framework and use the framework to select the right solutions to each barrier.

The application has started by modelling the scenario of interoperation. In the scenario, a set of needs and objectives for new solutions have been defined from the point of view of an SME shipper. For examples, (Semi-) automatic integration of Carrier Services, data and process mapping, user interface, predefined and easy configurable adapters, and configuration etc. The targeted interoperation concerns the all four enterprise levels (business, process, service, and data). Federated and unified approaches are preferred to full integration to keep autonomy/flexibility at the two sides.

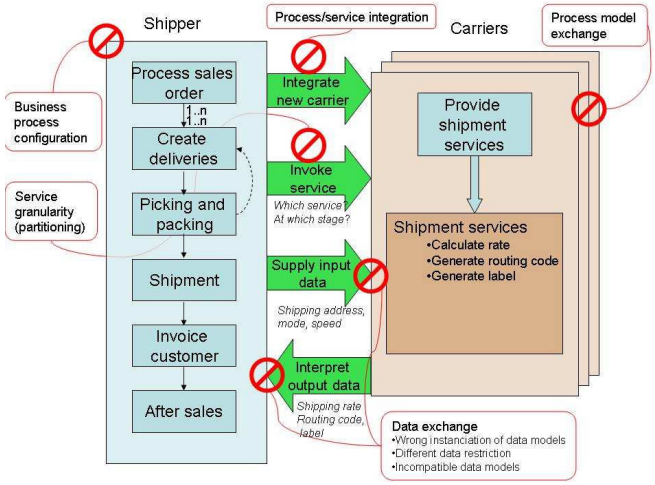

Fig. 4. Scenario mapped to the interoperability barriers

The barriers identified and presented in figure 4 are mapped to the interoperability framework. Each barrier is described in detail (using template) including the levels of enterprise concerned, the interoperability problem encountered, the ATHENA solutions identified and possible adaptations necessary to implement the solutions. As an example, for the data level, the main problem found is that different models adopted by the companies makes data exchange difficult as enterprise can not exchange their data automatically. A conceptual barrier – related to an incompatible syntactic and semantic representation of data at each interaction – has been detected. The identified conceptual solution is to adopt annotation of proprietary models according to common ontology to allow data reconciliation. The identified technical solution is to use ATHENA A3 tools or WSDL Analyser to detect mismatches between shared data.

During the phase of search of solutions, some ATHENA solutions were selected according to their ability to remove the identified barriers. Each solution is described at the two levels of abstraction: (1) conceptual solution independent of a technology, (2) technological solution (usually one conceptual solution may have several implementation options). In the implementation and test phase, a new interoperability measurement needs to be performed to evaluate the gap between the targeted interoperability degree and achieved one.

This case study allows validating the applicability of the methodology for interoperability by identifying the barriers (incompatibilities) between the elements that must be exchanged and shared. Only one of the possible interoperability barriers between enterprises has been presented in this paper. The complete case study can be found in (ATHENA, 2007).

5. CONCLUSION

This paper has presented a methodology for developing enterprise interoperability based on the barrier concept. The methodology is supported by an interoperability framework developed in consistency with the methodology and provides interoperability solutions and interoperability measurement method to evaluate the ability to interoperate (interoperability degree and performance). The methodology also proposes a structured approach to guide enterprises to implement interoperability solutions in a step-by-step manner to avoid hazardous approaches. The generalised incompatibility concept (not only at technical level but also organisation and business levels) is fundamental in our approach. In the future, some other researches are still to be developed. Currently interoperability is considered only between two partners. It will be interesting to study interoperability for multi-partnership, for example in a relationship between a provider and two customers which are competitor. Another issue is that in this methodology the operational performances limited to the technical aspects (performance of communication and exchange of information). It is also important to integrate these performance measurements to the global performances of a partnership. It means to measure the impact to the business and to verify the necessity (justification) to implement interoperability. Finally, a limitation of this work is that interoperability is related to the exchange of information between different persons belonging to different enterprises. These people can be reticent to share their information, thus creating obstacles to the implementation of interoperability and to the success of the partnership.

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