A Maturity Model for Enterprise Interoperability

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Abstract. Existing interoperability maturity models are fragmented and only cover some interoperability aspects. This paper tentatively proposes a maturity model for enterprise interoperability which is elaborated on the basis of existing ones. It is also consistent to the Enterprise Interoperability Framework currently under the standardization process. After a brief introduction, the paper reviews existing maturity models for interoperability and recalls the basic concepts of the Enterprise Interoperability Framework. Then the proposed maturity model for enterprise interoperability is discussed in details. Metrics for determining maturity levels are presented as well. Finally the last part of the paper gives the conclusions and perspectives for future work.

Keywords: Interoperability measure, maturity models, assessment, enterprise interoperability.

1 Introduction

Developing interoperability implies establishing measures of merit to evaluate the degree of interoperability. Maturity is one of the possible measures, describing the stages through which systems can evolve to reach higher degree of interoperability. The interoperability maturity assessment allows companies knowing their strengths and weaknesses in terms of ability to interoperate with others, and defining priorities to improve interoperability.

Today there exist many maturity models. Few were developed for interoperability assessment. The objective of our research is to propose a Maturity Model for Enterprise Interoperability (MMEI) which deals with all major aspects of interoperability and covers the main concepts of existing interoperability maturity models. The Framework for Enterprise Interoperability (FEI) initially elaborated in INTEROP NoE [12] and now under CEN/ISO standardization process (CEN/ISO 11354) is used as a basis to build this MMEI.

Previously, survey and comparison studies [1] [2] have been performed to evaluate existing interoperability maturity models: LISI (Levels of Information System Interoperability) [4], OIM (Organizational Interoperability Model) [5], LCIM (Levels of Conceptual Interoperability Model) [6], and EIMM (Enterprise Interoperability Maturity Model) [7], as well as ISO/15504 (SPICE) [3] although it is not dedicated to

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interoperability assessment. Existing interoperability maturity models focus, in most of cases, on one simple facet of interoperability (data, technology, conceptual, Enterprise modeling, etc.). They are complementary rather than contradictory. Consequently it is necessary to structure them into a single complete interoperability maturity model to avoid redundancy and ensure consistency. This paper aims at presenting a preliminary research result on the development of such a Maturity Model for Enterprise Interoperability. This development is a long and iterative process which needs significant industrial applications and case-studies for its improvement and validation. The model presented in this paper should be considered as a basis and a starting point for further research and development.

The paper is structured as follows. In section 2, the Framework for Enterprise Interoperability is briefly presented. Main relevant interoperability maturity models are mapped to the framework to evaluate their coverage. In sections 3 and 4, the proposed maturity model for enterprise interoperability and associated metrics are outlined. Finally section 5 concludes the paper and proposes future work.

2 Framework for Enterprise Interoperability

The Framework for Enterprise Interoperability [12] defines three basic dimensions as follows:

- Interoperability concerns, defining the content of interoperation that may take place at various levels of the enterprise (data, service, process, business).
- Interoperability barriers, identifying various obstacles to interoperability in three categories (conceptual, technological, and organizational)
- Interoperability approaches, representing the different ways in which barriers can be removed (integrated, unified, and federated)

The first two dimensions, interoperability concerns and barriers, constitute the problem space of enterprise interoperability. The intersection of a barrier and a concern is the set of interoperability problems having the same barrier and concern. The three dimensions together constitute the solution space of enterprise interoperability.

Prior to the development of MMEI, existing interoperability maturity models were mapped to the FEI. Fig. 1 shows the framework with the first two dimensions and the coverage of existing interoperability maturity in the enterprise interoperability problem space of FEI.

While ISO/IEC 15504 model targets enterprise processes and is not specific to interoperability, it is however shown in the figure. In fact, using this model to improve processes will increase the interoperability potential, and as shown, it covers the three categories of interoperability barriers (conceptual, technological and organisational). LISI maturity model focuses on technology (IT) issues, and mainly concerns communication, data exchange and service (application) interoperability. LCIM deals with data interoperability and focuses on data representation issues (syntax and semantics) as well as data interchange, interface and accessibility. EIMM

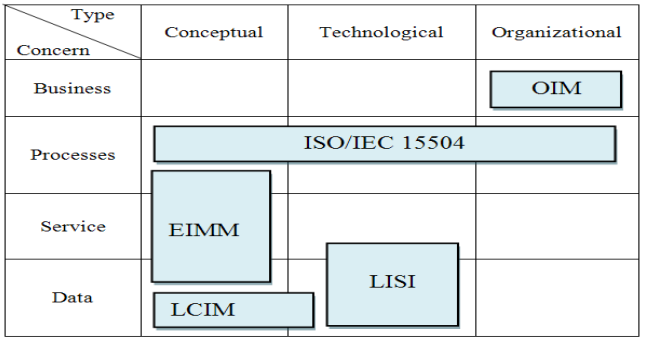

Fig. 1. Mapping of main maturity models to FEI (here the two dimensions only)

aims at evaluating enterprise modelling/model maturity and covers data, service and process interoperability issues. OIM assesses organisation maturity issues at business/ company level. Most of existing models were developed based on the main concepts of CMMI [13] which is considered as an instance of ISO/IEC 15504 and thus not presented here.

3 Maturity Model for Enterprise Interoperability (MMEI)

In this section, the proposed MMEI is presented. It covers the whole problem space of the Framework for Enterprise Interoperability (four interoperability concerns and three types of interoperability barriers). Main issues and concepts of existing interoperability maturity models are used as a basis to define criteria and requirements for accessing maturity levels.

Generally speaking, the maturity can be measured *a priori* (in this case the measure is concerned with the interoperability potentiality, i.e. with a possible future partner. The partner is not known at the moment of evaluation) or *a posteriori* (interoperation already exists between partners and in this case the assessment is concerned with the existing interoperability situation, i.e. considering the incompatibilities between two known systems). While MMEI is designed in an interoperability potentiality view, it might be exploited as well *a posteriori*.

3.1 Overview

When enterprise wants or needs to be able to properly interoperate with others, different tools such as guidelines or metrics might be useful. Evaluating its interoperability potentiality using the MMEI allows an enterprise having an idea of the probability it has to support efficient interoperations. But also to detect precisely the weaknesses which can be sources of interoperability problems. MMEI defines four levels of interoperability maturity as shown in the table 1. Each level identifies a certain degree of capability to establish/improve interoperability.

Table 1. Interoperability maturity levels

Maturity Level	Maturity assessment
Level 4 - Adapted	Capable of negotiating and dynamically accommodating with any heterogeneous partner
Level 3 - Organized	Capable of meta modeling for necessary mapping in order to interoperate with multiple heterogeneous partners
Level 2 - Aligned	Capable of making necessary changes to align to common formats or standards
Level 1 - Defined	Capability of properly modeling and describing systems to prepare interoperability
Level 0 - Unprepared	Not relevant: there is no capability for interoperation

Levels 0 and 1 correspond to the situation where there are no or some ad-hoc interoperations. From levels 2 to 4, three levels of maturity are defined corresponding to Interoperability Approach dimension of FEI (Integrated, Unified and Federated). Table 2 shows the mapping between maturity levels and interoperation environments.

Table 2. Maturity levels vs. interoperation environments

Maturity Level	Interoperation environments
Level 4 - Adapted	Federated: No pre-defined format or meta-models. Dynamically adjust and accommodate
Level 3 - Organized	Unified: Use of meta-models allowing heterogeneous systems to map one to others
Level 2 - Aligned	Integrated: Common format (or standard) for all partners to build there systems (components)
Level 1 - Defined	Connected: Simple electronic exchange of information, messaging, etc.
Level 0 - Unprepared	Isolated: Occasional and manual exchange of information (document, fax...)

Each level of maturity also corresponds to a degree of interoperability ranging from no interoperability to full interoperability as shown in table 3.

Table 3. Maturity levels and interoperability degree

Maturity Level	Interoperability degree
Level 4 - Adapted	Generalized (full interoperability to any potential partners worldwide)
Level 3 - Organized	Extended (many-to-many relation, multiple heterogeneous partners)
Level 2 - Aligned	Restricted (Peer-to-peer relation, to use a common format or standard)
Level 1 - Defined	Limited (with only some ad hoc interoperations)
Level 0 - Unprepared	Inexistent

Table 4 gives a high level view of MMEI and shows the focuses and concerns at each maturity level and for each interoperability barrier category.

Table 4. Focus and concern of MMEI

Maturity Levels/ Barriers	Conceptual	Technological	Organizational
Level 4 - Adapted	Accommodated	Reconfigurable	Agile
Level 3 - Organized	Mapped	Open-architecture	Trained
Level 2 - Aligned	Adhered	Arranged	Flexible
Level 1 - Defined	Modeled	Connectable	Specified
Level 0 - Unprepared	Incomplete	Inaccessible	Inexplicit

In the following sections, each maturity level is described with a table based on the FEI (dimensions of interoperability concerns and interoperability barriers). Each cell defines requirements (or criteria to meet) which are necessary to reach that interoperability maturity level. The transition from one level to a higher one corresponds generally to the removal of interoperability barriers and satisfaction of requirements.

3.2 Level 0 (Unprepared)

The initial level of interoperability maturity is characterized by proprietary or closed systems. In such systems, resources are not meant to be shared with others. System modeling and description are not complete or even inexistent. Organization is not explicitly specified. There is in general no interoperation possible or desired. Communication remains mainly manual exchange. Systems run stand-alone and are not prepared for interoperability.

The level 0 of interoperability maturity is described in table 5.

Table 5. Description of the MMEI level 0

		Conceptual	Technological	Organizational
Level 0	Business	Heterogeneous visions, strategies, politics (not properly described)	No IT infrastructure /platform in place, or incompatible ones	Undefined /heterogeneous methods of work
	Process	Heterogeneous processes (not formally described)	Manual processes	Undefined /heterogeneous procedures of work
	Service	Heterogeneous services (not formally defined)	Stand-alone services	Responsibilities /authorities not known
	Data	Heterogeneous data representation, not completely modeled	Closed data storage devices, manual exchange	Responsibilities /authorities for data not defined

3.3 Level 1 (Defined)

Although the systems are still entirely distinct, some ad hoc interoperations can take place, but the interoperability remains very limited. Some basic IT devices are connectable. Simple electronic data exchange becomes possible. Systems and organisations are in general defined and modelled. Modelling tools are in place and used for design time (specifying systems), but these tools are technology dependent and can only run in some specific platforms. Responsibility and authorities to model, update and maintain data, services, processes are explicitly defined.

The description of this level is shown in the table 6.

Table 6. Description of the MMEI level 1

		Conceptual	Technological	Organizational
Level 1	Business	Business models, strategies, politics described /modeled	IT infrastructure/ platform in place, and connectable	Organization structure defined and in place
	Process	Process modeling is performed	Platform dependant Process modeling tools (design time)	Responsibilities/ authorities for managing process defined
	Service	Services defined and documented	Platform dependant Service modeling tools (design time)	Responsibilities/ authorities for managing services defined
	Data	Data models explicitly defined	Devises connected/ simple electronic exchange possible	Responsibilities/ authorities for managing data defined

3.4 Level 2 (Aligned)

This level of maturity requires that the company is able (i.e. has the capabilities) to make changes in its system in order to adhere to common formats (imposed by a partner). Relevant standards are also used as much as possible. Some flexibility has been achieved in organization structure. IT infrastructure and platform are connected. Tools remains platform dependent but they are used not only for modeling (design time) but also executable at run time.

Generally speaking the efforts (time and cost) to make changes in systems are big and in general not easily reversible. The achieved interoperability by aligning to a common format or standard is said limited in the sense that it is confined to certain fixed and homogenous partners or situations such as for example companies' merge or fusion. It corresponds to the integrated environment/ approach defined in the Framework of Enterprise Interoperability.

The description of level 2 is shown in table 7.

Table 7. Description of the MMEI level 2

		Conceptual	Technological	Organizational
Level 2	Business	Business/IT alignment	IT Infrastructure / platform connected (peer-to-peer)	Flexible organization structure
	Process	Aligned process models using common formats / standards	Platform dependent Process execution tools (run time)	Procedures of work defined
	Service	Aligned service models using common formats / standards	Platform dependent Service execution tools (run time)	Guidelines for service exchanges in place
	Data	Align data models using common formats / standards	Data bases connected, remote access to data base possible	Rules and methods for data interoperability management in place

3.5 Level 3 (Organized)

At this level, enterprise is well organized to deal with interoperability challenges. Interoperability capability is extended to heterogeneous systems/partners, and often in a networked context. Although companies systems remain heterogeneous but the meta-modeling is performed, and mapping using meta-models is generalized. Organization and decision-making are in general decentralized to improve flexibility and reactivity.

Companies are able to interoperate with multiple heterogeneous partners. This level corresponds to the unified environment/ approach defined in the Framework for Enterprise Interoperability.

The development of an ontology, reference or standardized meta-models is required. Level 3 requires that people has been trained with collaborative approaches and interoperability notions and guidelines.

The description of the level 3 is shown in table 8.

Table 8. Description of the MMEI level 3

		Conceptual	Technological	Organizational
Level 3	Business	Business models for multi partnership and networked enterprise	Open and cross-enterprise infrastructure/ platform (many-to-many)	Organization team trained for interoperability
	Process	Process specification for mapping	Collaborative process engineering and execution tools	Guideline for cross-enterprise collaborative process
	Service	Services annotation and mapping	Collaborative service orchestration /choreography Composable services	Multiple roles and responsibilities
	Data	Meta models for data mapping	Remote access to data bases possible for applications	Non functional quality for interoperable data management

3.6 Level 4 (Adapted)

This level corresponds to the highest level of interoperability maturity (universal). Companies are able to dynamically adjust and accommodate 'on the fly'. There exist in general shared domain ontologies.

At the level 4 companies are able to interoperate with multi-lingual and multi-culture heterogeneous partners. This level corresponds to the federated environment / approach defined in the Framework for Enterprise Interoperability.

At this level all information and interoperability itself becomes a subject of continuous improvement (evolution and adaptation). This level is rarely reached by systems.

The description of this level is shown in table 9.

Table 9. Description of the MMEI level 4

		Conceptual	Technological	Organizational
Level 4	Business	Continuous Business/ IT alignment	Reconfigurable IT infrastructure / platform	Agile organization for on-demand business
	Process	Dynamic process re-engineering	Platform independent dynamic and adaptive tools and engines for processes.	Real-time monitoring of processes Adaptive work procedures
	Service	On-demand/ adaptive service modeling	Platform independent reconfigurable services architecture for services composition	Dynamic and on-demand allocation of resources to services
	Data	Adaptive data model (both syntax and semantics)	Direct database exchanges capability and full data conversion tool	Adaptive data management rules and methods

3.7 Remarks and Discussions

It is important to note that a lower interoperability maturity for a company does not systematically mean a dysfunction at all levels and for all functions of the company. The maturity is only evaluated from the interoperability point of view and cannot be applied for other purpose.

High level degree of interoperability cannot be achieved for free. It is generally costly and time consuming. Each enterprise must define its needed interoperability requirements and maturity level to reach. It is not recommended to all enterprise to look for the highest interoperability level regardless of their needs.

4 Maturity Model Metrics

We associate a metric M_k to each maturity level k. M_k is obtained from the different scores S_{ij} assigned by the evaluators, for each interoperability concern i and interoperability barrier j. These factors represent the proportion to which an evaluator thinks that the evaluated system is in the state described by the element (k, i, j) of the matrix (IML, EC, IL), IML representing the interoperability maturity levels; EC being the interoperability concerns; and IL the interoperability barriers.

We were inspired by the rating scale of SPICE [3], which uses a linear percentage scale against which each attribute is assessed in [0, 100] %. This allows us to define, in a coherent manner, a person's judgment which is subjective.

Let the scores S_{ij} be a percentage of achievement, i.e. in [0, 100] %. For a maturity level k, the following scale can be used:

- $0 < S_{ij} \leq 15$ => not achieved
- $16 < S_{ij} \leq 50$ => partially achieved
- $51 < S_{ij} \leq 80$ => achieved
- $81 < S_{ij} \leq 100$ => fully achieved

From these assigned scores, we can determine whereas the maturity level k is reached or not by calculating the metric M_k following the formula (1). A necessary condition for that is that the previous level (l-1) is already fully achieved ($81<M_{k-1}\leq 100$).

$$M_k = \frac{1}{n_i \times n} \sum_{i,j=1}^{n,n_i} s_{ij}. \quad (1)$$

With:

- n_i the number of the interoperability barriers to evaluate,
- n the number of interoperability concerns,
- s_{ij} the scale associated to the interoperability concern j at the interoperability level i.

The considered level is reached (achieved) at least if $M_k > 0.51$.

Because it is difficult for people making a fine judgment and assigning coherent numerical values, it can be convenient to use directly the linguistic variables for representing the assigned scores. In this case, the formula (1) would be changed to a fuzzy version, which can be treated using fuzzy logic to obtain directly a linguistic qualification of the maturity. This is one of our perspective works.

Example. To make the use of the maturity model and its metrics more concrete, we present here an example, for which we show how to determine interoperability level on the basis of examples considering two interoperating enterprises E1 and E2. When a particular interoperability project starts (i.e. the partner is known), barriers to interoperability can exist at each level of the company and of its partner. After a series of interviews, the evaluators give a report for the maturity level L_2, shown in table 10.

Table 10. Example of degrees assigned after a series of interviews

	Concerns	Conceptual	Technological	Organizational
Level 2	Business	0.5	0.7	0.8
	Process	0.65	0.85	0.5
	Service	0.8	0.7	0.7
	Data	0.9	0.9	0.4

To evaluate the general enterprise interoperability at all its levels, the maturity level is calculated by:

$$M_2 = \frac{1}{3\times 4}(0.5 + 0.65 + 0.8 + 0.9 + 0.7 + 0.85 + 0.7 + 0.9 + 0.8 + 0.5 + 0.7 + 0.4) = 0.7. \quad (2)$$

$M_2 > 0.51$, so the global interoperability maturity is at the level L_2.

5 Conclusion and Future Work

In this paper, the development of a maturity model for enterprise interoperability has been proposed. Five levels of maturity and metrics were defined and described. Based on the FEI, the proposed MMEI covers the four main enterprise interoperability

concerns (data, service, process, and business) and the three main problem areas (conceptual, technical, and organizational) which were usually dealt by separated distinct maturity models.

Future work is planned to refine the proposed model and metrics, and to perform some case studies in enterprises. A detailed questionnaire associated with a structured methodology will also be elaborated to support the use of MMEI in industry.

MMEI is also based on the concepts and notions coming from general system theory which is considered as relevant to develop a science base for enterprise interoperability [8]. The MMEI is intended to be used in association with OoEI (Ontology of Enterprise Interoperability) [9] to develop a knowledge based system to support enterprise interoperability analysis and diagnostics.

References

1. Panetto, H.: Towards a classification framework for interoperability of enterprise applications. International journal of Computer Integrated Manufacturing 20(8), 727–740 (2007)
2. Guedria, W., Naudet, Y., Chen, D.: Interoperability maturity models – Survey and Comparison. In: Proc. of the 3rd IFAC/IFIP, OTM workshop, EI2N 2008 (Enterprise Integration, Interoperability and Networking), Monterrey, Mexico (2008)
3. International Organization for Standardization and International Electrotechnical Commission, ISO/IEC 15504 Software Process Improvement and Capability DEtermination Model (SPICE) (2001)
4. C4ISR Interoperability Working Group, Levels of information systems interoperability (lisi), Tech. report, US Department of Defense, Washington, DC (1998)
5. Clark, T., Jones, R.: Organisational interoperability maturity model for c2. In: Proc. of the 1999 Command and Control Research and Technology Symposium, Washington (1999)
6. Tolk, A., Muguira, J.A.: The levels of conceptual interoperability model. In: 2003 Fall Simulation Interoperability Workshop, USA (September 2003)
7. ATHENA. Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and their Applications, FP6-2002-IST1, Integrated Project Proposal (April 2003)
8. Von Bertalanfy, L.: General System Theory: Foundations, Development, Applications. Georges Braziller, Inc., New York (1968)
9. Naudet, Y., Guédria, W., Chen, D.: Systems Science for Enterprise Interoperability. In: I-ESA 2009 workshops, 5th International Conference Interoperability for Enterprise Software and Applications, Beijing, China (2009)
10. CompTIA: European Industry Association. European Interoperability Framework, white paper - ICT Industry Recommendations (2004), `http://www.comptia.org`
11. INTEROP, Enterprise Interoperability -Framework and knowledge corpus- Final report, INTEROP NOE, FP6 -Contact n 508011, Deliverable DI.3 (2007)
12. Method Integrated Team.: Standard CMMI Appraisal Method for Process Improvement (SCAMPI), Version 1.1: Method Definition Document Members of the Assessment (2001)