

An Approach for Enterprise Interoperability Measurement

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Abstract. Developing or improving enterprise interoperability implies that the degree of interoperability can be measured, and causes identified and analysed. This paper aims at presenting an enterprise interoperability measurement approach developed within the frame of the two main European IST projects in this field: INTEROP NoE and ATHENA IP. Having given the basic concepts on enterprise interoperability, the paper focuses on presenting three kinds of enterprise interoperability measurements: interoperability potentiality, interoperability compatibility and interoperability performance. Future works and perspective are discussed as part of conclusion.

Keywords: Enterprise interoperability, interoperability measurement.

1. Introduction

Interoperability is still a vague concept and has many definitions and connotations to different people in different sectors and domains. Starting from a pure software problem in the middle of 90's, interoperability is taking on a wider meaning to cover the many knowledge spaces, dimensions and layers of single and collaborating enterprise. Since a decade, although some efforts have been made to develop enterprise interoperability, especially in Europe [2], [9], [14] where several research projects have been launched under FP5/FP6, there is still no an overall satisfactory solution on interoperability. Research in this area is still fragmented. Most of researches and developments are focused on the technology aspect to solve interoperability problems. Few approaches are developed to evaluate the degree of interoperability. Although some works have been performed in this domain [3], [10], [11], [12], [17], however it is difficult to define metrics, mainly due to the difficulty to identify the attributes to characterise the interoperability. Thus, developing interoperability measurement is becoming an important challenge.

This paper is concerned with the research undertaken within INTEROP NoE and ATHENA IP during the period of 2003-2007. The objective is to present enterprise interoperability measurement concepts and principles. After having given basic

concepts on enterprise interoperability in section 2, the paper discusses in detail in section 3 the three basic interoperability measurements (potentiality, compatibility and performance). The three measurements proposed are consistent to and built on the conceptual interoperability framework presented in section 2. An illustration example is outlined in section 4 to show how to identify interoperability barriers through an interoperability compatibility measure. Future works are given as part of conclusion at the end of the paper. It is to note that the approach proposed in the paper should be considered as a basis. Detailed and operational methodology still needs to be developed to guide users to carry out these measurements.

2. Basic concepts and definition

Generally speaking, interoperability is the capability for two (or more) systems to exchange information [13] and to use reciprocally their functionality [19]. It has been considered that: (i) Enterprises are not interoperable because of barriers to interoperability; (ii) Barriers are incompatibility of various natures at different enterprise levels; (iii) Barriers common to all enterprises can be identified and tackled [4], [14].

2.1 Interoperability barriers

Three categories of barriers (conceptual, technological and organisational) are identified as follows [14]:

- The barriers of a *conceptual* nature which relate to the syntactic and semantic differences of information to be exchanged. These barriers concern the modelling at the high level of abstraction (ex.: enterprise models of a company) as well as the level of the programming (ex.: low capacity of semantic representation of XML).
- *Technological* barriers relating to the incompatibility of information technologies (architecture & platforms, infrastructure...). These barriers concern the standards to present, store, exchange, process and communicate data and information through the use of software systems.
- The barriers of an *organisational* nature which relate to the definition of responsibility and authority so that interoperability can take place under good conditions. These can be seen as 'human technologies' or 'human factors' and are concerned with human and organisation behaviours which can be obstacles to interoperability.

2.2 Interoperability concerns

This section defines the interoperations that can take place in the various areas of concerns of the enterprise [14].

- The interoperability of data: It refers to make work together different data models (hierarchical, relational, etc.) and of the different query languages, to find and share information coming from heterogeneous bases which can moreover reside on

different machines with different operating systems and data bases management systems.

- The Interoperability of services: It is concerned with identifying, of composing and making function together various services/applications (designed and implemented independently) by solving the syntactic and semantic differences as well as finding the connections to the various heterogeneous data bases.

- The interoperability of processes: it aims to make various processes work together. Generally in a company, several processes run in interactions (in series or parallel). In the case of the networked enterprise, it is also necessary to study how to connect internal processes of two companies to create a common process.

- The interoperability of business: It refers to work in a harmonised 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.

2.3 Interoperability approaches

According to ISO 14258 (Concepts and rules for enterprise models), there are three basic ways to relate entities together to establish interoperations [15]:

- Integrated approach: there exists a common format for all models. This format must be as detail as models. The common format is not necessarily a standard but must be agreed by all parties to elaborate models and build systems.

- Unified approach: there exists a common format but only at a meta-level. This meta-model is not an executable entity as it is in the integrated approach but provides a mean for semantic equivalence to allow mapping between models and systems.

- Federated approach: there is no common format. To establish interoperability, parties must accommodate 'on the fly'. Using federated approach implies that no partner imposes their models, languages and methods of work.

Fig. 1 describes formally the basic concepts defined above and their relationships.

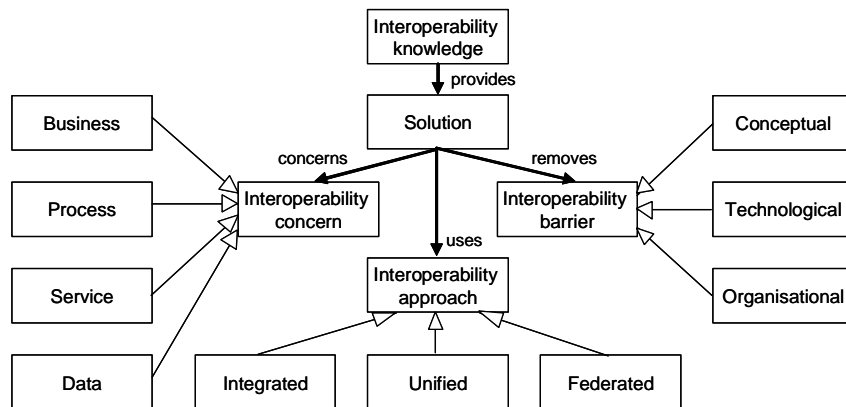


Fig. 1. Basic concepts of enterprise interoperability [6]

3. Interoperability measurement

The fact that interoperability can be improved means that metrics for measuring interoperability can be defined. Measuring interoperability allows a company knowing its strengths and weaknesses to interoperate and to prioritize actions to improve the interoperability. Current state-of-the-art focuses on solving some specific interoperability problems at technological level; few researches have been done to deal with interoperability measuring problem. Existing approaches mainly focus on maturity measure issues [7], [10], [11], [17], [18]. No approaches have been found in the literature on interoperability compatibility measure and interoperability performance measure. At the current stage of research, three kinds of interoperability measurement can be considered: (i) interoperability potentiality measure; (ii) interoperability compatibility measure, and (iii) interoperability performance measure [5], [8], [14]. These measures take into account of existing works in this area and are based on the concepts of enterprise interoperability presented in section 2.

3.1 Interoperability potentiality measure

The interoperability potentiality is concerned with a set of characteristics that have impact on the ability to interoperate with a third partner. The objective of this measure is to evaluate the potential of a system to accommodate dynamically to overcome possible barriers when interacting with a partner.

We define the *potentiality* as the fact that an enterprise possesses intrinsic attributes related to interoperability, which make it easier to interoperate with other enterprises, in the eventuality of a partnership. In other words, potentiality is an intra-enterprise evaluation without the need to know the interoperating partner. The main goal is to increase the capability of interoperation and decrease the risk to meet problems during a partnership. Generally speaking, through this measure the potentiality for an enterprise to interoperate with a unknown partner can be accessed, such as for example, the use of standards, the flexibility of its organization, the openness of its ICT infrastructure, the existence of its enterprise models, etc.

Today few methods are developed for measuring interoperability potentiality. Existing approaches mainly focus on maturity measure, for examples the LISI (Levels of Information Systems Interoperability) proposed a maturity model for measuring interoperability in five levels of maturity [3]: isolated, connected, functional, domain, enterprise; Other approaches based on LISI proposed similar models [7], [18]; ATHENA project has also elaborated for the manufacturing enterprise the EIMM (Enterprise Interoperability Maturity Model) to address interoperability issues at all levels of the company [1].

The proposed enterprise interoperability potentiality model concerns the evaluation of an enterprise according to the three categories of barriers that impact the development of interoperability, and the four areas of concern where interoperability takes place, *i.e.* business, processes, services and data. For each category of barriers and each concern, five levels are defined to characterize the potentiality [8]:

- (1) **Isolated:** total incapacity to interoperate;
- (2) **Initial:** interoperability requires strong efforts that affect the partnership;

- (3) **Executable:** interoperability is possible but the risk of encountering problems is high;
 - (4) **Connectable:** interoperability is easy even if problems can appear for distant partnership;
 - (5) **Interoperable:** which considers the evolution of levels of interoperability in the enterprise, and where the risk of meeting problems is weak.
- Fig. 2 gives interoperability maturity model illustrated at the business level.

| Potentiality Level | Conceptual potentiality | Organizational potentiality | Technological potentiality |
|-----------------------|---|---|---|
| Business | Isolated, Initial, Executable, Connectable, Interoperable | Isolated, Initial, Executable, Connectable, Interoperable | Isolated, Initial, Executable, Connectable, Interoperable |

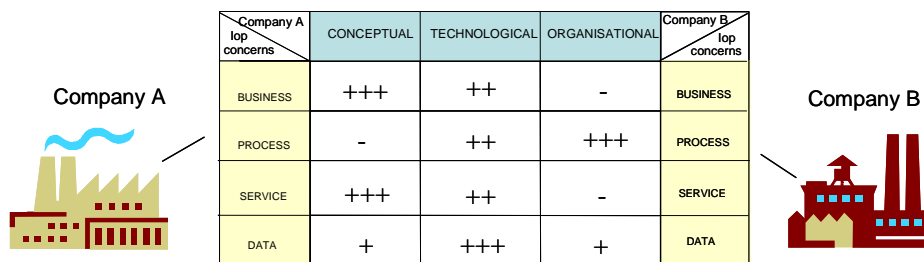
Fig. 2. The enterprise interoperability potentiality model at business level

It is to note that the maximum potentiality does not imply full interoperability. Indeed, the use of standard tools by an enterprise does not ensure that a partner will use the same ones. Hence, problems of interoperability can still appear.

3.2 Interoperability compatibility measure

The interoperability compatibility measurement has to be performed during the engineering stage i.e. when systems are re-engineered in order to establish interoperability. In contrary to interoperability potentiality measure, the interoperability compatibility measure can only be performed when the two partner/system of the interoperation is known. The measure is done with respect to the identified barriers to interoperability. The highest compatibility means there is no barrier to interoperability. The inverse situation means the poorest compatibility for interoperability.

As an example, Fig. 3 shows an illustration of barriers identified at the moment when company A and company B wish to establish interoperability. In the figure, ‘+++’ means that there exist an important barrier between the two enterprises, ‘+’ means weak barrier, ‘++’ is in between, and ‘-’ means that there is no barrier.



| Company A top concerns | CONCEPTUAL | TECHNOLOGICAL | ORGANISATIONAL | Company B top concerns |
|------------------------|------------|---------------|----------------|------------------------|
| BUSINESS | +++ | ++ | - | BUSINESS |
| PROCESS | - | ++ | +++ | PROCESS |
| SERVICE | +++ | ++ | - | SERVICE |
| DATA | + | +++ | + | DATA |

Fig. 3. Compatibility measure matrix example

Identifying interoperability 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. Typically, not all of the information managed by two systems is shared. Therefore, interoperability requires identifying the shared elements and possible barriers between these elements.

The compatibility measure can be performed with the help of a questionnaire. For example, regarding the three categories of interoperability barriers, following questions can be asked:

Conceptual compatibility: *Syntactic:* is the information to be exchanged expressed with the same syntax? *Semantic:* does the information to be exchanged have the same meaning?

Organizational compatibility: *Persons:* are authorities/responsibilities clearly defined at both sides? *Organization:* are the organization structures compatible?

Technological compatibility: *Platform:* are the IT platform technologies compatible? *Communications:* do the partners use the same protocols of exchange?

The measure can also be valued. If an incompatibility is detected, the coefficient 1 is assigned to the interoperability concern and the barrier that are considered. Conversely, the coefficient 0 will be given when none incompatibilities is detected. Following this rule, the compatibility matrix (Fig. 4) can be built.

| Barriers Concerns | Conceptual | | Organizational | | Technology | |
|----------------------|------------------|-----------------|-------------------------------------|---------------------|-----------------|----------------------|
| | <i>syntactic</i> | <i>semantic</i> | <i>authorities responsibilities</i> | <i>organization</i> | <i>platform</i> | <i>communication</i> |
| 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. 4. The valued compatibility measurement matrix

3.3 Interoperability performance measure

The performance measurement is to be done during the test or operation phase of two interoperate enterprises. Criteria such as cost, delay and quality can be used to measure the operational performance. Each kind of measurement can be evaluated with local coefficients in order to get a global coefficient ranging from “poor interoperability” to “good interoperability”.

3.3.1 Time of Interoperation

The time of interoperation corresponds to the duration between the date when information is requested and the date when the requested information is used. The time of interoperation can be decomposed in several periods of time. Fig. 5 proposes a decomposition of the time of interoperation (adapted from Kasunic [11]).

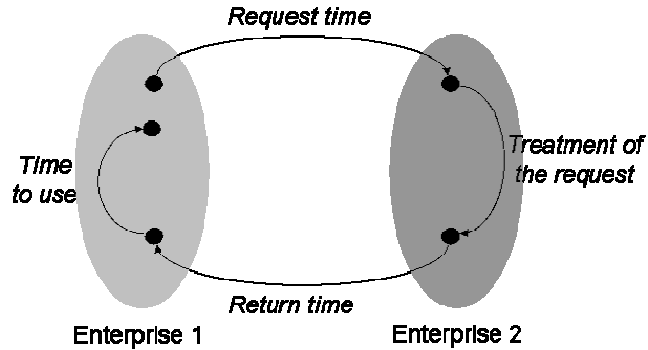


Fig. 5. Decomposition of the time of interoperation

The request time represents the duration between the date when a request is sent and the date when the request is received by the partner. The treatment time of the request corresponds to the time to treat the request. The return time corresponds to the duration between the date when the requested information is sent back and the date when the information is received. The time to use represents duration of latency, *i.e.* the duration between the date when the information is received and the date when the information is exploited.

Thus, the real value of the time of interoperation can be defined as the sum of all the periods of time composing this one. This real value can be noted as follow [2]:

$$t_{ineff} = \Delta t_{req} + \Delta t_{treat} + \Delta t_{ret} + t_{use}$$

Where:

- t_{ineff} , represents the real value of interoperation time
- Δt_{req} , represents the request time
- Δt_{treat} , represents the time of treatment of the request
- Δt_{ret} , represents the return time
- Δt_{use} , represents the time to use

The assessment of the time of interoperation corresponds to the comparison between the real value of the time of interoperation and the time expected by the partners. If the time measured is longer than expected, then there is a deficiency in terms of time of interoperation.

3.3.2 Quality of Interoperation

The quality of interoperation takes in consideration three kinds of quality: (1) the quality of exchange, (2) the quality of use and, (3) the quality of 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 in comparison with the number of information requested. A number of information received superior (difficulty to treat all information) or minor (shortage of information) to the number of information requested means a deficiency. The quality of conformity corresponds to the exploitation of the information *i.e.* if the information received is exploitable or not.

Thus the quality of interoperation can be defined as the sum of the three kinds of quality. The quality of interoperation can be noted as follow [2]:

$$q_{in} = \Delta q_{ex} + |\Delta q_{ut}| + \Delta q_{conf}$$

Where:

- q_{in} , the quality of interoperation
- Δq_{ex} , the quality of exchange
- $|\Delta q_{ut}|$, the absolute value of use
- Δq_{conf} , the quality of conformity

The assessment of the quality of interoperation corresponds to the comparison between the real value of the quality of interoperation and the quality expected by the partners. A difference means a deficiency in terms of quality of interoperation.

3.3.3 Cost of Interoperation

The cost of interoperation is defined by the costs induced by the removing of the barriers and the modification of the systems to obtain a satisfying time and quality of interoperation. It is defined as [2]:

$$C_{in} = C_{ex} + C_{ut}$$

Where:

- C_{in} , the cost of interoperation
- C_{ex} , the cost of exchange, i.e. the cost to exchange information
- C_{ut} , the cost needed to make the information exchanged usable

The assessment of the cost of interoperation corresponds to the comparison between the real value of the cost of interoperation and the cost expected by the partners. If the cost measured is higher than the expected cost, it means a deficiency in terms of cost of interoperation.

4. An illustration example

This section presents an illustration example based on a Carrier-Shipper Scenario to show the use of the compatibility measure to detect possible interoperability barriers. The case was provided by SAP and used in ATHENA A8 project [2]. 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. **Fig. 6** shows the internal process of the three companies and cross companies interoperations between the three processes. The targeted interoperations take place at the all four interoperability concerns (business, process, service, and data).

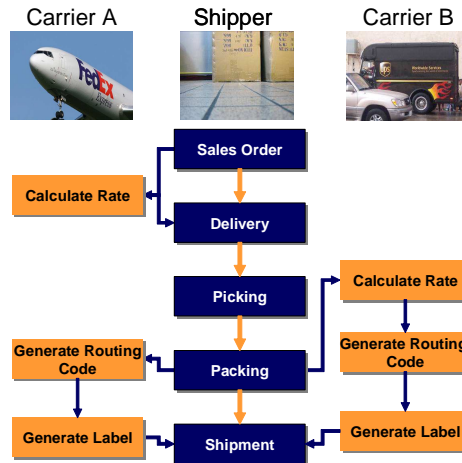


Fig. 6. Scenario mapped with interoperability barriers [2]

To analyze existing situation and identify possible barriers between the three companies, interoperability compatibility measure has been performed.

Fig. 7 shows an illustration example of the measure. Tools and methods used in two companies in the four areas of interoperability concerns were identified and compared, and their compatibilities assessed. For example, different data models/formats with different semantics are used by the two companies, resulting in important conceptual barriers at data level. A template was developed in the project to document more in detail the barriers encountered and potential solutions that may be used to overcome the barriers. An example of this template is shown table 1.

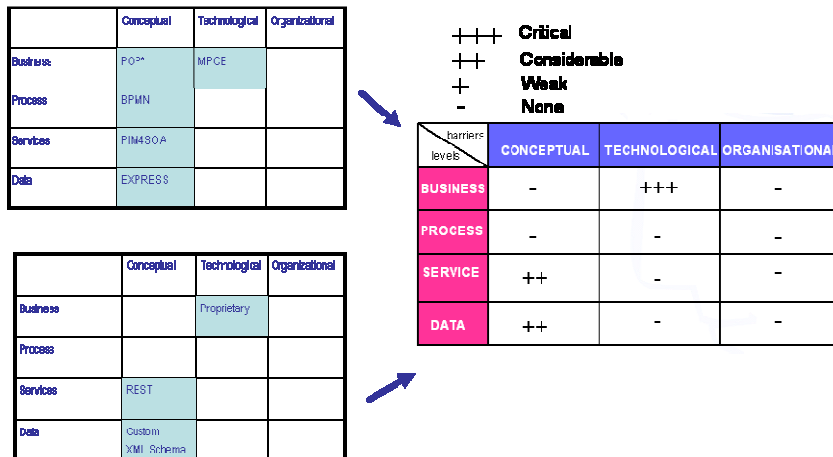


Fig. 7. Compatibility measure illustration example

Table 1. Excerpt of the template description [2]

| Template elements | Description |
|-----------------------------|--|
| Interoperability concerns | Data, Service |
| Interoperability barriers | Conceptual barrier - Incompatible syntactic and semantic representation of data at each interacting partner |
| Interoperability problem | Different models adopted by the companies makes data exchange difficult as enterprises cannot exchange their data automatically |
| ATHENA solutions identified | - Conceptual solutions: Annotation of proprietary models according to common ontology to allow data reconciliation - Technical solutions: A3 tools, WSDL Analyzer |

5. Discussion

The proposed work is related to existing researches in the following ways:

Existing works [11], [3], [17] etc. mainly focus on the technology aspect and maturity measure. The approach proposed extends the interoperability measurement to interoperability compatibility measure and interoperability performance measure. The interoperability potentiality measure concept proposed in the paper generalizes and extends the maturity concept to potentiality concept which includes not only maturity aspect but also other aspects such as openness, flexibility, configurability, adaptability (not dealt explicitly in the paper) etc.

The proposed potentiality measure model allows extending the LISI maturity model (dedicated to information systems) to cover the four areas of enterprise interoperability concerns (data, service, process, business) and three categories of interoperability barriers (conceptual, technological, organizational).

The interoperability compatibility measure can be done only if the two systems in question are known. At the current stage, the measure is performed using questionnaire to collect the information on the systems and applications used at the both sides and possible incompatibilities determined by experts of the domain. For example, if two ERP systems use two different terms to designate customer orders (ex. Order and Command) then there is semantic incompatibility.

The interoperability performance measurement is not only concerned with the technology aspect (IT systems) but also human and organizational ones. For example, the time measure covers not only possible data/information transmission time by IT systems which is quite small, but also delay caused by human factors (such as rigid and centralized organization, long human reaction delay etc.). The interoperability concept itself considered in the paper takes into account both IT and human aspects.

The calculation of metrics for interoperability potentiality and compatibility measurements is done through human judgment and evaluation. Knowledge-based system can be built for these measures in the future.

The use of these measures depends on the context and objective of the companies. Generally speaking, the potentiality measure can be used at any time in a company to evaluate its interoperability potential. A questionnaire can be elaborated to help collect relevant information. The compatibility measure can be used in an interoperability project: at the beginning to determine existing interoperability degree and identify existing barriers between two enterprise systems; and at the end of the project to measure the interoperability degree achieved and improvement. The performance measure is used after the project when two systems are in interoperation so that operational performance (time, quality, and cost) can be accessed.

Interoperability solutions can be categorized according to their ability to overcome interoperability barriers and linked to interoperability problems identified by these measures. An interoperability solution repository can be built based on the conceptual interoperability framework presented in section 2.

6. Conclusions

This paper has presented basic concepts and approaches of enterprise interoperability measurement. The paper also contributed to establish a science base of enterprise interoperability considered in the roadmap for enterprise interoperability by the European Commission [16]. The basic concepts of enterprise interoperability presented in section 2 served as basis by European Standardisation Committee CEN TC310/WG1 to elaborate an international standard in collaboration with ISO TC184 SC5/WG1: CEN/ISO 11354 (Framework for Enterprise Interoperability).

The three kinds of enterprise interoperability measurements allows considering the three aspects of interoperability evaluation: measuring the set of intrinsic properties of the system for interoperability (potentiality measure); detecting barriers between two particular enterprises (compatibility measure); and performance evaluation during the operational phase (performance measure). The three measures are complementary and consistent with respect to enterprise interoperability concepts.

Concerning interoperability potentiality measurement, the approach presented mainly focused on the maturity measure. Other system properties that have impact on interoperability such as openness, flexibility to change and to adapt, configurability (not only for IT system, but also organizational structure), etc. need to be investigated and explicitly considered.

Relating to compatibility measurement, it is to note that the measure can be used in an interoperability engineering project to evaluate both existing interoperability degree at the beginning of the project and the achieved degree at the end of the project so that improvement of interoperability can be assessed.

For interoperability performance measurement, the measures proposed at this stage of research are rather straightforward and need to be tested in more industrial cases for refinement and validation. It is also to note that the criteria used (time, quality and cost) are also used in other approaches to evaluate industrial system's performance in general.

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