1

Framework for Enterprise Interoperability

1.1. Introduction

Enterprise interoperability means many things to many people. It is interpreted in many different ways in different contexts with different expectations [CHE 03, CHE 04]. This is not only true in industry but also in research communities and sometimes even within a working group. Without a clear and shared understanding on the precise meaning of interoperability, research and development efforts cannot be efficiently carried out and coordinated. The proposed Framework for Enterprise Interoperability aims, on the one hand, to clarify the enterprise interoperability concept, and, on the other hand, to define and delimit the enterprise interoperability domain [INT 07].

The Framework for Enterprise Interoperability was developed under European FP6 NoE INTEROP (Interoperability Research for Networked Enterprises Applications and Software) [INT 03]. It was inspired from or influenced by the following works: LISI (Levels of Information Systems Interoperability) [C4I 98], IDEAS Interoperability Framework [IDE 03], European Interoperability Framework [EIF 04] and ATHENA Interoperability Framework [ATH 03].

Enterprise interoperability defined in this framework is considered as the ability to (1) communicate and exchange information, (2) use the information exchanged and (3) access to functionality of a third system. This definition is based on some existing ones defined in [IEE 90, VER 96, IDE 03]. It has been considered that enterprise systems are not interoperable because of barriers to interoperability. Barriers are incompatibilities of various kinds at the various enterprise levels. There exist common barriers to interoperability and generic solutions to remove those barriers.

Chapter written by David CHEN.
This chapter is based on the paper [CHE 09].

1.2. Enterprise interoperability concepts

There are many concepts relating to interoperability. This section focuses on the basic concepts for the purpose of helping to understand the framework for enterprise interoperability and its underlying domain. These concepts are identified based on the state-of-the-art of relevant interoperability researches [INT 04].

1.2.1. *Interoperability barriers*

Interoperability barriers are a fundamental concept for understanding interoperability problems. Many interoperability problems are specific to particular application domains. These can be issues like support for particular attributes or particular access control regimes. However, general barriers or problems of interoperability exist and can be identified; and most of them being already addressed [KAS 04, EIF 04, ERI 04]. Consequently, the objective is to identify and categorize those common barriers to interoperability. The term "barrier" means an "incompatibility" or "mismatch" that obstructs the sharing and exchanging of information. Three categories of barriers are identified: (a) *conceptual*, (b) *technological* and (c) *organizational*.

a) *Conceptual barriers*

Conceptual barriers are concerned with the syntactic and semantic incompatibilities of information to be exchanged. These problems concern the representation of information at the high level of abstraction (such as, for example, the enterprise models of a company) as well as the level of programming (for example, low capacity of semantic representation of XML):

– syntactic incompatibility can be found whenever different people or systems use different structures (or format) to represent information and knowledge. To tackle this problem, the UEML initiative [UEM 01] developed a neutral model to allow mapping between different enterprise models built with different syntaxes;

– semantic incompatibility is seen as an important barrier to interoperability as the information and knowledge represented in most of the models or software have no clearly defined semantics to allow unambiguous understanding of the meaning of information. At the current stage of research, the most known technique to solve this problem is semantic annotation and reconciliation using ontology.

Conceptual barriers are the main barriers to interoperability.

b) *Technological barriers*

Technological barriers are concerned with the use of computers or ICT (Information and Communication Technology) to communicate and exchange information. Typical technological barriers are for example incompatibility of IT architecture & platforms, infrastructure, operating system, etc. From a purely technical perspective, these problems concern the ways to present, store, exchange, process and communicate data and information through the use of software systems. Examples of technological barriers are:

– communication barriers, e.g. incompatibility of the protocols used to exchange information;

– content barriers, e.g. different techniques and methods used to represent information, or incompatibility in the tools used to encode/decode the information being exchanged;

– infrastructure barriers, e.g. use of different incompatible middleware platforms.

Technological barriers are additional barriers with respect to conceptual ones. They are caused by the use of computer. Technological barriers only exist if computers are involved in an interoperation.

c) *Organizational barriers*

Organizational barriers are concerned with the incompatibilities of organization structure and management techniques implemented in two enterprises. For example, one organization structure barrier is related to the way of assigning responsibility and authority. Indeed, if two companies have different organization structures (e.g. hierarchical vs. networked) and management techniques, some necessary mappings may need to be done before the two sides become interoperable at an operational level:

– responsibility needs to be defined to allow two parties knowing who is responsible for what (process, data, software, etc.). If responsibility in an enterprise is not clearly and explicitly defined, interoperation between two systems may be obstructed;

– authority is an organizational concept which defines who is authorized to do what. For example, it is necessary to define who is authorized to create, modify, maintain data, processes, services, etc.;

– organization structure refers to the style by which responsibility, authority and decision-making are organized. For example, we can talk about centralized versus decentralized organizations, or hierarchical versus matrix or networked organization structures.

Organizational barriers are also additional barriers. Compared with conceptual barriers (centered on information problems) and technological barriers (concerned with IT problems), organizational barriers originate from the problems of humans.

1.2.2. *Interoperability concerns*

This section defines the interoperations that can take place from the various concerns (or viewpoints) of the enterprise. Although the definitions are mainly given from the point of view of IT-based applications, they apply to non-computerized systems as well. This categorization is based on the ATHENA Technical Framework [GUG 05].

The interoperability of communication is a basic condition to allow for interoperability to take place. It relates primarily to the interconnection of systems and equipment as well as communication means. From an IT point of view, it is concerned with communication protocols (i.e. from cable connection to the protocol of layers 1 to 4 of the OSI model) and interfaces (layers 5 to 7 of the OSI model). Since the topic of interoperability of communications is already widely discussed, it will not be a subject of discussion in this section.

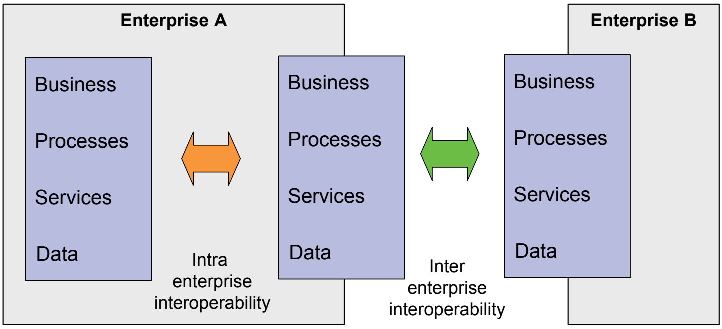

Figure 1.1. *Adapted from [ATH 07]*

In the domain of enterprise interoperability, the following four interoperability concerns are identified as shown Figure 1.1: (a) data, (b) service, (c) process and (d) business. In an enterprise, data is used by services (or functions to provide a service). Services (functions/activities) are employed by processes to realize business of the enterprise. From another point of view, the goal of an enterprise is to run its business. To realize the business, we need processes. Processes employ services/functions that in turn need data to perform activities.

a) *Interoperability of data*

The interoperability of data refers to the simultaneous operation of different data models (hierarchical, relational, etc.) and the use of the different query languages. Moreover, their content is 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 concerned with finding and sharing information coming from heterogeneous databases, and which can, moreover, reside on different machines with different operating systems and database management systems.

Data interoperability plays an essential role in enterprise interoperability. It is concerned with the ability to exchange both non-electronic data (documents) and machine transportable data (data files, data stored in a database) and use the data/information exchanged. Data interoperation may occur when two partners simply exchange two data files (e.g. Excel files); or in the case of process interoperability or service interoperability themselves employ data to perform activities. Typical barriers which prevent data interoperations are for example conceptual ones, such as different semantics and syntax to represent data, and also technological one (different database technologies and coding techniques) and organizational ones (database management, security policy, etc.).

b) *Interoperability of service*

The interoperability of service is concerned with identifying, composing and operating various applications (designed and implemented independently) by solving the syntactic and semantic differences as well as by finding the connections to the various heterogeneous databases. The term “service” is not limited to IT applications, but includes functions of the company or of networked enterprises.

Service interoperability deals with the capability of exchanging services (works) among partners. Service interoperability has two main problems: service exchange between a service demander and a service provider; interconnection between different services to form a complex service (the last case is related to process interoperability as well). A service is provided by a resource (computer type, machining type and human type). Issues relating to service interoperability are concerned with the description (both from the syntax and semantic aspects) of the services required and provided, the mechanisms to search and discover a distributed service provider, the ICT supports for service discovery, composition and the organizational issues relating the management of service exchange, etc.

c) *Interoperability of process*

The interoperability of processes aims at making different processes work together: a process defines in which order services (functions) are related. 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 connect the internal processes of two companies to create a common process.

More precisely, process interoperability arises when linking different process descriptions (be they documents or supported by software) to form collaborative processes and perform verification, simulation and execution. Usually, different process description languages are used to define different process models for different purposes. Typical barriers that prevent process interoperations include: different semantics and syntax used in different process modeling languages; incompatible process execution engines and platforms; different process organization mechanisms, configurations and managements. Developing process interoperability means to find solutions to allow mapping, connecting, merging, and translations of heterogeneous process models, applications and tools.

For interoperability reasons, these solutions are concerned with the connection points of the processes and not with the processes as a whole. The latter would lead to process integration.

d) *Interoperability of business*

The interoperability of business refers to work in a harmonized 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.

In other words, business interoperability is concerned with how business is understood and shared without ambiguity among interoperation partners. Business interoperability explores interoperability from a business perspective and identifies the fundamental artifacts related to business issues. These issues range from the business vision and culture to the ICT infrastructure support as well as the compatibility between different organization structures, methods of work, accounting systems and rules, labor legislations, etc. Developing business interoperability is a means to find ways to make those issues be harmonized or at least understood through necessary mappings and negotiations. It is worth noting that for interoperability reasons, these solutions are concerned with the connection points of the business not with the business as a whole. The latter would lead to business integration.

1.2.3. *Interoperability approaches*

Defining the enterprise interoperability domain is not only a matter of identifying barriers and solutions for removing barriers, but also the ways in which these barriers are removed. Establishing interoperability requires relating entities in some way. According to ISO 14258 (concepts and rules for enterprise models) [ISO 99], there are three basic ways to relate entities together: (a) integrated, (b) unified and (c) federated, as shown in Figure 1.2.

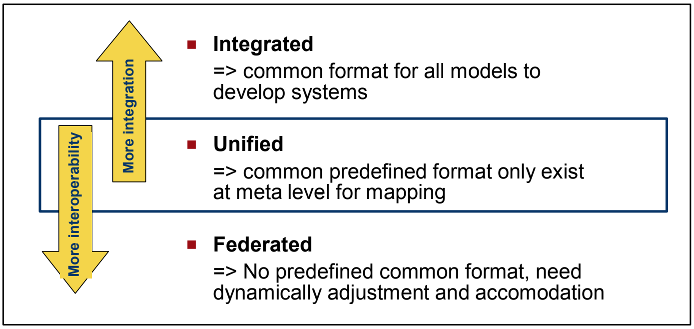

Figure 1.2. *Basic approaches to develop interoperability*

a) *Integrated approach*

Developing interoperability through an *integrated approach* means that there exists a common format for all models. Diverse models are built and interpreted using/against the common template. This format must be as detailed as the models themselves. The common format is not necessarily an international standard but must be agreed by all parties to elaborate models and build systems. Example of developing interoperability using an integrated approach is ebXML.

The integrated approach is more relevant to full integration rather than full interoperability. This approach is suitable when designing and implementing new systems rather than re-engineering existing systems for interoperability. To some extent, the integrated approach is more adapted to developing intra-enterprise interoperability rather than inter-enterprise.

The integrated approach ensures the global consistency and coherence of the system. Various components of the system are designed and implemented using a common format (or standard) so that interoperability is seen as designed-in quality (of the system's components). Interoperation between various parts can be obtained *a priori* without any interfacing effort.

b) *Unified approach*

Interoperability can also be established using a *unified approach*. It means there is a common format but it only exists at the meta-level. This format is not an executable entity, as is the case in an integrated approach. Instead, it provides a mean for equivalence to allow mapping between models and applications. For example, using the meta-model, a mapping between the constituent models is possible even though they might encounter loss of some semantics or information.

Most research results developed in the domain of interoperability have adopted the unified approach. For example, UEML (Unified Enterprise Modeling Language) aims at defining a neutral format at meta-modeling level to allow mapping between enterprise models and tools. The STEP initiative elaborated in ISO TC184 SC4 also defined a neutral product data format at the meta-modeling level to allow various product data models exchanging product information.

The unified approach is particularly suitable for developing interoperability for collaborative or networked enterprises. To be interoperable with networked partners, a new company just needs to map its own model/system to the neutral meta-format without the necessity to make changes on its own model/system. This approach presents the advantage of reduced efforts, time and cost in implementation. It is also adapted to the situation where a large company needs to interoperate with SMEs. Normally, a SME works with more than one big company; to interoperate with different companies, the unified approach seems to be a suitable solution.

c) *Federated approach*

In the case of using a *federated approach*, there is no format which is common to all. To establish interoperability, parties must accommodate and adjust “on the fly”. Using the federated approach implies that no partner imposes their models, languages and methods of work. They must negotiate dynamically to reach the needed agreements. This means that they must share some ontology.

The federated approach can also make use of meta-models for mapping between diverse models/systems. The difference to a unified approach is that this meta-model is not pre-defined but established “dynamically” through negotiation. Consequently, this approach is more suitable for “peer-to-peer” situations rather than the cases mentioned in the unified approach. It is particularly adapted to Virtual Enterprises, where diverse companies join their resources and knowledge to manufacture a product with a limited duration.

Using the federated approach to develop enterprise interoperability is the greatest challenge and little activity has been performed in this direction. A main research area is the development of a “mapping factory” which can generate on-demand customized AAA (Anybody-Anywhere-Anytime) mapping agents among existing systems. It is worth noting that a specific support for the federated approach is seen in entity profiles which identify particular entity characteristics and properties relevant for interoperation (ISO 15745 and ISO 16100).

All three approaches allow for developing interoperability between enterprise systems. The federated approach is considered as the most interesting to achieve full interoperability. However, the choice depends on the context and requirements. If the need for interoperability comes from a merger of enterprises, the integrated approach seems to be the most adapted one. In this case, there is only one common format for all systems, and all models are built and interpreted according to this one. If the need for interoperability concerns a long-term collaboration, the unified approach would be a possible solution. For that, a common meta-model across partners’ models provides a means for establishing equivalence allowing for mapping between diverse models. Finally, if the need for interoperability originated from a short-term collaboration project (e.g. virtual enterprise), the federated approach can be used. Partners must dynamically adapt to find necessary agreements.

Figure 1.3 summarizes enterprise interoperability concepts with the aim to define the ontology of enterprise interoperability (adapted from [NAU 07]).

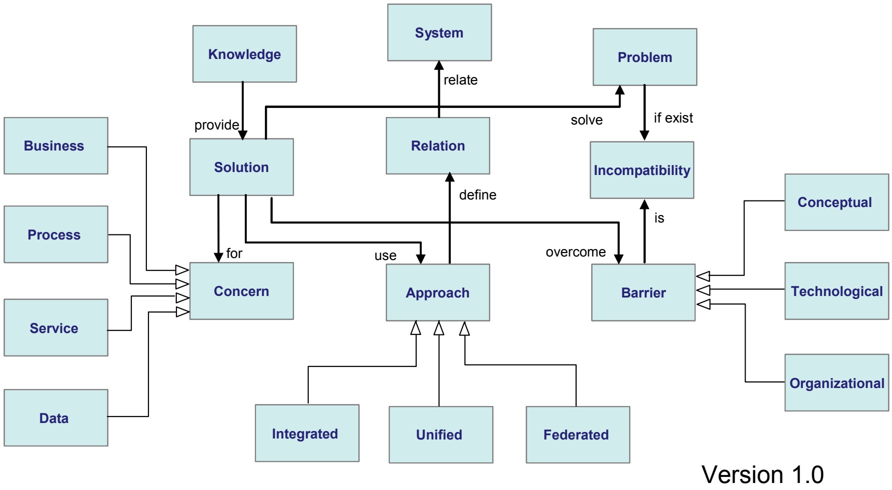

Figure 1.3. *Towards an ontology of enterprise interoperability*

1.3. Framework for Enterprise Interoperability

The term “framework” is a conceptual model. It refers to an organizing mechanism for structuring and categorizing “things” relative to a domain. A framework does not provide an operational solution to solve a business problem. The interoperability framework presented in this chapter aims at structuring the main concepts of the enterprise interoperability domain. The framework has three basic dimensions: interoperability concerns, interoperability barriers and interoperability approaches.

1.3.1. *Problem space versus solution space*

The first two dimensions: interoperability concerns and interoperability barriers constitute the problem space of enterprise interoperability (see Figure 1.4). The intersection of an interoperability barrier and an interoperability concern is the set of interoperability problems having the same barrier and concern. The three dimensions together constitute the solution space of enterprise interoperability. The intersection of an interoperability barrier, an interoperability concern and an interoperability approach is the set of solutions to breakdown a same interoperability barrier for a same concern and using a same approach.

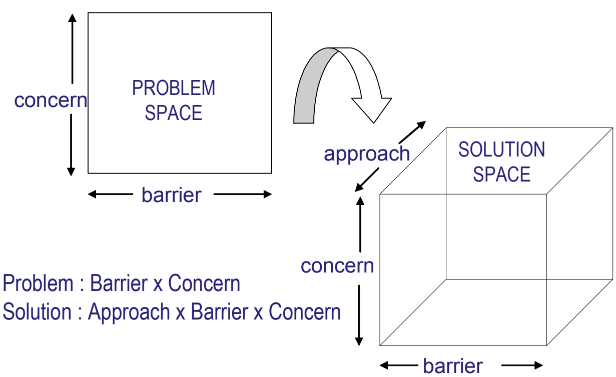

Figure 1.4. *Problem versus solution spaces*

1.3.2. *The two basic dimensions*

Based on these concepts, and the categorizations presented in the previous section, the two basic dimensions of the enterprise interoperability framework are shown in Figure 1.5: (1) interoperability concerns and (2) interoperability barriers.

Some examples of interoperability barriers and problems are also shown in the figure. For example, at the intersection of conceptual barrier and process concern, one of the interoperability problems encountered is for example the impossibility of exchanging process model information between IDEF3 and BPMN models because of the syntax incompatibility of the two models.

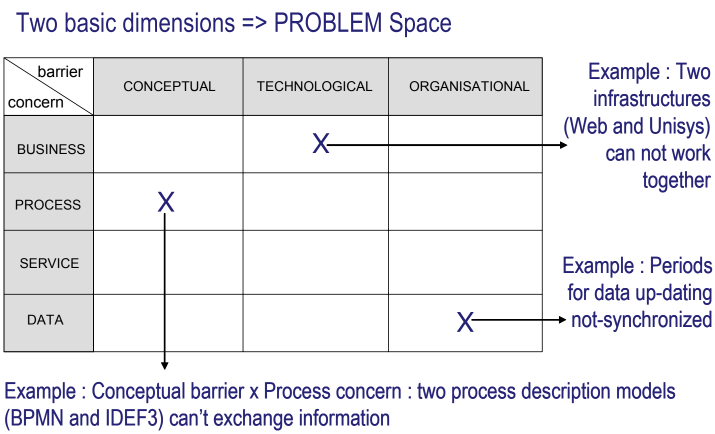

Figure 1.5. *Framework for Enterprise Interoperability (two basic dimensions)*

Adopting the barrier-driven approach to tackle interoperability problems implies that research is bottom-up to find knowledge and solutions to remove barriers. Although the three categories of barriers concern all the four levels, conceptual and organizational barriers are more important at the higher levels while technological (barriers due to the use of ICT) ones have a greater impact on the lower levels.

1.3.3. *The third dimension*

The third basic dimension (interoperability approaches) added to the two dimensional framework allows for categorizing solutions of enterprise interoperability according to the ways of removing the barriers. As discussed in the previous section, this dimension considers the three basic approaches to develop interoperability: integrated, unified and federated.

The framework, with its three basic dimensions, is shown in Figure 1.6. We recall the three basic dimensions as follows:

– *interoperability concerns* that define the content of interoperation that may take place at various levels of the enterprise (data, service, process, business);

– *interoperability barriers* that identify various obstacles to interoperability in three categories (conceptual, technological and organizational);

– *interoperability approaches* that represent the different ways in which barriers can be removed (integrated, unified, and federated).

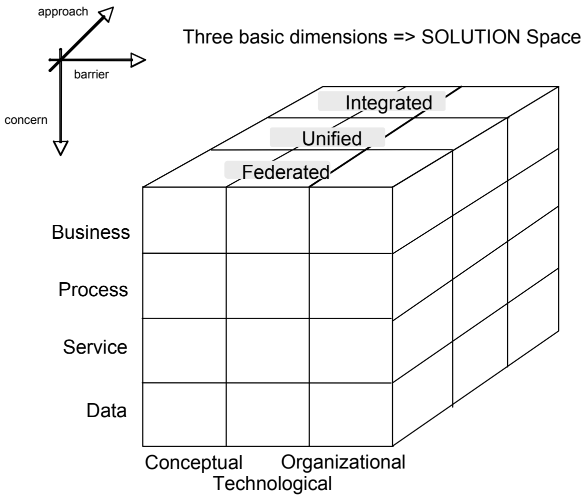

Figure 1.6. *Framework for Enterprise Interoperability*

The third dimension allows for capturing and structuring interoperability solutions according to their ability to remove interoperability barriers. For example, Process Specification Language (PSL) [SCH 00] is a solution that contributes to removing the *conceptual* barrier (both syntax and semantics) concerning *process* through a *unified* approach. Figure 1.7 shows the position of a PSL solution in the framework.

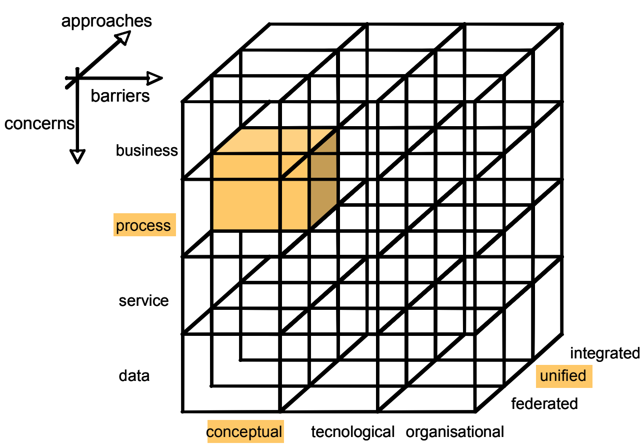

Figure 1.7. *Position of a PSL in the framework*

To help capture the solutions and their positioning in the framework, a template is proposed. Figure 1.8 shows a simplified example of the template to describe a PSL solution.

Interoperability knowledge/solution template	
Name of the knowledge/solution: PSL	
1. Interoperability concern	Process level
2. Interoperability barrier	Conceptual (Syntax and sematics)
3. Interoperability approach	Unified approach
4. Interoperability problem	different process models use different process languges and are not interoperable
5. Interoperability knowledge	Define a neutral Process Specification Language (PSL) and related ontology as a metamodel to allow mapping between different process models
6. Example (optional)	
7. Remarks	Initially proposed by NIST, now moved to standardisation at ISO level
8. References	ISO CD 18629 (2001), Industrial automation systems and integration, Process Specification Language (PSL), JW8/ISO 184/SC4/SC5

Figure 1.8. *Template example to collect a PSL solution*

1.3.4. *Complementary dimensions*

The third dimension (interoperability approaches) discussed above can be replaced by other complementary dimensions according to the objective related to a particular usage of the framework. In other words, the third dimension can be considered as an open dimension. At the current stage of this research, there are three possible dimensions to be identified.

Interoperability engineering dimension

This dimension aims at defining a set of phases (steps) to follow for establishing interoperability between two enterprises (or any two business entities). The system life cycle phases defined in ISO 15704 Standard [ISO 00] have been adapted and three main phases have been defined as follows: (1) requirements definition, (2) design specification and (3) implementation. Figure 1.9 shows this dimension in relation to the two basic dimensions of the framework.

Using this framework in an interoperability project, the requirements definition phase identifies possible barriers to interoperability that exists between two enterprises and the interoperability concerns to be addressed. At the design specification phase, search/develop interoperability solutions for removing the barriers is defined. The implementation phase allows for implementing and testing the solutions and measuring the interoperability achieved.

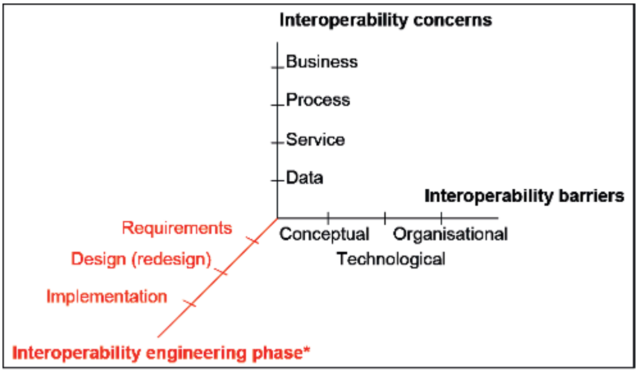

Figure 1.9. *Interoperability engineering phase dimension*

Interoperability measurement dimension

The degree of interoperability is a measure characterizing the ability of inter-operation between two enterprises (or systems). At the current stage of research, three types of measurement are identified as shown in Figure 1.10: (1) interoperability potentiality measurement, (2) interoperability compatibility measurement and (3) interoperability performance measurement. The interoperability degree of a given enterprise (or a system) can be defined by a vector characterized by the three measurements [DAC 06].

The potentiality measurement is concerned with the identification of a set of system properties that have impact on the interoperability. This measure is performed on one enterprise/system without knowing its interoperation partner. The objective is to evaluate the potentiality of a system to adapt accommodate it to overcome various possible barriers. For example, an open system has a higher potential of interoperability than a closed system.

The compatibility measurement is performed when the partner/system of the interoperation is known. The measure is done with respect to the identified barriers to interoperability. The highest degree means there is no barrier to interoperability. The inverse situation means the poorest degree of interoperability.

The performance measurement is performed at run time to evaluate interoperations between two cooperating enterprises (or systems). Criteria such as cost, delay and quality can be used to measure the interoperation performance. Therefore, each type of measurement has to be valued with local coefficients in order to get a global coefficient ranging from “poor interoperability” to “good interoperability”.

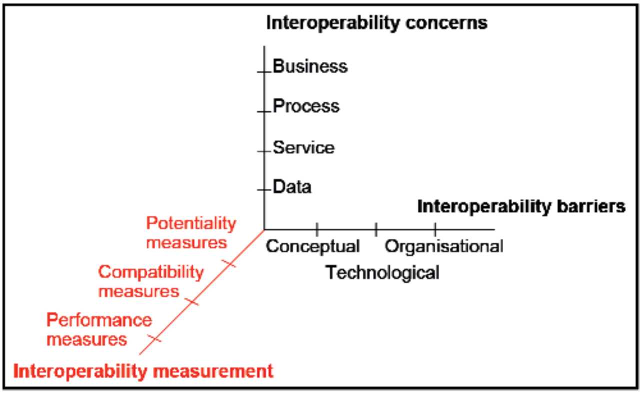

Figure 1.10. *Interoperability measurement dimension*

Interoperability knowledge dimension

From an abstraction level point of view, there are two types of knowledge/solution: conceptual or technological, as shown in Figure 1.11. The notion of a conceptual versus technological solution also comes from engineering design where we distinguish between conceptual design and technical design. Conceptual design aims at specifying a conceptual solution that is independent from technology for implementing the solution. For a given conceptual solution, there may exist several different technologies to implement the solution. The technology choice is made at technical design stage. This technical design is also called the detail design.

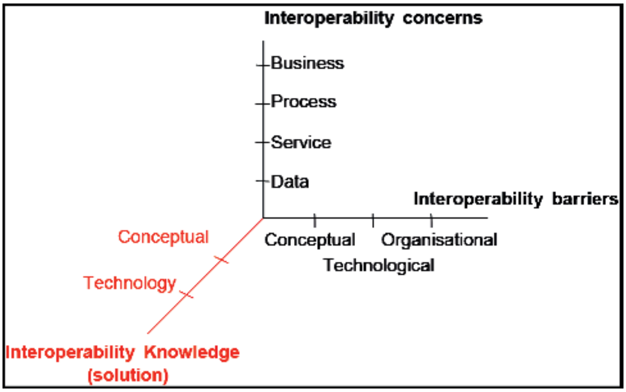

Figure 1.11. *Interoperability knowledge/solution dimension*

Conceptual solution also means the conceptual description of a solution. In this case, a conceptual solution describes the "ideas" that allow solving a problem without specifying how to concretize the "ideas", i.e. how to implement the "ideas".

Conceptual solution can also be a conceptual representation of an existing technical solution. In this case, only generic aspects of the solution (for example functions) are "filtered" and represented without specific technological details.

With this dimension, it is possible to position interoperability knowledge (solution) in the framework in a more precise way. For each category of barriers (conceptual, technological and organizational), solutions can be conceptual, technological or both. For example, the "semantic annotation" is a method to move semantic barrier concerning the all four levels (conceptual knowledge/conceptual barrier/all concerns). A* tool developed in ATHENA project is a technological solution to remove semantic barrier concerning all the concerns (technology knowledge/conceptual barrier/all concerns).

1.4. Conclusion and prospects

This chapter presented a Framework for Enterprise Interoperability in which the problem and solution spaces defined the domain of enterprise interoperability. With respect to the existing interoperability frameworks (ATHENA, IDEAS, EIF, etc.), the proposed framework is barrier driven. If a problem or a solution cannot find its place in the framework, it is not an enterprise interoperability problem or solution. The complementary dimensions allow for "personalizing" the framework according to a specific user's need.

Establishing interoperability means relating two (or more) systems and removing any incompatibilities. Incompatibility is the fundamental concept used in defining the scope of interoperability domain. The concept "incompatibility" has a broad sense and is not only limited to "technical" aspects as usually considered in software engineering, but also "information" and "organization", and concerns all levels of an enterprise. Another fundamental consideration is the generic characteristic of the interoperability research. Indeed, there are generic problems and solutions regardless of the content of information exchanged between two systems.

Benefits and applications of the framework include a better understanding of enterprise interoperability research problems. Furthermore, knowledge and solutions can be structured in the framework to allow gap analysis, so that future research orientation can be defined to close the gaps. It also contributed to the standardization work in this area. The International Standard EN/ISO 11354 (Framework for

Enterprise Interoperability) elaborated jointly by CEN TC310/WG1 and ISO TC184 SC5/WG1 has adopted the proposed framework.

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