01 INTEROPERABILITY
INTEROP PROJECT – OVERVIEW AND RESULTS

Kurt Kosanke
CIMOSA Association e. V., Germany, kosanke@cimosa.de

Collaboration and co-operation of enterprises is the new paradigm in enterprise operation. This requires interoperation of the different enterprise operational systems, which can be easily established and can be executed reliably for the exchange of information. Information which is understood with the same meaning and which is trusted by all parties involved in the exchange. This paper reports on the European INTEROP Network of Excellence concerned with interoperability research for networked enterprises applications and software, its goals, rationale and results. The different activities of the INTEROP network to solve problems of research fragmentation in this domain are identified. The current status in relevant standardisation is presented as well.

1. INTRODUCTION

Virtual Organisations, virtual and extended enterprises, supply chains are all organisational forms that have a common need: real time information exchange between the operational systems of their collaborating partners.

Such exchanges are needed for the operational control and to an even larger extend for the decision-making processes during the establishment of the cooperation like market opportunity exploration and co-operation planning and its implementation. Therefore, both the easy communication between the people involved and the quality of interoperation between the supporting systems of information and communication technology (ICT) play a key role in such undertakings. Today, the establishment and operation of such networked business encounters significant problems due to the lack of interoperability between enterprise systems.

The role of research in this area is to create ICT technologies that enable the organisation of such networks and their support during their operation. However, the research community in this domain is rather fragmented and there is neither an overall guidance nor a sufficient collaboration between the institutions involved to avoid redundancies in the research work and to provide the critical mass needed to produce meaningful results.

In addition, there exists no explicit research on interoperability of enterprise applications and software at the European level. A starting point for a common research agenda has been defined by the roadmap for interoperability research developed by the European project IDEAS (2001) and is described by Chen and Doumeingts (2003). This roadmap emphasises the need for integrating three key

thematic domains: a) Architectures and Platform, b) Enterprise Modelling and c) Enterprise Ontologies, which have been identified as the main domains of interoperability solutions. Following this roadmap, the European Commission in its 6th Framework has initiated a call for proposals in the area of interoperability, which has lead to a cluster of projects addressing interoperability from different point of view. The cluster has the following project members: ATHENA, CROSSWORK, ECOLEAD, INTEROP, NO-REST and TRUSTCOM.

To ensure efficient industrial impact, in particular through future standardisation, INTEROP specifically interacts with the integrated project ATHENA (2004). This cooperation is part of an initiative from European key research organisations and industrial actors to push interoperable solutions for networked business to market.

Following some discussions on interoperability and its different understanding in section 2, the INTEROP project and the different results achieved are presented in section 3. The paper concludes with section 4 identifying long lasting follow-on activities in the area of interoperability.

2. INTEROPERABILITY

But what is the meaning of interoperability?

Stegwee and Rukanova (2003) identify three levels of inter-communication in a system: a) *interconnectivity*: ability to exchange information at a network (syntactical) level, b) *interchangeability*: ability to use information at a presentation (semantic) level and c) *interoperability*: ability to use information at an application (pragmatic) level.

According to Chen and Doumeingts (2003) interaction between two systems can at least take place at three levels: a) *data*, b) *resource* and c) *business process* and interoperability may therefore be achieved on multiple levels: i) *inter-enterprise coordination*, ii) *business process integration*, iii) *semantic application integration*, iv) *syntactic application integration*, and v) *physical integration*.

But the pragmatic level (Stegwee and Rukanova) is very much domain specific. Besides the three areas in which communication is required: 1) between *people*, 2) between *people and ICT*, and 3) in the *ICT itself*; there are the different business domains like industry, finance, health, each one having sub-domains like categories of humans (managers, experts, operators), of devices (controllers, actuators, sensors), and of systems (computers, machines, communication networks) with their specific needs for communication in general and interoperation in particular.

In addition there is the heterogeneity of ICT implementation – the ICT communication problem, which leads to different solution spaces depending on the combination of existing systems and in many cases such solutions are not transferable to other cases.

The recommendations in Chen and Doumeingts are to address the subject of interoperability through the three main research domains identified above: Architectures and Platform, Enterprise Modelling and Enterprise Ontologies. These three areas are concerned with a) representing the inter-networked organisation to establish interoperability requirements; b) defining implementation solutions to achieve interoperability; and c) addressing the semantics necessary to assure interoperability.

2.1 Definitions

There exist numerous definitions of interoperability, interoperation, interaction, portability. E.g. a very careful chosen web search produced 22 entries on interoperability. Examples from literature are:

- *Interoperability:* ability of two or more systems or components to exchange information and to use the information that has been exchanged (IEEE, 1990)
- *Interoperability:* (computer science) the ability to exchange and use information (usually in a large heterogeneous network made up of several local area networks (WordNet 2.1))
- *Interoperation:* implies that one system performs an operation on behalf of another (Chen, Doumeingts, 2003)

Related definitions are:

- *Interaction:* a mutual or reciprocal action; interacting (WordNet 2.1)
- *Portability:* (1) the ease with which a system, component, data, or user, can be transferred from one hardware or software environment to another; and (2) a quality metric that can be used to measure the relative effort to transport the software for use in another environment or to convert software for use in another operating environment, hardware configuration, or software system environment TOGAF (Open Group, 2000)

More specific definitions are provided in the ISO standards 14258 and 16100:

- *Interoperability* may occur between two (or more) entities that are related to one another in one of three ways (ISO 14258, 1998)
  - *Integrated* where there is a standard format for all constituent systems
  - *Unified* where there is a common meta-level structure across constituent models, providing a means for establishing semantic equivalence
  - *Federated* where models must be dynamically accommodated rather than having a predetermined meta-model
- *Manufacturing software interoperability:* ability to share and exchange information using common syntax and semantics to meet an application-specific functional relationship across a common interface (ISO 16100-1, 2003)

Opting for the computer science definition of interoperability, in reality it seems very unlikely that interoperability or interoperation on a larger scale will occur in any one of the three ways identified in ISO 14258, but in a combination of those. Assuming a global environment there will be neither the possibility for global unification nor for global integration and even federation in the dynamic mode as identified above seems very hard to achieve without any a priori knowledge about the entities that have to interoperate.

3 INTEROP-NOE (NETWORK OF EXCELLENCE)

The INTEROP-Network of Excellence (2003) started 2003-11-01, is carried out in two phases of 18 months each and will end in 2007. The network gathers 51 organizations from 15 countries and is coordinated by the University of Bordeaux.

The primary goal of the project is the sustainable structuring and shaping of European research activities on interoperability for enterprises applications and software and the emergence of a lasting European research community that will influence standards, affect policy and solve recurrent problems in networked enterprises. For this the project is preparing to set-up a durable, self sustaining European-wide virtual laboratory dedicated to enterprise interoperability with both academic and industrial involvement aiming to extract and exchange new knowledge from the integration of the three thematic domains identified in the IDEAS roadmap (Chen, Doumeingts, 2003) and shown in Figure 1.

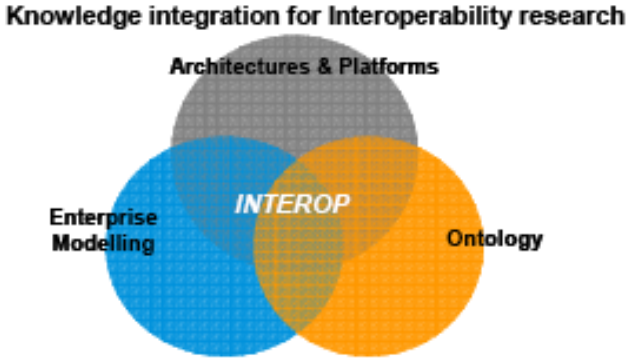

Figure 1 – INTEROP areas of work

Therefore, the INTEROP Work programme deploys a collaborative approach with three aims:

- To integrate the knowledge in ontology, enterprise modelling, and architectures & platforms to give sustainable sense to interoperability,
- To structure the European research community and influence organisations' programmes to achieve a critical research mass,
- To animate the community and spread industrially significant research knowledge outside the network.

During the first phase (18 month) the project and addressed the following work areas, (Integrating, Joint Research and Spreading of Excellence activities) which have been carried out in a number of work packages:

- **Integrating activities (IA)** addressed research fragmentation by capturing the knowledge about interoperability research in Europe, provided a web portal and supporting services to make knowledge on interoperability available, supported researcher mobility - to get people to know each other personally, and enabled project management through a common integrated methodology and performance indicators.

- **Joint research activities (JRA)** provided a common framework for distributed organisations, which explore modelling, simulation, analysis, and design interoperability solutions, improved modelling techniques to allow interoperability between enterprise models, provided a complete approach to make interoperability operational by harmonizing and synthesizing existing research like model driven approach, service-oriented architecture, peer-to-peer architectures, agent architectures and federated architectures.
- **Spreading of excellence activities (SE)** provided training facilities to spread the knowledge added by INTEROP, increased awareness of interoperability within the European research community, created an Interoperability Laboratory Network to promote Interoperability services towards SMEs

During the second phase the emphasis is still on the three domains identified in the IDEAS roadmap, but supported by a specific interoperability domain and interdisciplinary task groups and task forces with participation crossing the previous work package organisation of the integrating and joint research activities. The task groups will tackle specific interoperability themes like model synchronisations, model driven interoperability, model morphisms, semantic enrichment, business/IT alignment, methods and trust/confidence/security.

3.1 Results

In the meantime the INTEROP project has delivered results in all of its work areas. Selected results are described in the following:

K-Map (Deliverable D1.1, 2006): the concept of the knowledge map has been completed providing an information classification framework structured according to the INTEROP work areas ontologies with 4 sub-areas, enterprise modelling with 19 sub-areas and architectures and plat-forms with 14 sub-areas. Table 1 provides an overview of this taxonomy by showing the top categories identified in each domain and a selection of the currently defined sub-areas.

Table 1 – K-Map categories

Ontologies	**Enterprise modelling**	**Architecture & Platforms**
Ontology representation and reasoning	Networked, Extended, Virtual, and Integrated enterprise	Development technologies and architectures
Ontology engineering and management		Standards for enterprise integration
Ontology Interoperability	Enterprise modelling languages	Enterprise architecture E-business frameworks
Ontology-based services for Enterprise Application Interoperability	Business process	Services
	Enterprise engineering methodologies	Work management & execution

A first version of the K-Map has been implemented on the INTEROP portal (www.interop-noe.org) capturing knowledge and competencies of INTEROP partners. Access is currently limited to partners, but with the intention to open the K-

Map to the public as part of the V-Lab initiative, which will be established as a follow on to the INTEROP project (see below).

Interoperability framework (Deliverable DI.1, 2006): the framework defines interoperability domain and sub domains and identifies current barriers in the different sub-domains proposing research activities in those areas. At present, four levels of interoperability (data, services, process and business) and three categories of barriers (conceptual (syntactical, semantically, expressiveness), technological (architecture & platforms, infrastructure) and organisational (responsibility, authority, organisation structure) have been defined (see table 2).

Table 2 – INTEROP interoperability Framework

Levels/barriers	*conceptual*	*technological*	*organizational*
Business	Semantic incompatibilities	ITC incompatibilities	Org. structure incompatibilies
Process	Semantic and syntactical incompatibilities		Incompatibilities of authorities and responsibilities
Service			
Data	Semantic incompatibilities		Incompatibilities of responsibilities

Knowledge, which potentially can reduce or remove barriers has been collected from other areas of INTEROP work, evaluated and categorised according to the framework dimensions. Most of this knowledge is based on 'Good Practices and Solutions for interoperability' and 'Principles and Patterns for interoperability'.

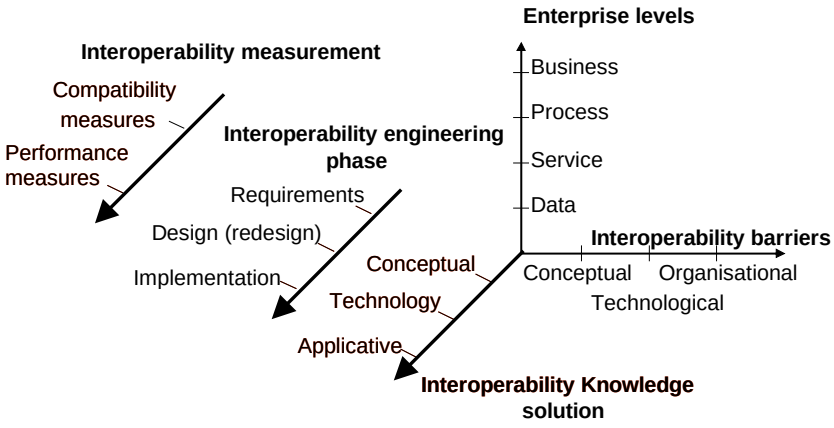

Figure 2 – Interoperability Framework with complementary dimensions

Complementary dimensions of the framework have been defined (Figure 2), which allow to use the framework for different applications.

The framework is part of a new work item proposal (NWIP) which has been presented to CEN and ISO standardisation groups and which will be submitted for ballot by the end of this year.

Interoperability explicit knowledge repository (IEKR) (Deliverable D10.2, 2006): the concepts of the IEKR have been developed and first versions of the repository and a document classification support tool have been implemented for INTEROP internal use. To verify the concepts developed the current version holds 201 papers presented at the I-ESA#05, which are classified following the INTEROP knowledge taxonomy (see Glossary).

Interoperability glossary (D10.1, 2006): the current version of the glossary contains 283 terms, which have been selected from a set of more than 1500 terms collected from papers, experts and the internet. Analysis and evaluation of the original set has been done via the Internet using an INTEROP developed Glossary Web Module (GWM). The GWM allowed experts to vote on the relevance of the terms for the interoperability domain, the correctness of the definition and also to add missing definitions.

UEML 2.1 (Unified Enterprise Modelling Language), (Deliverable DEM1, 2006): the current version of UEML uses the UEML template approach to describe (or model) enterprise-modelling languages**.** This approach requires a detailed (ontological) analysis of the constructs found in enterprise modelling languages and allows to formally defining correspondences between constructs in distinct languages. The template is being validated using 9 different languages including PetriNets, IDEF 1/3, WPDL, ISO 19440, BPML, ebXML, and UML 2.0.

Synchronisation of Different Distributed Enterprise Models (SDDEM), (Deliverable DTG1.1 2006): a life cycle model for synchronisation and management of enterprise models across organisations has been proposed, which will ensure consistency between models over their life cycle. The proposed life cycle consists of 5 phases (identification of synchronisation needs/target, synchronisation requirements, update/design for synchronisation, use of synchronised models, finish synchronisation). The proposal will be validated in the remaining project time frame.

Model Morphism (MoMo), addresses all kinds of transformations of models, including mappings, alignments, abstractions, etc. A MoMo ontology – based on OWL (Web Ontology Language) has been developed, which provides a formal definition allowing evaluate approaches, tools, and methodologies in the field of model transformations. An online MoMo toolbox, which assembles a methodological mapping/transformation framework and tool repository, is available.

Spreading of excellence activities (SE) has been achieved through a number of public workshops on specific interoperability themes, which have been organised by different workpackages, presentations at scientific conferences, publications of papers in scientific journals, the quarterly edition of the INTEROP newsletter and last not least through feedback into European (CEN) and international (ISO/IEC) standards organisation. The INTEROP portal (www.interop-noe.org) provides authorised access to project information as well as general access to information publicly available. The latter includes project deliverables, event announcements, the INTEROP Newsletters, Tutorials and general information. Two international scientific conference (I-ESA'05/'06) have been organised jointly with the ATHENA project in Geneva, Switzerland and Bordeaux/France and I-ESA'07 will be held in Funchal, Madeira, 2007-03-26/30.

Take-up actions towards SME's (Deliverable DM12.2 2006): with the intention to build a European interoperable supplier capability, an SME oriented imple-

mentation methodology and SME based pilot scenarios and test cases for implementation of interoperable technologies are developed.

The 5 pilots are: Business technology network, Collaborative Forecasting Management, Implementation of IT solution, Order transfer & tracking within Supply Chain, and Design of products with all pilots based on projects performed by INTEROP partners, but extern to the project. Evaluation of the methodology is done through a questionnaire. First results from the evaluation lead to a generalisation of the methodology for its use across different applications. This included the use of special features like the interoperability cube (identification of interoperability elements) applied to the collaborative forecasting case and interoperability technical workflow used in the order transfer & tracking within a supply chain test case.

The pilot scenarios represent the viewpoint of the implementation of interoperability solutions within SMEs. In the intensive discussion about the pilots in relation with the methodology points of interest from the user side were identified: Concepts for SME supporting Virtual Payment, Prediction of the ROI of the implementation of interoperability solutions, The indication of realisations close to customers (and customer needs), Few technical requirements e.g. only the Internet Browser might be required

Virtual Lab (V-Lab) will be established as the INTEROP follow-on organisation, which will take the responsibility to continuing according to the INTEROP goal to maintain and further increase the European interoperability research community ,to reduce fragmentation in this area and to support the research activities on interoperability for enterprises applications and software and continue to influence standards, affect policy and solve recurrent problems in networked enterprises. The project is preparing to set-up the V-Lab as a durable, self sustaining European-wide virtual organisation with local regional and national poles dedicated to enterprise interoperability with both academic and industrial involvement aiming to extract and exchange new knowledge from the integration of the three thematic domains identified in the IDEAS roadmap and its evolution. The INTEROP-V-Lab will be organised as a European Economic Interest Group (EEIG) formed by 10 regional poles covering Europe with round 70 members from academic, industry and public organisation.

The V-Lab support of a European Master on Enterprise Interoperability, both from academic and professional structure, will reinforce the promotion and the development of the concepts and practices in EI.

4 CONCLUSIONS

Interoperability becomes an urgent requirement for enterprises acting and competing in the worldwide market. An organisation’s ability to enter into commercial and functional alliances with partners more quickly and under better conditions to execute contracts becomes a business advantage. However from a technological as well as from a business process point of view, there are numerous gaps between the existing paradigms and the comprehensive interoperable systems required to enable true-networked enterprises. But an interoperability development requires not only technical solutions, but needs organisational, economical and social changes as well. To successfully elaborate on this very complex endeavour, it is necessary to develop

a research environment involving knowledge and competencies of all disciplines concerned. The originality of the INTEROP approach is to integrate the solutions provided in the three technical domains Enterprise Modelling, Architectures & Platforms and Ontology, and to develop interoperability in networked enterprises.

The project contributes to this goal through the results achieved or in progress in the area of interoperability research support by providing and structuring relevant knowledge (K-Map, repository, framework, glossary) and investigating particular solutions (UEML, model synchronisation, model morphisms). Awareness in the public domain on the issue of interoperability will continue being addressed by a particular work area in the INTEROP project. The I-ESA'07 conference, workshops, presentations, publications, INTEROP Newsletter and the INTEROP portal will further increase this awareness. Special aspects are solutions for SMEs, which are addressed through a particular work package and standardisation. For the latter inputs from both the INTEROP and ATHENA projects have already lead to the introduction of a new work item proposal on interoperability. Another effort that will also continue through the Virtual Laboratory and the Enterprise Interoperability Centre (EIC) – the ATHENA follow-on organisation.

The INTEROP Network of Excellence approach of bringing together leading academics, research centres and industrial stakeholders is considered as a first step towards a multidisciplinary research (not only technical, but also social and economical), which will lead to a sustainable re-organisation of the research activities in Europe and to fruitful international co-operations envisioned as the European Virtual Laboratory.

5 ACKNOWLEDGEMENTS

This work is supported by the Commission of the European Communities under the sixth framework programme (INTEROP Network of Excellence, Contract IST 508011, <www.interop-noe.org/>).

6 REFERENCES

1. ATHENA (2004) IST-507 849, Integrated Project, Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and their Application www.athena-ip.org
2. Chen, D., Doumeingts, D. (2003), European Initiatives to develop interoperability of enterprise applications - basic concepts, framework and roadmap. Journal of Annual reviews in Control, 27 (3), 151-160, Elsevier, December
3. Deliverable (2006), INTEROP Project, www.interop-noe.org D1.1 Knowledge map of research in interoperability in the INTEROP NoE, 1st version, DI.1, D10.1 Interoperability glossary, D10.2 Interoperability Explicit Knowledge Repository IEKR, DM12.2 Reports on the Pilot implementations and on the possibility to generalise the methodology to develop take-up actions towards SME's, DEM1 Interoperability knowledge corpus, TG1.1 Report on Generic Approaches and SDDEM Life Cycle Model TG Synchronisation of models for interoperability

4. IDEAS (2001), IST-2001-37368, Thematic Network, Interoperability Development for Enterprise Application and Software – Roadmaps, www.ideas-roadmap.net,
5. IEEE (1990), IEEE (Institute of Electrical and Electronics Engineers): Standard Computer Dictionary- A Compilation of IEEE Standard Computer Glossaries
6. INTEROP (2003): IST-508 011, Network of Excellence, Interoperability Research for Networked Enterprises Applications and Software, www.interop-noe.org
7. ISO 14258 (1998), Concepts and Rules for Enterprise Models *TC 184/SC5/WG1*.
8. ISO 16100 (2003), Manufacturing Software Capability Profiling for interoperability *TC 184/SC5/WG4.*
9. Open Group (2000): TOGAF: The Open Group Architecture Framework, Document No. 1910, Version 6, December.
10. Stegwee, R.A., Rukanova, B.D. (2003). Identification of Different Types of Standards for Domain-Specific Interoperability. In Proceedings of the Workshop on Standard Making: A Critical Research Frontier for Information Systems, John L. King and Kalle Lyytinen, (eds.), Seattle, WA, December 12-14, 2003, pp. 161 - 170. Available on line at: http://www.si.umich.edu/misq-stds/proceedings/139_161-170.pdf
11. WordNet Browser 2.1, Princeton University Cognitive Science Lab