PROJECT FINAL REPORT

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1 Final publishable summary report

1.1 The Challenge

With the advent of Future Internet and, before that, the one of Internet of Services a new generation of software applications arise. The architecture of such applications varies so much as well as their complexity that new architectural approaches are needed in order to cope with such issues.

A reference architecture subsumes reoccurring and well-proven concepts and patterns of a set of specific software architectures. In the context of Internet of Services, the main goal of the NEXOF-RA project was to provide a reference architecture for service-based software systems which facilitates the reuse of well-proven service-oriented concepts.

1.2 Addressing the Challenge: the project's proposition

The overall ambition of the NEXOF-RA project is to deliver a Reference Architecture for the NESSI Open Service Framework (NEXOF) which ranges from the infrastructure up to the interfaces with services consumers. This Reference Architecture is not built from scratch, but leverages on relevant existing achievements either research results and best practices.

The NESSI European Technology Platform (www.nessi-europe.com) defined NEXOF with the aim of providing a framework for building service-based software systems according to the “NEXOF Independence Principle”, i.e. the framework to be independent from the size of the business, the domain and the implementing technology. In order to build such a framework a supporting reference architecture revealed a crucial instrument. The main reasons are:

- Need an overarching architecture strategy to accommodate:
    - cross domain, business size and technology aspects
    - system level solutions for a shared environment: frame choices to ensure integrated, consistent and coherent concepts
- Provide the basis for making incremental specific design decisions and product choices later on in the system building process
- A high-level parameterised (i.e. based on reference properties) framework for a system that defines its overall target structure (components and relationships among them) in a systematic consistent manner which in turn (due to the adoption of “architectural patterns” as the basic approach) allows:
    - Identification and clarification of issues and choices
    - Concentration on small number of issues at a time

In the light of the e-services business ecosystems, the above reasons are due to the following main challenges to be faced:

- Incomplete Scenarios and thus requirements to be addressed
- Heterogeneity of current solutions and thus lack of interoperability between different solutions

- Few (Integrated) tools and methodologies aimed at supporting the architect's problem
- Multiplicity of languages, models, and frameworks with insufficient coherence and consistency
- Difficultly to perform an adequate conformance (compliance) test.

1.3 Who can benefit from NEXOF-RA

1.3.1 NEXOF Reference Architecture Stakeholders

The NEXOF Reference Architecture stakeholders are the service-based systems architects and Internet of Service researchers.

In this context those two professions can be found in the primary and secondary audience towards which NEXOF-RA presented its outcomes. In turn these two audiences group:

- Primary Audience
    - IT Sector
    - Large Industry
    - SME
    - Public Administrations
    - Scientific Community
- Secondary Audience
    - EU funded projects
    - Project Beneficiaries

A sketched description about how these audiences will benefit from the NEXOF-RA results is mentioned hereafter.

Large Industry - Main benefits for large companies on the adoption of NEXOF Reference Architecture can be summarized through the need of an overarching architecture strategy to accommodate:

- Cross domain, business size and technology aspects.
- Provide the basis for making incremental specific design decisions and product choices later on in the system building process.
- System level solutions for a shared environment: frame choices to ensure integrated, consistent and coherent concepts.
- A high-level parameterized (i.e. based on reference properties).Framework for a system that defines its overall target structure (components and relationships among them) in a systematic consistent manner.

SME - In what the SME's is concerned, SME's can benefit from NEXOF-RA as follows:

- Efficiency through flexibility
- Interoperability and quality

- Mastering complex systems
- Developing novel technologies
- Fostering citizen related parameters.

Considering SME size and technology perspective the following table summarises priorities concerning the above interests.

Size/Type	ICT SME	User (Hi Tech) SME (Technology)	User SME (Non Technology)
Micro (1-10)	• **Awareness [Special case]** • **Bespoke developers**	• **Out of Scope**	• **Out of Scope**
Small (10-100)	• **Efficientising** • **Mastering complex systems**	• **Developing novel technologies (Non ICT)**	• **Out of Scope**
Medium (100-250)	• **Efficientising** • **Mastering complex systems** • **Developing novel technologies (ICT related)**	• **Efficientising** • **Mastering complex systems** • **Developing novel technologies (Non ICT)**	• **Efficientising (Outsourced)**

Public Sector - NEXOF-RA provides the Public Sector with architectural choices to make efficient services and software infrastructures improving their flexibility, interoperability and quality. In addition, the Public Sector is not homogeneous for what concerns size, domain and responsibilities. In this respect the approach of NEXOF-RA to build a reference architecture based on the "Independence Principle" could represent a success factor allowing specific instances of ICT service-based systems to be built in agreement with the peculiarities of each administration.

The Scientific Community - According to the domain diversity support from NEXOF-RA a large number of research communities can benefit from the NEXOF-RA results in different ways, including the traditional research activities as well as experimental, industry-oriented approaches.

Due to the integration-nature of NEXOF-RA the developed framework provides the foundation to align and improve future research activities in the service engineering and SOA fields. On the one end it can be used to structure future research activities such as fundamental research and industry-oriented research with practical impact and on the other end it can be used for the integration of existing research results into the NEXOF-RA framework. Thereby, NEXOF-RA might also reveal gaps in existing research results including both basic and advanced topics, this fostering an effective alignment and collaboration of further research activities.

Furthermore, it supports the challenging aim to perform trans-disciplinary research across different subject fields such as computer science, business engineering, and economics which are in the scope of service-oriented architectures. Moreover, it allows the exploitation of synergy effects between the results of the different fields.

EU funded projects - The collaboration with other EU funded projects, and in particular the NESSI Strategic Projects, has been a major target of NEXOF-RA. As per the scientific community NEXOF-RA provides a ground for integrating complementary results or

comparing similar results which follow different approaches. The latter case makes NEXOF-RA, and particularly its repository a basic benchmark ground.

Project Beneficiaries - Academia, SMEs and Industrial project beneficiaries are target audience in terms of needing information about the project results and progress. Industrial partner such as British Telecom, Telefonica, Thales, HP, Atos Origin, and Engineering, as well as Academia and SMEs represent, in the NEXOF context, their clients communities.

1.3.2 Why contribute to the Reference Architecture

Several of the motivations which are relevant for Open Source Communities can be transferred to the NEXOF-RA project.

In the context of individuals contributions, the interest in contributing to NEXOF-RA can be seen in the incentive for people to learn and share their experience concerning building service-based systems and, more in general, concerning models and modelling. The same is true for reusing existing contributions of other NEXOF-RA community members and the attainment of reputation within the community. Reasons for participation are also founded in intrinsic factors, such as the sense to participate in a large shared effort and of belonging to a community. Example of such communities, in the case of FP7, are represented by relevant projects in the field, such as the NESSI Strategic or Compliant Projects; other communities are those formed by the NESSI relevant Working Groups. It should be noted that the at the point in writing this document the NESSI membership is over 400 organisations.

When it comes to organisations they can be motivated to share their existing knowledge in terms of technology strategies by the outlook that they are going to be validated by other community members. This way valuable input from community members both industry and academic fields could be obtained, for instance. Additionally, the NEXOF Reference Architecture could be seen as platform to advertise the existing solutions that an organization offers in terms of technological approaches, models of products, and, of course, services.

In the context above, NEXOF-RA invites possible contributors to join with leading actors from both industry and academia, and contribute to its effort explicitly defined as an important community effort which has characteristic such as openness, transparency, and independence. In participating in this effort, contributors will influence and build the service architecture of the future and give visibility to the results of their research and development. In addition, as stated in text of Invitations for Contribution, “contributors will be recognised as co-authors”.

In particular, the NEXOF-RA investigation teams can act as incubators of specifications that can be further evolved in the context of standardization bodies. In this context, relevant players are motivated to join forces around the overall NESSI vision and requirements set out by the NEXOF-RA architecture and work together on a seed specification that will form part of NEXOF-RA but also proposed and further developed as part of other standardisation organizations.

Open source communities and open alliances that focus on software components of NEXOF have also a strong motivation to participate into this process. The NEXOF-RA results will offer the blueprints and increase the potential impact of the software developed

by these communities so participation is key for them. For instance, the concept of Open Alliance has been proposed and driven by NEXOF-RA as a highly committed and motivated sort of community that gravitate around a NESSI Strategic project and coordinate the activities with other projects in order to contribute to the NEXOF-RA reference architecture.

1.4 Highlights of Achievements

In line with is effort it has been recognised that the main assets of NEXOF-RA form in particular the concepts and process for specifying, assessing and comparing/selecting architectural patterns. In order to show the effectiveness of the proposed approach a set of patterns, integrating the contributions coming from the various NESSI Strategic Projects and the NEXOF Community, have been produced. Summarising the main results achieved by the project are:

- The Open Architecture Specification processes
- The Architectural Framework, Principles and Model (the Model include an extensive Glossary)
- The Validation process based on fully functional Proof-of-Concepts (PoC). This process includes principles and selection criteria for the PoC as well as the assessment model
- A methodology to write instantiation guidelines for architectural domains of the NEXOF Reference Architecture
- A sample set of Architectural Patterns. The chosen set of patterns belongs to three different domains: Enterprise SOA, Cloud Computing and Internet of Services. The latter provides an architectural design of a world-wide internet-based platform to enable anyone to deliver, consume and *prosume* services at global scale.

1.5 The results

1.5.1 The Open Architecture Specification processes

By design, the process used for the construction of the NESSI Open Service Framework (NEXOF) Reference Architecture must promote the active involvement of external parties. This is driven by many reasons, which can be summarized as follows:

- inclusion of external parties allow the project to leverage the best-of-breed architectures and technologies, thereby enhancing the quality and applicability of the overall architecture
- inclusion of the relevant stakeholders enhances the level of adoption of the overall architecture

This is implemented through a combination of governing and contributing bodies. The governing aspects are handled through the Architecture Board, which is the technical decision making authority of the project and includes architects from the key contributing external initiatives. The open contribution aspects are handled through the Open Construction Cycles (OCC) of the Open Architecture Specification Process (OASP).

The construction process is centred on parallel execution of OCC, each focused on a specific, well defined topic. These topics are made public through an Invitation to

Contribute, which is distributed to the widest community possible. Any party can participate in the construction cycles, including academic institutions, industry players of all sizes, and individuals. The only requirement is a commitment to contribute in a proactive and constructive fashion to the construction process. All contributions must be compatible with the inclusion of results in an “open” document with derivative rights. While participation is voluntary and is not be funded by the NEXOF-RA project, the process is driven, managed and supervised by members of the NEXOF-RA project team, under the technical supervision of the NEXOF-RA Architecture Board.

Each OCC is following a standard path:

- Publication of the Invitation to Contribute. The invitation contains a list of topics to be addressed in the OCC foreseen in the invitation. Each topic is leaded by an expert appointed within the project team
- During the two months following the publication of the Invitation to Contribute, prospective contributors should register their interest and formulate a position through a position paper. During this period, the lead for each topic answers questions, reviews registrations and submissions, and verifies interest to build the Investigation Team which is the operative body of the next phase
- During the following 2.5 months, the Investigation Team formulates a common position based on the consensual convergence of various proposals. This position is then refined by the NEXOF-RA project team for inclusion in the relevant architecture documents.

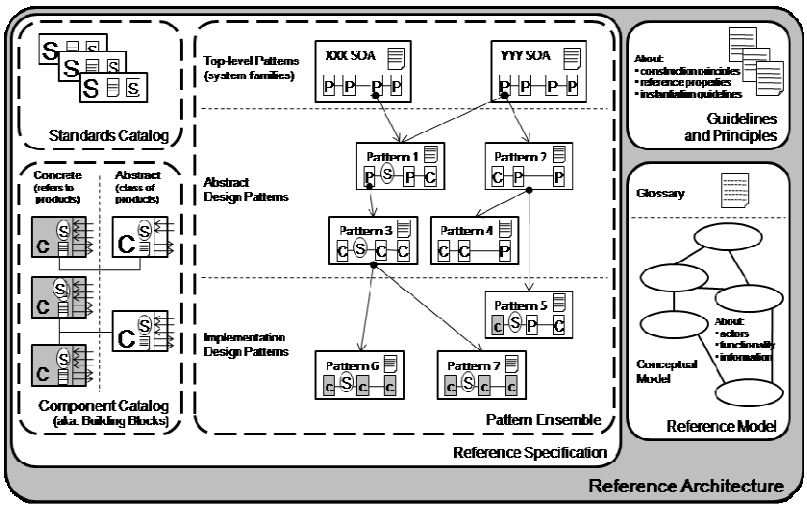
While there is no absolute requirement to synchronize the execution of the OCC, groupings in batches of topics is likely to occur.

During the project life two Invitations to Contribute were published: on July 21st, 2008, on February 5th 2009.

1.5.2 The Architectural Framework, Principles and Model

1.5.2.1 Overview of the NEXOF Reference Architecture Structure

As depicted in the following picture, the main constituents of the NEXOF Reference Architecture are:



- **The Guidelines and Principles**: this captures the principle underlying the construction of the framework, the set of reference-properties associated with each of the components and patterns in the Reference Architecture, and the guidelines used to instantiate a specific system architecture according to its requirements
- **The Reference Architecture Model**: this is the Conceptual Model which describes the essential entities that constitute service-based systems, as well as the relationships between these entities and the key elements in the context. In addition, it contains also the Glossary which defines the terms used across the whole NEXOF-RA project. This Glossary has been built and will be maintained under the auspices of the NEXOF-RA Architecture Board where sit representatives of all NESSI Strategic Projects.
- **The Reference Architecture Specification**: This constituent is formed by three collections:
  - **The Standards Catalogue**: the standards referred to in the Reference Architecture are described in this catalogue. Each standard is linked to the relevant elements of the Guidelines and Principles as well as to the concepts it addresses
  - **The Component Catalogue**: the level of granularity considered in the Reference Architecture is that of components, which roughly correspond to coherent sets of functionality delivered as software products or software components which can be configured separately. This catalogue groups both abstract descriptions of components (e.g. an UDDI registry) as well as product or software-based components (e.g. the jUDDI library). Each description refers to the standards it implements, the concepts it addresses, as well as its behavioural characteristics
  - **The Pattern Ensemble**: the actionable part of the Reference Architecture is represented by the patterns, which define various ways of realizing some functionality by associating components and other patterns in a specified manner. The Architecture Specification includes three types of patterns: top-level patterns which describe the characteristics of service framework families, abstract design patterns which refer to abstract components and patterns, and implementation design patterns which refer to at least one concrete component. Relationships between patterns (e.g. “excludes” or “requires”) are explicitly described. Each pattern description also refers to the standards it implements, the concepts it addresses, as well as its behavioural characteristics.

The next two sections provide more details about the Model and the Architectural Framework and Principles.

1.5.2.2 The NEXOF-RA Model

The NEXOF Reference Architecture is provided in form of a construction kit that guides the construction of specific service-based infrastructures. The construction kit consists of a set of building blocks implementing architectural patterns which in turn are related to a conceptual model. The NEXOF Reference Model captures the relevant entities and dependencies among them that constitute a service-oriented system on a conceptual level in order to foster the communication between the relevant service-based systems stakeholders on a higher abstraction level.

The NEXOF Reference Model specification is organised in three parts. The first part focuses on defining the syntax and semantics of the model. This includes describing the goals, scope and boundaries of the model and the terminology used within the model as well as across all NEXOF-RA documents. A specific section of this part is dedicated to the introduction of the structure of the model. It is explained which views, concepts and diagram types are used for the different purposes of the model following the idea of separating structure and behaviour/functionality. Thus, the first part provides a guideline on how to read, use and interpret the model specification by explaining what the syntax and semantics of the different elements constituting the NEXOF Reference Model are.

The actual specification of the reference model constitutes the second part. Since the NEXOF Reference Architecture is structured into nine concerns, the specification of the model is organized according to those concerns. It defines the functionalities provided by a NEXOF compliant architecture qualifying the value of these functionalities by specifying the input-output relations along with the actors involved in these functionalities. Diagrams as well as all contained concepts constituting the reference model are furthermore explained by textual descriptions and examples.

The third part of focuses on the application of the NEXOF Reference Model in order to demonstrate how it can be used in practice. For this it is explained how the reference model is embedded into the overall NEXOF Reference Architecture with emphasis on the dependencies with other elements. First of all, the relations with the business- and system requirements are described, which form the baseline for the specified functionalities, and then with the patterns, which provide different ways of implementing the described functionalities. To this extent, an example scenario is provided in order to illustrate how the model can help in the derivation of actual NEXOF compliant architecture instances.

The Reference Model is accompanied by the NEXOF-RA Glossary and the complete set of functionality descriptions enriched with explicit dependencies towards the system requirements and references to the sources of such functionality. The Glossary contains in addition to standard definitions interesting for the project team itself, also specific definitions produced by the NEXOF team at large, i.e. including the contributions from the NESSI Strategic Projects.

1.5.2.3 The NEXOF-RA Architectural Framework and Principles

The very nature, approach and aims of the NEXOF-RA project required to lay down precise and wide accepted principles and baseline for the creation of *NEXOF-RA Specification*. These mainly fixes rules and restrictions for the formal aspects of the specification, such as the format, the structure and its development approach. As far as it concerns architectural solutions, the NEXOF-RA Architectural Framework does not state any restricted principle, since a key foundation requirement of the NEXOF Reference Architecture is to be domain and technology independent. A part from the restriction on the very general domain of SOA Infrastructures, any concern, problem and solution related to this domain generally is interesting for the project.

In this context the “NEXOF-RA Architectural Framework, Principles and Model” provides:

- a description of what the NEXOF Reference Architecture is, what it is useful for and what its overall structure is. This scope is fundamental to understand all the principles and baseline introduced afterwards

- a list of principles used for the development of the specification. They have been selected as guidelines for the specification process in order to produce an open and easily evolvable specification
- the introduction and definition of the idea of *constructional patterns* as the basic mechanism (baseline) that is used to develop the overall specification
- the description of the *Pattern Development Process*. This process is a part of the overall specification process and covers the development of each individual pattern.

1.5.3 The Validation Process

The validation process is based on fully functional Proof-of-Concepts (PoC). This process includes principles and selection criteria for the PoC as well as the assessment model.

A Proof-of-Concept (PoC) is defined as a (set of) software artefact(s) used to validate patterns of the NEXOF-RA specifications. Although the principles and the process to validate the NEXOF-RA specification via identification, set-up and execution of PoCs have been defined for the purpose, they follow general and well recognised software engineering principles which allow them to be adopted beyond the specific context of the NEXOF-RA project.

Practical experience in software architecture evaluation recommends limiting the number of qualities to be evaluated. Following this recommendation, the scope of a single PoC should be limited to the validation of few patterns and quality attributes even if, in general, there can be several patterns addressing a scenario's requirements.

Some of these patterns may be more appropriate for a specific domain, others may present a different trade-off among quality attributes, etc.

To consider this heterogeneity of cases, given the limited scope of a single PoC, the NEXOF-RA validation process fosters the identification and definition of a set of PoCs that can allow comparison of patterns across domains or according to their similarity.

In addition, some clear principles guide the validation process:

- *Requirements and scenarios* provide the baseline for validation of patterns via PoCs. Problem domains to be investigated and patterns to be validated are identified on the basis of scenario analysis. Backward traceability from PoCs to requirements and scenarios has to be ensured in a PoC. Scenario generation techniques are used to derive assessment criteria and metrics for PoCs.
- *Comparison of available alternatives* in a specific problem domain is fostered in the process allowing the identification and selection of PoCs whose results can be used by the validation team to argue about similarities, differences and business cases for which a particular pattern is preferable to others.
- *Validation coverage* allows the balancing of validation activities across different domains and different elements of the reference architecture, as well as to ensure validation from different perspectives besides pure technical ones.
- *Independence of the reviewers* is promoted and, whenever possible, ensured.

The NEXOF-RA validation process grounds its most critical steps in widely adopted and recognised best practices, industrial methods, and standards. Moreover, it is generic and complete enough to be applicable beyond the NEXOF-RA project. As such, it is a key element for sustainability of work engaged through committed projects of the NESSI

technological platform, and it is extensible to support additional analysis on the validated patterns.

1.5.4 A methodology to write instantiation guidelines for architectural domains of the NEXOF Reference Architecture

Defining the architecture of a software system or defining architectural extensions to existing software systems are the core tasks performed by software architects. When performing these tasks, the architects have to take some important decisions that will have some long lasting effects on the resulting systems. The decisions taken (or not taken) by the architects in this phase will be very difficult to catch up later in the subsequent phases of the software development process.

The decisions to take have to do mainly with two different elements: functional and non-functional requirements. Both kinds of requirements address as a whole, the needs and demands to be fulfilled in each specific context (e.g. E-SOA, IoS, etc.).

Functional requirements are related specifically to the functionality the system is expected to offer; such functionality must result at the end of the design process of any system architecture or architectural extension. In order to fulfil these requirements, the architect has to combine different architectural blocks (i.e. functional patterns) in order to provide as outcome, one or more architectural configurations addressing the required functionality. This process has to be done taking into account and respecting the relationships that can be set up between those patterns. This/these architecture/s are termed *functional architecture/s*.

However, how architects achieve security, scalability, maintainability, high availability, etc. in the system architecture is one of the most difficult key points to materialize for guaranteeing the success of a software system. So, with regard to non-functional requirements (a.k.a. quality attributes), the architect has to be very focused in how to accommodate those cross-cutting patterns that allow to fulfil them in the functional system architecture/s.

The process of instantiating architectures is complex, especially in the case of reference architectures such as the one aimed by NEXOF-RA. The evolving nature of this kind of architectures requires adding extensions to the core reference architecture, for example when a new application context/domain appears. This characteristic, in NEXOF-RA, is called “Extendability”.

The methodology proposed by NEXOF-RA, establishes the steps that should be performed in order to write instantiation guidelines for different technological domains of the reference architecture either those ones exemplified within the project (E-SOA, Cloud Computing and Internet of Services) or concerning future extensions of the NEXOF-RA. The methodology describes how to instantiate a given architecture taking into account both, functional and non-functional requirements. In this way, the instantiation guidelines resulting from applying this methodology can document how NEXOF-RA can be used by system architects as an entry point to understand particular contexts and architectural extensions.

For the purposes of the usability of the methodology, this is accompanied by a full example of instantiation guidelines developed for the High Availability and Scalability domain of the ESOA top-level pattern.

1.5.5 A sample set of Architectural Patterns

In order to proof the approach chosen by the consortium, a set of architectural patterns specifically built to support the design of NEXOF Compliant (SOA) Infrastructures have been produced.

The set of “RA Specification – Pattern”, constitutes the effective content of the NEXOF-RA Specification. For each pattern there is a document providing the complete and self-contained description of an architectural pattern that NEXOF has evaluated as fundamental for the design of SOA Infrastructures and has approbated, by the NEXOF Architecture Board, to be part of the final specification.

Actually each document also introduces concepts that form the context of the pattern and that is used in order to clearly describe the pattern, to qualify the standards that the pattern is compliant with and finally to describe the concrete components (implemented solutions) that are already available to implement it or some of its parts. These information are those in the NEXOF-RA Model and are needed to develop the Standards and Components Catalogue of the NEXOF Reference Architecture.

The target audience of the document is the same of the overall NEXOF Reference Architecture, and this is clearly qualified into the project deliverable D13.5. Anyway the architectural solutions provided by the different patterns that constitute the specification are particularly targeted to software system architects. In fact each pattern claims the added-value, in terms of architectural choices, it offers when applied to design a SOA Infrastructure. These important claims are helpful and are expected to drive a software system architect to properly select and effectively exploit pattern solutions into their SOA-based system designing.

The “RA Specification – Pattern Compass”, an accompanying document, provides a compass to access all the set of patterns in order to navigate the them in a more easy way. In addition to providing the complete list of patterns that are into the specification, it shows the main relationships among the patterns themselves. Hence, the compass is intended to guide a software architect to access, find, select and use patterns of the specification in a consistent and effective manner. The compass also provides a short abstract description of each pattern, and some other few information concerning the authors, its category type and level, and a reference to the document where the complete specification of the pattern is provided.

The “RA Specification – Pattern Compass” is organized into three main sections:

- first section concerns with the **Internet of Service** domain
- second section concerns with the **Cloud** domain
- third section concerns with the **Enterprise-SOA** domain.

Actually the set of patterns includes also patterns that are still in their development phase or that have been simply identified to be developed. Such state of each pattern, of course, is clearly reported into the compass document.

1.6 The pilots

The project did not implemented any pilot according to the standard definition. Nevertheless, given the nature of the expected and achieved results, a set of proof-of-concept prototypes have been developed with the aim to validate major architectural choices.

Together with such proof-of-concepts a specific methodology on how to select and implement specific proof-of-concepts have been developed.

1.7 Availability of results

All the project results are public domain under the creative common Attribution-NonCommercial-NoDerivs 3.0 Unported licence and are available in the project portal at www.nexof-ra-eu.

1.8 Potential impact of the results

1.8.1 Setting-up the scene

NEXOF aims at supporting next generation service oriented systems by creating a reference architecture. Leaving a more detailed analysis of the market trends and status to the relevant project deliverables (D12.1 *The NEXOF Roadmap*), currently the market sees the presence of vendors which have established products in this field. Such vendors include SaaS platform providers (e.g. Amazon Web Service, Azure Services Platform, Force.com, Google App Engine), SOA infrastructure suites vendors (e.g. IBM, Oracle, Red Hat, SAP, Sun) and services platforms (e.g. Alcatel-Lucent 8690 Open Services Platform, the IBM Service Provider Delivery Environment).

Existing SOA suites are a set of products that provide SOA capacities. They combine components such as ESB, application server, workflow engine, development tools to provide means to integrate, deploy, secure and manage business processes and composite applications. Existing solutions provide similar functional coverage and implement the same standards. The weakness of such suites is the complexity of product options and the relatively low integration level between the products. SaaS platforms mostly focus on hosting infrastructure, computing power, storage, associated with a development environment to build applications. Service platforms currently target only the telecommunication domain.

NEXOF-RA aims at going beyond the combination of SOA and SaaS approaches to design a comprehensive and agile service platform with a high level of integration between the different functional components. NEXOF-RA specifications will lead to service platforms that are interoperable and that enable to deliver services with interfaces based on open standards that can be combined in different ways to meet changing business requirements. The framework will enable development and execution of service applications providing capacities spanning across the whole service lifecycle from requirements and model centric engineering to address complexity, to virtual business relationships and virtual collaboration going through secure and seamless data exchange, protocol and technologies for federation of services.

The Reference Architecture NEXOF-RA aims creating at is not starting from scratch, but leveraging from the significant work that has already been performed in other research initiatives as well as in standardisation bodies. In addition NEXOF-RA is considering and will also consider existing available technologies in order to understand current limitations, but also the way these technologies could be integrated, or can cooperate, in order to build a more comprehensive and coherent framework.

NESSI, as described in its SRA Volume 2, says that at the moment there is not such a comprehensive framework. This way NEXOF-RA aimed at performing research tasks as needed to fulfil the missing concepts, components and solutions, i.e. the NEXOF-RA Reference Architecture is not just a compilation and aggregation of existing solutions, but an architecture which will create a comprehensive framework which at this stage does not exist.

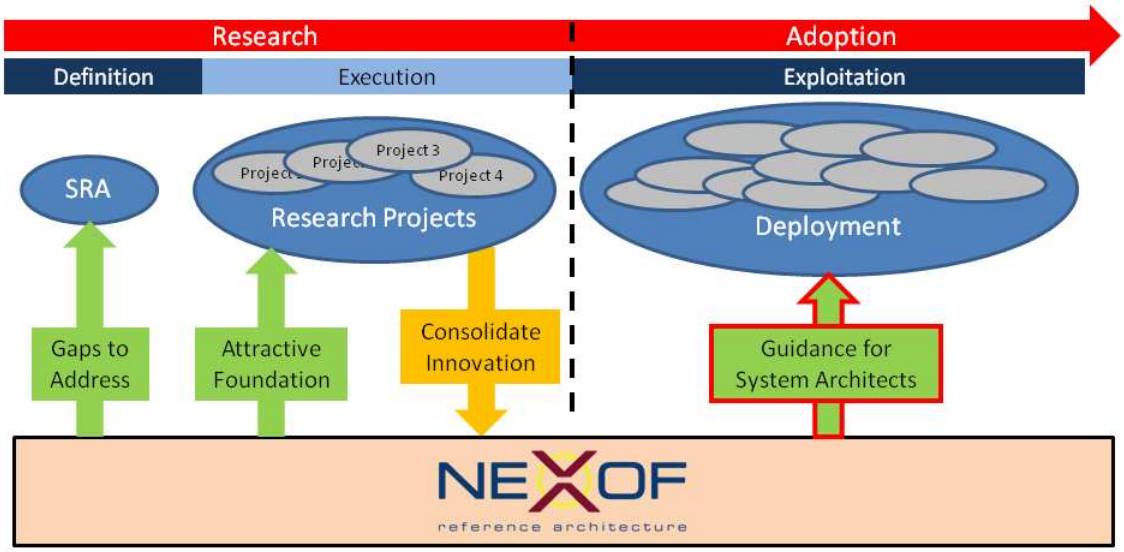
Summarising, the NEXOF Reference Architecture aims at being a solid first step in the transition of current technologies towards Future Internet.

1.8.2 NEXOF-RA and the Technology Maturity Lifecycle

Consideration for the dimension of time is one of the distinguishing characteristics of the NEXOF Reference Architecture. While most reference architectures aim to be as complete as required to meet the needs of architects, they are most often not designed for evolution. In contrast, the NEXOF Reference Architecture is designed to consider evolution. To this extent, the NEXOF-RA project interacts with the Technology Maturity Lifecycle in two different manners:

- At a given level of maturity, through the evolvability characteristics of the reference architecture, described above
- Across the maturity lifecycle, where the reference architecture supports the link between the various phases

In the context of the European Framework Programme, the Technology Maturity Lifecycle can be mapped to three major phases: definition, execution, and exploitation. The reference architecture has a specific role in each of these phases.



The NEXOF Reference Architecture is designed to be a guide to facilitate the precise implementations of interoperable service environments meeting requirements. Identifying these requirements is the subject of a specific project activity. Considering the nature of the project, the set of available technologies represented in the reference architecture will not satisfy all requirements in an optimal manner. The reference architecture will therefore enable the identification of the corresponding technology gaps, which can then be captured in the Strategic Research Agenda and transcribed in the Framework Programme, as well as in National Research Programmes, to be addressed by future research projects.

One fundamental belief behind the concept of NEXOF is that only a combination of research results from a wide range of research projects will be able to meet the challenges of building the Open Service Framework. This combination will not be successful by chance; coordination is a definite success factor. The role of the reference architecture is core to this coordination. Research projects which want to contribute to the construction of the Open Service Framework need to relate to one-another. This means they must adopt in a sensible manner an existing chorus of results as baseline to which they will add value. As a side benefit, this allows research projects to focus on core research focuses, rather than spending energy in establishing a technology baseline outside of their primary domain of expertise. The research projects then contribute back the result of their research to the common pool of results, making sure these results are consolidated with the other results, focusing on a clear identification of the relationships.

The chorus of research results, which then form a coherent and consistent set as a result of the reference architecture construction process, forms the core of the guidance to architects.

The reference architecture makes no claims to the level of maturity of each of the technologies it describes. In this regard, integration in the reference architecture is an important step forward in the technology maturity lifecycle, but cannot on its own replace experimentation and deployment as a way to mature technologies.

1.9 Lessons learned during the project

The lessons learned during the execution of the project can be subdivided into two areas: research concern, managerial concern.

1.9.1 Research Concern

Main lessons learned are:

Impossibility to build a unique monolithic reference architecture for the Internet of Service Domain. The complexity of the field is huge and too many aspect have to be taken into consideration at the same time and in addition from very different perspectives. In order to address this lesson the project adopted the architectural pattern approach. This approach carries many positive aspects:

- maximisation of the orthogonality of the architectural choices
- easiness to tackle complete architectural aspects
- reuse of the same architectural choice in different architectural contexts
- possibility to evolve the architecture without impacting the whole structure

On the other end it is also true that some cons exist:

- non existence of a single unique architecture as such
- possible proliferation of redundant architectural solutions

While the first cons cannot be avoided, as by definition and choice there is no unique monolithic architecture, the second can be mitigated through organisational means. In the context of the NEXOF-RA project a dedicated Architecture Board have been established with the aim at governing the building process.

It should be also noted that even if there is no single architecture, it exist a single Reference Model although this built through the help of specific views called in NEXOF "model concerns".

Specification framework "false" simplicity. In order to maximize the contributions from different sources (individuals, organisations, projects), the chosen approach was also chosen because its theoretical simplicity. In addition we put on it even less rules avoiding complex formal aspects. This simplicity anyway collapses with the fact that the approach in the end is "pragmatically complex" as anyway the specifications are targeted to experts (software systems architects).

1.9.2 Managerial concern

Specification Development Process adopted within the project resulted in too much parallelization. Although this was not a project initial choice as such (the project was significantly compressed and cut at negotiation phase – from 4 to 2 years) the consortium believed it was possible to have some activities with some parallelism. This resulted in the impossibility to have a clear feedback analysis from one result to the next one.

Our recommendation is that, particularly in complex projects such as NEXOF-RA aiming at building referential European assets, such parallelism should be kept at physiological minimum. This is particularly true for activities such as Requirements Analysis, Conceptual Model, Pattern Development, PoC development.

1.9.3 Areas of improvement

- Improve the architectural problem descriptions
    - The conceptual model, referring to the NEXOF-RA one, should be enhanced: the top-level patterns have to be integrated into the model having a corresponding conceptualisation. This way the link between the model and the patterns is immediate
- Improve the quality and the relationships of the requirements to the architectural problems
    - Enhance the analysis and the description of how domains differs with respect to requirements
    - Identify and improve the description of non-functional architectural challenges

1.9.4 Open Challenges

With respect to the architectural framework some new architectural challenges have been identified. These are:

- Enhance services and contexts (semantic) descriptions to **increase "self-adaptation" of services** in specific contexts
- **Support data-flow execution engine and code mobility** to inherently enhance scalability
- Particular focus has to be given to **provide Internet-user's privacy and trust** since information comes from unknown potentially unreliable sources
- Improve portability, interoperability and **flexibility** in **resources infrastructure**, in particular network and storage.

1.10 Beneficiaries

List of Beneficiaries

Beneficiary name	Beneficiary short name	Country	Date enter project	Date exit project
Engineering Ingegneria Informatica S.p.A	ENG	Italy	month 1	month 29
Alcatel-Lucent France	ALF	France	month 1	month 9
Alcatel-Lucent Bell Labs France	ALF	France	month 10	month 29
ATOS Origin Sociedad Anonima Española	ATO	Spain	month 1	month 29
British Telecommunications plc	BT	UK	month 1	month 29
Hewlett Packard Limited	HP	UK	month 1	month 29
University of Limerick	LUL	Ireland	month 1	month 29
Universitaet Duisburg-Essen	LDU	Germany	month 1	month 29
LogicaCMG Nederland B.V.	LOG	The Netherlands	month 1	month 29
MO.M.A. S.R.L. - Modelli Matematici ed Applicazioni	MOM	Italy	month 1	month 29
Siemens Aktiengesellschaft	SIE	Germany	month 1	month 29
Telefonica Investigacion y Desarrollo SA Unipersonal	TID	Spain	month 1	month 29
Thales Services SAS	THA	France	month 1	month 29
TIE Nederland B.V.	TIE	The Netherlands	month 1	month 29
Universidad Politecnica de Madrid	UPM	Spain	month 1	month 29
IBM Israel - Science and Technology Ltd	IBM	Israel	month 1	month 29
Consorzio Interuniversitario Nazionale per l'Informatica	CIN	Italy	month 1	month 29

1.11 Contacts

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