
The ATHENA Interoperability Framework

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Abstract. In this paper we present results from the ATHENA Integrated Project in defining the ATHENA Interoperability Framework (AIF) for enterprise applications and software systems. The AIF provides a compound framework and associated reference architecture for capturing the research elements and solutions to interoperability issues that address the problem in a holistic way. The AIF also provides an associated methodological framework which describes the approach towards interoperability from the decision to evaluate collaboration until solution maintenance, and the reference guidelines for the adoption of the reference architecture.

1 Introduction

Systems interoperability is a growing interest area, because of the continuously growing need of integration of new, legacy and evolving systems, in particular in the context of networked businesses and eGovernment. Enterprises today face many challenges related to lack of interoperability. Enterprise applications and software systems need to be interoperable in order to achieve seamless business across organisational boundaries and thus realise virtual networked organisations.

IEEE defines interoperability as “the ability of two or more systems or components to exchange information and to use the information that has been exchanged” [1]. Interoperability should not only be considered a property of ICT

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systems, but also concerns the business processes and the business context of an enterprise. Therefore, interoperations are only meaningful, when all levels of an enterprise are addressed. The diversity, heterogeneity, and autonomy of software components, application solutions, business processes, and the business context of an enterprise must be considered.

We believe that there is a need for a framework that takes a more comprehensive approach to interoperability. In this paper we present results from the ATHENA Integrated Project [2] in defining the ATHENA Interoperability Framework (AIF) [3] for enterprise applications and software systems. The framework adopts a holistic perspective on interoperability in order to analyse and understand the business needs and the technical requirements, and a multidisciplinary and model-driven solution approach to solving the interoperability problems.

The paper is structured as follows: In section 2 we provide some background information and our research method. In section 3 we present the specification of the interoperability framework. Section 4 discusses the usage of the framework in terms of interoperability profiles. Conclusions and future work are presented in section 5.

2 Background and Research Method

The main objective of the ATHENA Interoperability Framework is to synthesise the research results of the ATHENA project. The framework aims at providing solution developers and integrators with guidelines on how to use the ATHENA solutions in addressing their business needs and technical requirements for interoperability.

2.1 Background

The ATHENA project adopts a holistic perspective on interoperability in order to achieve real, meaningful interoperation between enterprises. It builds upon the FP5 thematic network IDEAS (Interoperability Development for Enterprise Applications and Software, IST-2001-37368). The IDEAS network identified the need for a structured approach to collect, identify and represent the current state of the art, vision statements, and research challenges. It defined a framework for capturing and inter-relating this information from many perspectives called the IDEAS Interoperability Framework. The IDEAS framework describes that interoperability must be achieved on different levels (business, knowledge and ICT) between two co-operating enterprises.

The originality of the ATHENA project is to take a multidisciplinary approach by merging three research areas supporting the development of interoperability of enterprise applications and software. The three areas are: 1) enterprise modelling which define interoperability requirements and supports solution implementation, 2) architectures and platforms which provide implementation frameworks, and 3) ontology to identify interoperability semantics in the enterprise.

2.2 Research Method

Research in ICT can be described as a synthetic discipline that studies phenomena created by humans rather than those given by nature, and there is a huge room for creativity and few direct physical constraints. The focus is on artefacts. The goal of the research presented in this paper is to define the ATHENA Interoperability Framework. The framework has the following success criteria:

1. **Generic and extensible solution approach to interoperability.** This implies that the framework should be applicable and usable in numerous user scenarios having different interoperability requirements.
2. **Instantiation of the framework with research results from ATHENA.** This implies that the framework is able to successfully integrate results from the three research areas (enterprise modelling, architectures and platforms, and ontology) and provide a holistic view to solve interoperability issues at both the enterprise and ICT levels.

The development of the ATHENA Interoperability Framework follows a model-driven approach that can be divided into three main phases.

- **Problem definition and requirements:** Industry scenarios play an important role as sources of requirements and for the validation of the results. Pilots were set up that provide user requirements.
- **Development and innovation:** The development of the framework followed a more model-driven engineering approach with a focus on integrating the different solution pieces of ATHENA.
- **Validation:** The pilots will validate research results in pilot implementations.

3 Specification of the Interoperability Framework

The ATHENA Interoperability Framework (AIF) is structured into three parts:

1. **Conceptual integration** which focuses on concepts, metamodels, languages and model relationships. It provides us with a modelling foundation for systemising various aspects of interoperability.
2. **Applicative integration** which focuses on methodologies, standards and domain models. It provides us with guidelines, principles and patterns that can be used to solve interoperability issues.
3. **Technical integration** which focuses on the technical development and ICT environments. It provides us with ICT tools and platforms for developing and running enterprise application and software systems.

3.1 Conceptual Integration

The conceptual integration framework of the AIF has evolved from a number of pre-existing frameworks most notably the IDEAS Interoperability Framework [4], the IEEE Std 1471 [5] recommended practice for architectural description of software-intensive systems, and previous work on defining a model-driven interoperability framework [6] in ATHENA and INTEROP [7].

Whereas the IDEAS framework focus on structuring the interoperability issues (into business, knowledge, semantic, and architecture and platform issues), the AIF framework focus on the solution approaches. A common characteristic of the ATHENA solutions are the fact that they are model-driven. The universe of discourse is the collaborative enterprise and the ICT systems used by the collaborating enterprises. The solutions focus on modelling the interactions and information exchanges that occur in these collaborations, both on a business level and a technical level.

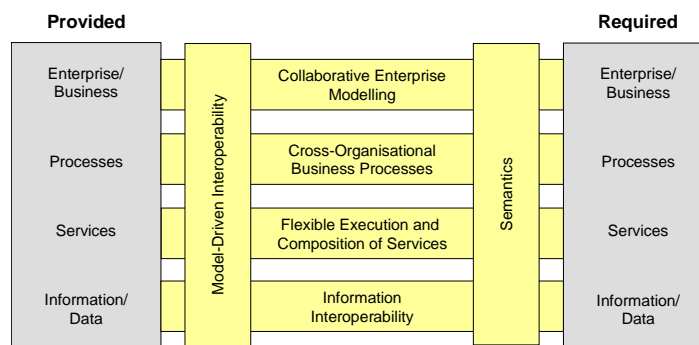


Fig. 1. AIF conceptual framework – simplistic view

The AIF provides a reference model in which the modelling solutions coming from the three different research areas can be related. Figure 1 above is a simplistic view of the reference model that indicates the required and provided artefacts of two collaborating enterprises. Interoperations can take place at the various levels (enterprise/business, process, service and information/data). For each of these levels we prescribe a **model-driven interoperability** approach where models are used to formalise and exchange the provided and required artefacts that must be negotiated and agreed upon. ATHENA defines a set of metamodels and languages (see table 1) that can be supported by tools and methods to construct the models in question. Starting at the top:

- Interoperability at the **enterprise/business** level should be seen as the organisational and operational ability of an enterprise to factually co-operate with other, external organisations in spite of e.g. different working practices, legislations, cultures and commercial approaches. **Collaborative enterprise modelling** is supported by the POP* metamodel [8].
- Interoperability of **processes** aims to make various processes work together. A process defines the sequence of the services (functions)

according to some specific needs of a company. In a networked enterprise, it is also necessary to study how to connect internal processes of two companies to create **cross-organisational business process**. This is supported by the CBP (cross-organisational business process) metamodel [9].

- Interoperability of **services** is concerned with identifying, composing and executing various applications (designed and implemented independently). Services are an abstraction and an encapsulation of the functionality provided by an autonomous entity. Modelling **flexible execution and composition of services** can be supported by the PIM4SOA (platform-independent model for service-oriented architecture) metamodel [10, 11].
- Interoperability of **information/data** refers are related to the management, exchange and processing of different documents, messages and/or structures by different collaborating entities.
- To overcome the **semantic** barriers which emerge from different interpretations of syntactic descriptions, precise, computer processable meaning must be associated with each concept. The OPAL (Object, Process, Actor modelling language) [12] offers a number of modelling notions to more precisely define the meaning of concepts. This allows us to relate concepts at the different levels (ensuring consistency amongst the levels) and relate concepts at the same level e.g. supporting **information interoperability**.

Although the following categorisation is mainly given from a point of view of ICT-based applications, it can also be applied to non-ICT systems. Moreover, the AIF defines an extended view of the reference model where this separation is made clearer.

Table 1. ATHENA solution space – metamodels and languages

Modelling	Solution	Type	Description
Collaborative enterprise modelling	POP*	Metamodel	The POP* metamodel [8] defines a core set of enterprise language constructs in the modelling dimensions Process, Organisation, Product (POP) and other dimensions like System and Decision (*) to be defined in an enterprise model. The POP* metamodel is a flexible intermediate language that facilitates model exchange between different enterprise modelling tools.
Cross-organisational business processes	CBP	Metamodel	The CBP (cross-organisational business process) metamodel [9] defines language constructs for modelling cross-organisational business processes using the concepts of view process and private process. A CBP defines the interactions between two or more business entities which links together view processes. A view process combine different (internal) private processes to an abstract level that enables companies to hide critical information from unauthorized partners.

Flexible execution and composition of services	PIM4SOA	Metamodel	The PIM4SOA (platform-independent model for service-oriented architecture) metamodel [10, 11] defines language constructs for modelling information, software services, software processes and quality of service. This model can be used to represent SOA solutions in a platform-independent way, integrate different technology platforms, and bridge the gap between the enterprise layer and the technical layer.
Information interoperability	XML, XSD	Format, Schema	During the last few years there has been a trend towards the use of XML for exchanging documents and messages. The XML Schema Definition Language (XSD) [13] is seen as a key enabling technology for achieving information interoperability. The ATHENA solutions build upon this foundation.
Semantics	OPAL	Modelling language	Today ontology languages present a syntax which looks not “natural” and are lacking of built-in primitives (i.e., modelling notions) domain experts are familiar with. The OPAL (Object, Process, Actor modelling language) [12] offers a number of modelling notions useful in the eBusiness domain, but general enough to be used in diverse business sectors (such as automotive, tourism or banking).

3.2 Applicative Integration

The applicative integration framework of the AIF is influenced by the Enterprise Unified Process (EUP) [14]. EUP is an extension to the Unified Software Development Process (UP) [15] which is a recognized and commonly used software development methodology. Whereas the UP defines a software development lifecycle, the EUP extends it to cover the entire ICT lifecycle.

The AIF applicative framework builds on the EUP and extends it further by introducing new interoperability disciplines. An interoperability discipline is a group of activities within a specific interoperability field which are logically grouped together. Each discipline is described according to the following basic structure of artefacts: *activity* (what to do), *objective* (what will be achieved by performing the activity), *input* (the artefact to be processed in the activity), *output* (the artefacts being the result of the activity), *roles* (the way people are related to the activity), and *supporting mechanisms* (i.e. information, document, models, systems, processes that are supporting the activity).

In figure 2 below, the AIF applicative framework is rendered from an overall perspective, showing the essential structure of phases and disciplines. The phases of an interoperability project lifecycle are represented by the columns. The rows in the figure outline the set of principles that characterize the mature approach for the definition, creation, operation and termination of an interoperability project. Within each discipline, the AIF recommends sets of activities to be performed in the different phases of the interoperability project. The kind of artefacts created and

manipulated by the activities are varying dependent on the phase. The load of activities within a discipline will also vary dependent on the phase.

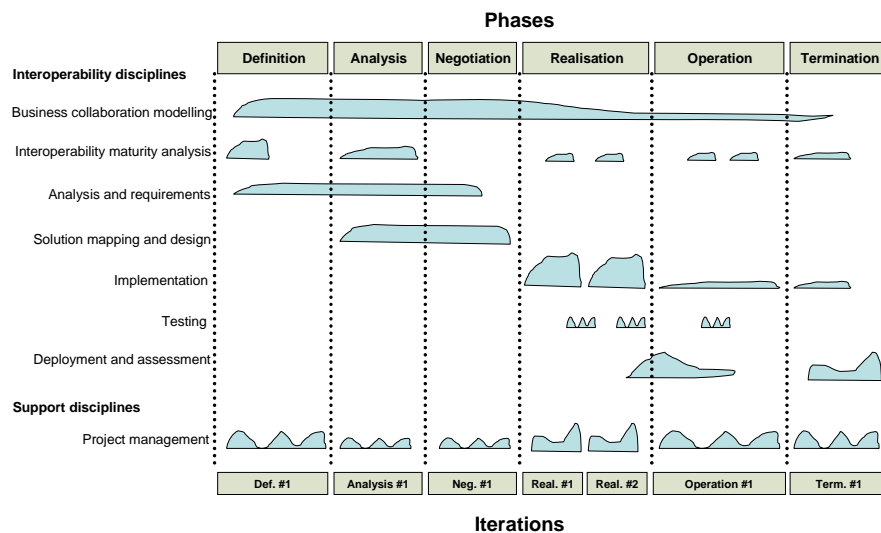


Fig. 2. AIF applicative framework

The framework defines a baseline methodology called the ATHENA Interoperability Methodology (AIM) which integrates the methods developed in the ATHENA project. The AIM should be considered a baseline which should be configured and/or extended to the specific needs of the interoperability project in question. Figure 3 below depicts a view of the AIM as a V-model. The activities of the AIM describe the use of the following methods:

- The **Business Interoperability Framework (BIF)** is a framework for determining business challenges related to interoperability according to strategic business needs. The BIF can be used to define the level of business interoperability for a given co-operation scenario. The co-operation model allows us to find optimization potential for one collaboration and compare results with other collaborations.
- The **Enterprise Interoperability Maturity Model (EIMM)** method defines a set of area of concerns and a set of maturity levels that provide the means to determine the current ability of an enterprise to collaborate with external entities and to specify the path to improve this ability.
- The **interoperability analysis** method focus on the common understanding of the enterprise artefacts needed to achieve interoperability on the different levels. This involves understanding and relating different enterprise models, defining cross-organisational business process models, agree on service interfaces over which the partners communicate and exchange messages.
- The **requirements – solution mapping** method takes as input the business needs and technical requirements identified in the interoperability analysis.

The mapping methodology is helping different kinds of users to find potential ATHENA solutions and solution packages regarding their requirements. Based on annotation by contextual elements of interoperability issues (reflecting a set of specific technical requirements) and generic solutions we can support semi-automated mapping between them.

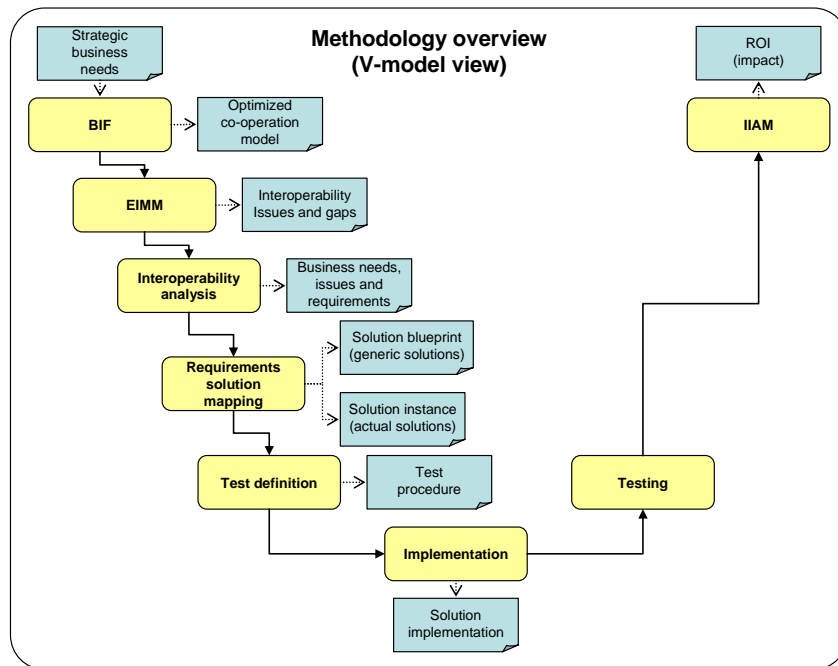


Fig. 3. Overview of the ATHENA Interoperability Methodology (AIM)

- The ATHENA Testing Framework which includes the activities **test definition** and **testing** is a framework to support conformance and interoperability testing. It describes a test architecture and how these can be combined to create a test configuration for various types of testing. It also describes the test material to be processed by this architecture, a markup language and format for representing test requirements, test cases and messages exchanged.
- The **implementation** activity focuses on the solution implementation. Depending on the indicated solution approach given by the requirements – solution mapping, different (and possibly alternative) implementation methods can be chosen. The implementation methods should follow a configurable and situational-based method engineering approach, where the individual method components can be characterised according to the AIF conceptual framework.
- The **Interoperability Impact Analysis Method (IIAM)** focuses on the return of investment (ROI) and the impact of the interoperability measures.

3.3 Technical Integration

The technical framework of the AIF describes an integrated architecture supporting collaborative enterprises. The architecture centres on a set of tools and infrastructure services to support collaborative product design and development, cross-organisational business process, service composition and execution, and information interoperability.

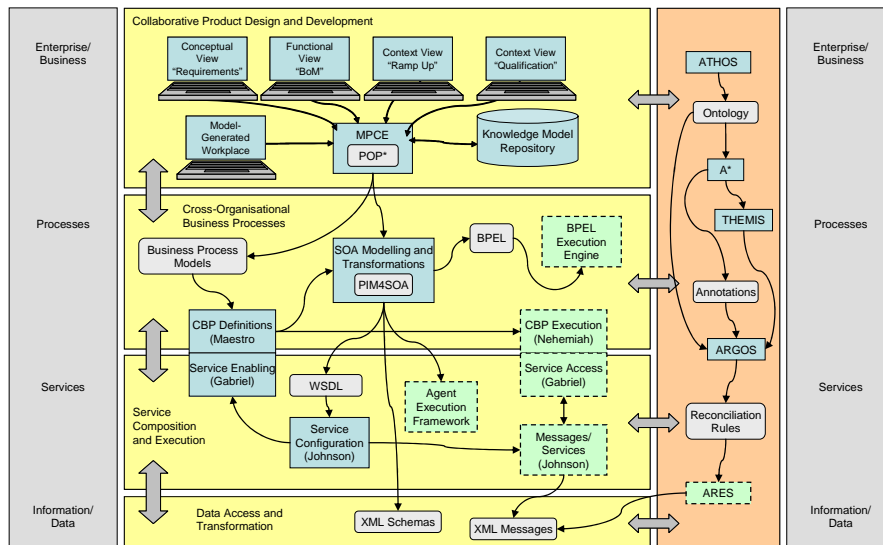


Fig. 4. AIF technical framework – overview

Figure 4 above depicts an overview of the technical framework illustrating some of the main components. The components are described in further details in table 2 below.

Table 2. ATHENA solution space – software tools and infrastructure

Level	Solution	Type	Description
Enterprise / Business	MPCE	Modelling platform	The MPCE (Modelling Platform for Collaborative Enterprises) supports the POP* language and provides model management and model exchange services. The MPCE can be used as a web-service hosted somewhere or can be locally installed. The major advantage of the POP* concept and the MPCE is the capability to keep models consistent even by using different modelling tools.

Processes	CBP Tool Suite	Tools, Method and Infrastructure	The CBP Tool Suite consists of Maestro, Gabriel and Nehemiah. Maestro is a business process modelling tool on a technical level that implements the CBP approach. It is possible to model private processes, view processes and CBPs and their interlinkage in a semi-automated way. Gabriel is a tool that service enables the cross-organisational business processes. Nehemiah is a process execution engine that is able to execute CBPs.
Services	ATHENA SOA Framework	Tools, Method and Infrastructure	The ATHENA SOA Framework [16] is composed of three parts: 1) The modelling part provides a set of modelling tools and services for mapping between PIM4SOA and platform-specific models (Web services and BDI agents). 2) The service part consists of a service enactment framework called Johnson and a WSDL analyzer tool. 3) The agent part defines Web service extensions to allow SOA to use agents for brokering, mediation and negotiation between Web services.
Information / Data	XML, XSD	Tools	All of the ATHENA solutions build upon the Web services architecture where XML and XSD are used to support syntactical information interoperability. The generation of XSD schemas are supported by model transformations.
Ontologies and semantics	Semantic Reconciliation Framework	Tools, Method and Infrastructure	The ATHENA Semantic Reconciliation Framework provides a basic set of semantic tools and services which can be used by other components in order to include semantic support for solving interoperability issues. The tool suite includes ATHOS (an ontology management system), A* (a semantic annotation tool), THEMIS (a repository), ARGOS (a transformation rules building tool) and ARES (a reconciliation engine).

4 Usage of the Interoperability Framework

Based on the domain and industry sector specific standards, the business need and the selected interoperability scenarios of an enterprise, an Interoperability Profile (IP) can be defined to ease the interoperability efforts for the enterprise by being valuable and applicable in the described scenarios. An interoperability profile consists of interoperability guidelines, specifications and solutions on the conceptual, the applicative and technical level, specifically selected, grouped and configured for the enterprise based on and derived by the ATHEN Interoperability Framework. A web-based portal or active knowledge model can be developed to support each application domain's viewpoint.

For four selected scenarios covering Supply Chain Management (SCM), Collaborative Product Development (CPD), Electronic procurement (e-Procurement) and Product Portfolio Management PPM), interoperability profiles denoted ATHENA Interoperability Profiles will be created.

Table 3. Interoperability profiles (application domain X industry sector)

Application domain Industry sector	Supply-chain management (SCM)	Collaborative product development (CPD)	Electronic procurement (e-Procurement)	Product portfolio management (PPM)
Aerospace	Where stable supply chains and dynamic supply networks will be considered	In which cross-functional and cross-organisational teams collaborate in product development.	Focusing on electronic purchasing and selling of goods and services.	Focusing on project classifications, selection, prioritisation, and resource allocation.
Automotive				
Furniture				
Telecom				

In each of these business domains we find domain-specific dictionaries, thesauri, nomenclatures and coding that will have impact on the development and usage of domain-specific reference ontologies. Furthermore, industry standards, and legislations and regulations given by the national legislative assemblies must also be taken into consideration. Each of these domains may prioritise specific software concerns and aspects differently and require their own custom-tailored views or models.

5 Conclusions and Future Work

We will conclude this paper by addressing each of the success criteria described in section 2 for the development of the ATHENA Interoperability Framework.

1. **Generic and extensible solution approach to interoperability.** The applicability and usability of the framework is being validated through a set of pilots, and through the ATHENA Interoperability Profiles. This is still ongoing work and currently we have only partial solutions and test data to validate such a claim.
2. **Instantiation of the framework with research results from ATHENA.** We have been successful in integrating the results from the three research areas in the conceptual framework. However, the integration of results into the applicative and technical parts of the framework do pose some integration challenges as some of the solutions are prototypes (not fully implemented), and are overlapping and/or represents alternative approaches.

The ATHENA Interoperability Framework presented in this paper is still under development. Future work includes finalizing the development of the interoperability profiles and validating these to our best extent in user scenarios both within and outside the ATHENA project.

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Heterogeneous Enterprise Networks and their Applications Integrated Project) [2]. The work does not represent the view of the European Commission or the ATHENA consortium, and the authors are solely responsible for the paper's content.

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