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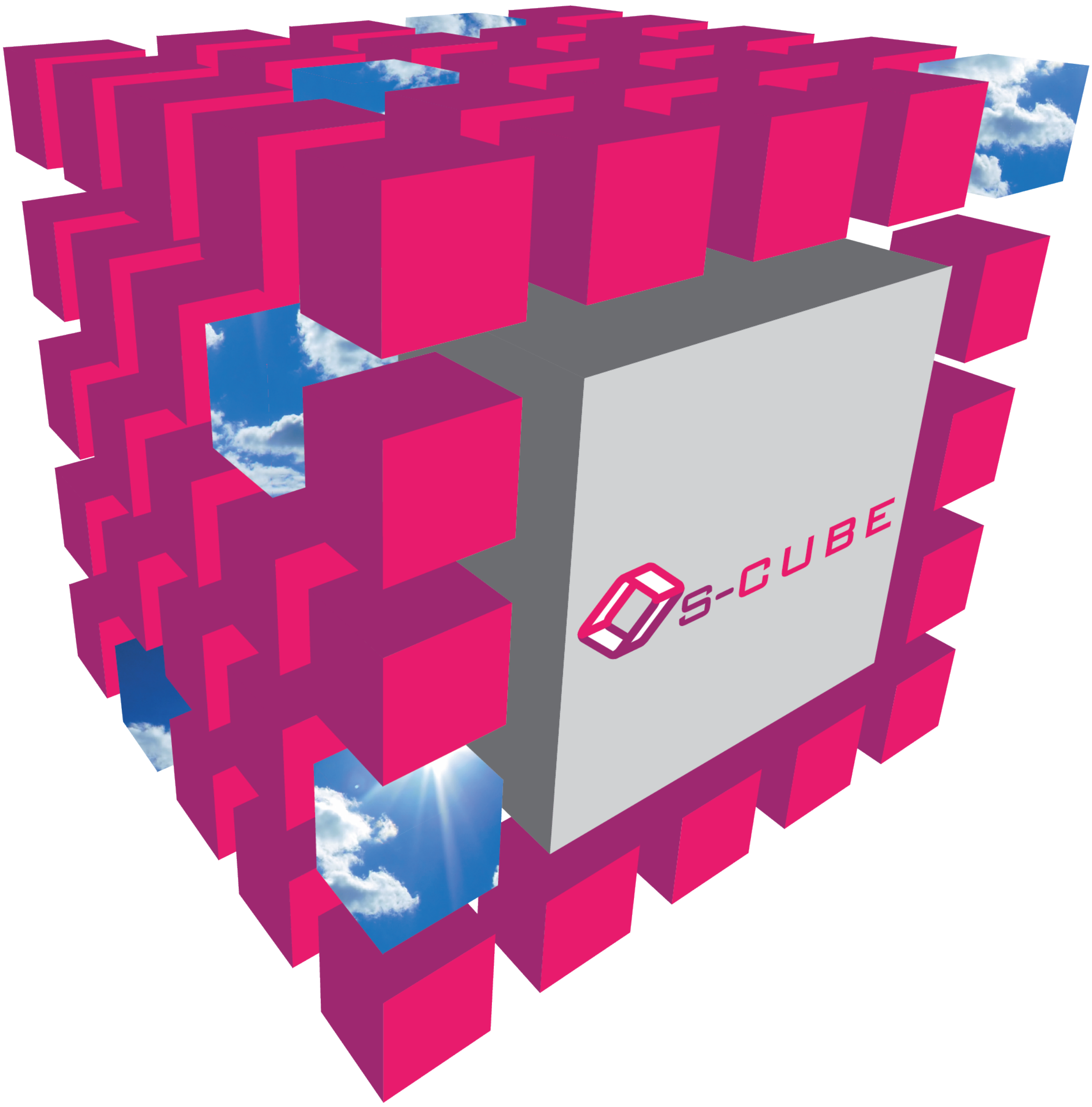

S-Cube Network of Excellence Final Report

PALUNO
The Ruhr Institute for Software Technology

S-Cube - The European Network of Excellence in Software Services and Systems

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1 The Challenge and the Proposition of S-Cube

The rapid evolution of information and communication technology implies a growing number of opportunities for new ways of computing and interacting. In this context one important opportunity is the development of innovative systems through the composition of software services, which are available over distributed computing infrastructures. Software services have the power to provide software functionality to users in a much more dynamic and flexible way than traditional software technologies.

Service-based applications and their corresponding software services require fundamental changes to the way software is developed, deployed, provided and maintained. Software that constitutes service-based applications is no longer owned by a single organization but distributed and shared amongst many organizations. This distributed ownership and access opens up a whole range of research challenges, including the design, evolution, adaptation and quality assurance of service-based applications.

S-Cube was motivated by the fact that about five years ago, many research organisations in Europe had developed or were in the process of developing individual research agendas on service-based applications with no concerted effort to address broader services research and technology requirements that cut across multiple research disciplines. Although the need for cross-cutting research was frequently touted, it was not addressed at all as the challenges it presented were well beyond the ability and means of a single group of researchers. As a result, research activities prior to S-Cube have been very fragmented with each research group and community predominantly concentrating on its own specific research techniques, mechanisms and methodologies. Moreover, there was research replication, no transfer of knowledge and only fractional alignment between research groups.

Fragmentation of research was especially visible when considering high-priority research that focussed on the functional layers of service-based applications. These require a synergy between sub-disciplines such as service infrastructure, software engineering, service composition and coordination and business process management. Service infrastructure issues were mainly addressed by the grid community and there was neither much interaction with the business process management nor with the software engineering communities. Similarly, topics in service composition and business process management were mainly researched in isolation by quite separate communities. Due to this fragmentation, proposed solutions addressed only very specific issues, lacked consistency and coherence, and there was no agreement concerning the underlying theoretical dimensions nor the methodological perspectives employed for services research. Transfer and accumulation of knowledge and further development of the central concepts and synergy potentials were left untapped.

S-Cube, the Software Services and Systems Network, has set out to address these challenges by bringing together researchers from various disciplines. As an EU FP7 Network of Excellence its overall objective was to increase the effort toward synergy, cross-fertilization, and synthesis of research results. The overall aim of S-Cube was to develop a coherent body of knowledge for each of the identified core problem areas in services research by combining insights from different target research groups and schools of thought. To this end, S-Cube pursued the following key objectives:

1. *Integration of Research Communities:* This objective encompassed the integration of research communities by re-aligning, re-shaping, and integrating research agendas of key European research organizations in different research areas and by synthesizing and integrating diverse knowledge, thereby achieving significant progress from the state of the art.
2. *Research on Engineering and Adaptation Methodologies and Service Technologies:* This objective encompassed the research on engineering, quality assurance and adaptation concepts and techniques for service-based applications, as well as research on service technology foundations to realize service-based applications. To this end, S-Cube aimed to jointly develop the next generation of engineering, quality assurance techniques and adaptation approaches which, by combining different competences, take a holistic view and empower service integrators, services providers and other relevant stakeholders to compose, evolve and adapt service-based applications. Furthermore, S-Cube aimed to jointly design and develop realisation mechanism and technologies for the next generation of service-based applications which support seamless engineering and adaptation across the business process, service composition, and infrastructure layers.
3. *Integration of Education:* S-Cube aimed to inaugurate a Europe-wide common program of education and training for researchers and industry that will support (and receive feedback from) the alignment and integration of European competence and knowledge and will contribute to the durability of its impact.
4. *Bonding of Research Staff*: S-Cube aimed to provide a pro-active mobility plan which supports the exchange of research staff and PhD students at the European level to foster a research alignment by achieving cross-fertilisation of knowledge and experience.
5. *Community Outreach, Spreading of Excellence and Collaboration:* As part of S-Cube’s community outreach objective, the network aimed to established European and international conferences and events to create awareness about S-Cube and to foster the integration of research communities. S-Cube further aimed to establish strong, long lasting links with European industry, preferably via ETPs (European Technology Platforms) such as NESSI (Networked European Software & Services). S-Cube further aimed at strong links with academic institutions and related EU FP7 research projects (specifically SSAIE and FIA projects) to establish collaborations and to gain knowledge and insights that influence and drive the integration and future of the field.

To reach the above objectives, S-Cube brought together over 120 researchers and Ph.D. students from 16 full member and 17 associate member institutions that jointly carried out a broad range of research integration and spreading of excellence activities over S-Cube's funding period of four years.

2 Highlights of Achievements

This section highlights S-Cube's main achievements accomplished during the network lifetime. The achievements are clustered along the five objectives introduced in the previous section.

2.1 Integration of Research Communities

The S-Cube Integrated Research Framework

The S-Cube *Integrated Research Framework* was a key mechanism of S-Cube to guide its research activities and to foster the consistent integration of research results (see 0 [1, 2, 9, 10]). The framework provides a clear separation of concerns, thereby allowing for the systematic and structured integration and alignment of research activities of the involved research disciplines and research organizations.

Figure 1 provides a high-level view on the S-Cube Integrated Research Framework.

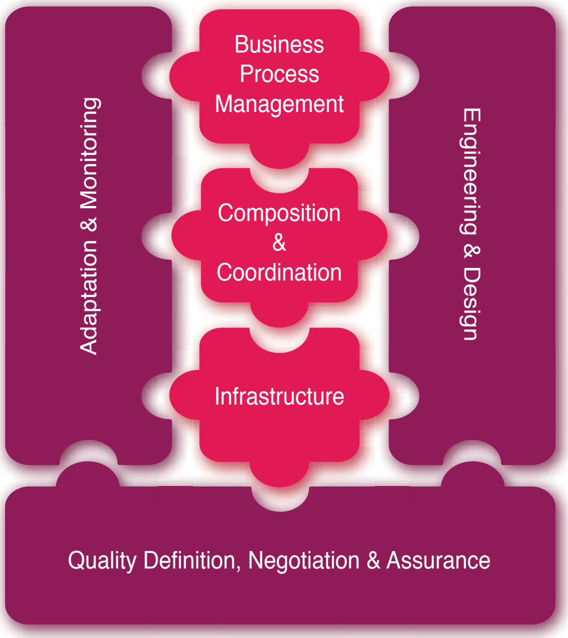


Figure 1: S-Cube Integrated Research Framework

The specific concerns are reflected in six building blocks of the Integrated Research Framework. The blocks are organized in two major categories: the service technology layers and the service techniques and methods planes. This structure provides a clear distinction between technology-focussed approaches of the service technology layers and the cross-cutting principles, techniques and methods provided by the techniques and method planes that together exploit and integrate the capabilities of the technology layers.

The technology layers consist of three building blocks:

- *Service Infrastructure:* The Service Infrastructure layer represents the most basic layer of the S-Cube framework. It facilitates services communication primitives and utilizes service middleware and architectural constructs that connect heterogeneous applications, provide multiple-channel access to services, and introduces a run-time environment for the execution of services.
- *Service Composition & Coordination:* The Service Composition & Coordination layer encompasses the functions required for aggregating multiple services into a single composite service offering.
- *Business Process Management:* The Business Process Management layer provides mechanisms for expressing, understanding, representing and managing service networks. Service networks comprise end-to-end processes which extend beyond organizational boundaries and may be loosely defined as a large, geographically dispersed complex networks of collaborating and transacting value-adding services.

The service techniques and method planes include:

- *Service Engineering and Design:* The Service Engineering and Design plane provides the principles, techniques and methods that interweave and exploit the mechanisms provided by the technology stack with the aim of developing high-quality service-based applications. The Service Engineering and Design plane provides requirements engineering and design principles and techniques, which – in conjunction with context, HCI and quality knowledge – help to create high-quality service-based applications.
- *Service Adaptation and Monitoring:* Service-based applications should possess the ability to continuously adapt themselves in reaction to context changes such as evolving user or customer requirements or the appearance of new services. The Service Adaptation and Monitoring plane supports monitoring, predicting (together with SQ) and governing the activities of a distributed services-system and performing control actions to adapt the entire services technology stack.
- *Service quality definition, negotiation and assurance:* This plane involves principles, techniques and methods for defining, negotiating and assuring end-to-end quality and conformance to Service Level Agreements. It provides novel facilities to predict problems and deviations in systems before quality is impacted and triggers the adaptations coordinated by the Service Adaptation and Monitoring plane to pro-actively respond to these situations.

Further information:

➚ http://www.s-cube-network.eu/about-s-cube-pages/irf

The S-Cube Life-Cycle Model

Where the Integrated Research Framework provided a static view, the *S-Cube Life-Cycle Model* provides a dynamic view by defining the relevant activities for adaptation and evolution of service-based applications and their mutual dependencies. Figure 2 provides a high-level view of the S-Cube Life-Cycle Model (see [11]). In contrast to traditional life-cycle models, the S-Cube Life-Cycle model considers the specifics of service-based applications, particularly focusing on dynamic adaptation techniques during run-time. In order to take into account design time as well as run-time aspects, the S-Cube Life-Cycle Model defines two loops, which can be executed in an incremental and iterative fashion:

- The *Evolution loop* (right hand side) builds on the traditional development and deployment activities, including requirements engineering, design, realization, and deployment. However, it extends them with "design-for-adaptation" steps, such as to define and implement how the system should monitor and modify itself when entering the left-hand side of the life-cycle.
- The *Adaptation loop* (left hand side) explicitly defines activities for autonomously addressing changes during the operation of service-based applications. The activities in the adaptation loop follow the steps of the MAPE loop (Monitoring-Analyse-Plan-Execute), which is typically found in autonomic systems.

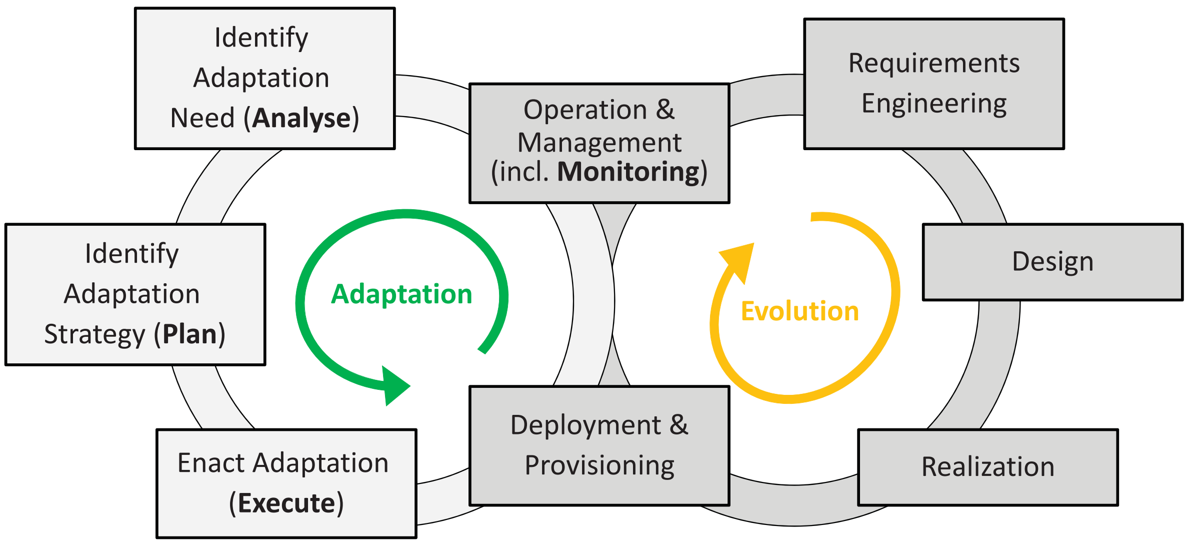


Figure 2: S-Cube Life-Cycle

The S-Cube Life-Cycle Model builds on established practices from software engineering. The life-cycle captures a highly iterative and continuous method for developing, implementing, and maintaining services. Feedback is continuously cycled to and from phases in iterative steps of refinement and adaptation which traverse the lifecycle. To that effect the method facilitates designing solutions as assemblies of services in which the assembly description is a managed, first-class aspect of the solution, and hence, amenable to analysis, change, and evolution. The method accommodates continuous modifications (through adaptation and evolution) of service-based applications and its quality (e.g., QoS and KPIs) at all layers.

Continuous modifications are based on monitoring and measuring service execution against Service Level Agreements (SLAs) and quality goals. In this way, the S-Cube Life-Cycle Model allows to continuously a) detect new problems, changes, and needs for adaptation, b) identify possible adaptation strategies, and c) enact them. These three steps are depicted on the left hand side of the life-cycle model. Once service-based applications (or parts thereof) have been adapted, they will be re-deployed and re-provisioned and put into operation.

Further information:

↗ http://s-cube-network.eu/about-s-cube-pages/jra-1.1/

The S-Cube Knowledge Model & Quality Reference Model

The *S-Cube Knowledge Model* provides an approach for capturing, managing and refining the knowledge produced by the network and related research disciplines. Its main objective is to assist in the consolidation of research and bridging the gaps between broad disciplines, The Knowledge Model allows mapping, integration and synthesizing the diverse concepts and knowledge from the different research areas and activities and provides a resource that can be used as a reference point to help classify research results, to identify network member's competencies, and to illustrate the use of knowledge through associations with common scenarios, case studies, and experimental tools.

The S-Cube Knowledge Model can be seen as a continuously updated on-line encyclopaedia and reference library of research material for the Internet of Services, and is available via the S-Cube web portal.

The network realised that the communities involved in S-Cube will not always be able to agree on a common terminology, so the Knowledge Model is designed to provide interrelated and contextual definitions such that researchers can translate between the vocabularies of the various research communities involved in this research.

The *S-Cube Quality Reference Model* is part of the Knowledge Model and provides a consolidated taxonomy of quality attributes for service-based applications, resulting from a thorough analysis of quality models used in software engineering, grid computing, business process management and service-based computing.

Figure 3 presents the top-level structure of the Quality Reference Model. The model can serve as a starting point to understand the relevant quality attributes of service-based applications and how these are related to each other.

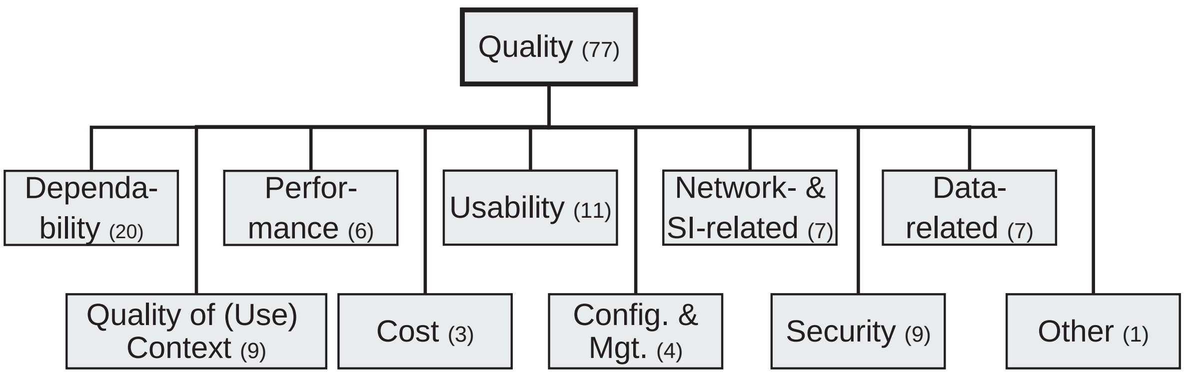


Figure 3: Overview of S-Cube Quality Reference Model
(number in brackets are quality attributes per cluster)

Further information:

↗ http://www.s-cube-network.eu/km
↗ http://www.s-cube-network.eu/km/qrm

2.2 Research on Engineering and Adaptation Methodologies and Service Technologies

Cross-Layer Monitoring and Adaptation

As visible from the S-Cube Integrated Research Framework (see Figure 1), service-based applications operate on different layers to implement their functionality and to provide their expected quality. However, the adaptations on those layers must be coordinated, since:

- *Conflicting adaptations* can arise, e.g., in cases where the individual adaptations cancel each other or interact in an undesired way (an anthology of cross-layer adaptation hazards is given in [12]). In S-Cube, fundamental solutions and frameworks were proposed to avoid the harmful side-effects resulting from independently acting adaptations (see [13, 14, 15, 16]).

- *Isolated adaptations* on a single layer might not be sufficient to compensate a problem in a service execution. S-Cube identified scenarios in which the coordination of adaptations on the infrastructure and the composition layer significantly increase the chance to avoid performance violations of the application based on an adaption of the service composition with aligned adaptation of the service infrastructure such as a cloud (see [17]).

Further information:

➚ http://www.s-cube-network.eu/about-s-cube-pages/jra-1.2/

Quality Prediction and Proactive Adaptation

Ideally, a service-based application predicts quality problems and requirements violations during run-time and proactively initiates adequate counter-measures. Proactive adaptation addresses key drawbacks of conventional reactive adaptation approaches, which suffer from costly repair and compensation activities. Within S-Cube, researchers investigated novel solutions for service quality prediction. These include:

- *Data mining* approaches, which leverage machine learning capabilities to train prediction models using historic monitoring data (see[18, 19]).
- *Run-time verification* approaches, which ascertain whether some predefined properties are met at run-time, e.g., using model checking (see [20]).
- *Online testing* approaches, which test the services of the service-based application in parallel to their normal use in order to gather additional evidence for failures (see [21]).
- *Static analysis* approaches, which systematically examine models of service-based applications to infer approximations of their execution (see [22]).
- *Simulation-based* approaches, which execute dynamic models of the service-based applications to simulate their future behaviour (see [23, 24]).

In order to align their efforts and to identify synergies between the different approaches, S-Cube's researchers have formed the Quality Prediction Working Group. The results of this group are published on the S-Cube website.

Further information:

- ➚ http://www.s-cube-network.eu/qp
- ➚ http://www.s-cube-network.eu/about-s-cube-pages/jra-1.3/

Business Transactions Monitoring

In simple terms, business transactions can be defined as trading interactions involving multiple parties, spanning many organizations, that strive to accomplish an explicitly shared business objective according to a mutually agreed upon contract.

Current distributed computing technologies can merely support the implementation of business transaction by simply composing software services into "static", application-level processes relying on standards such as the Business Process Execution Language (BPEL), and then defining traditional, infrastructure-level ACID-like transactions on top of them using standards such as WS-Transactions.

To address those shortcomings, one research line in S-Cube has produced the following outcomes:

- A *Business Transactions Monitoring Model* – grounded on a novel business transaction specification language – that allows correlating application-level critical business activities and events, QoS requirements, and application significant business data to system-level service-enabled processes at run-time (e.g. [25, 26]).

- A *causal-tracking and monitoring approach* to track the progress of business transactions against multi-party business agreements, typically a Service Level Agreement (e.g. [27]).

- A *preventive business process adaptation framework* that pre-empts end-to-end process Service Level Agreement violations, and automatically adapts the transaction execution in a way that meets the agreed end-to-end Service Level Agreements (e.g. [28]).

The business transaction management model and prototype system that have resulted from S-Cube work amalgamate existing service composition and monitoring techniques (e.g., BPEL) with complex event processing technology. The proposed system is a first important step toward effective support of end-to-end processes that can monitor their own performance by sensing and interacting with the physical world, and repair, upgrade, or replace themselves proactively.

Further information:

- ➚ http://www.s-cube-network.eu/about-s-cube-pages/jra-2.1/

Chemical Computing

S-Cube researchers elaborated and developed an innovative technique for building novel service infrastructures on the basis of chemical models. Such chemical computing abstracts the notion of computing as a chemical reaction. Data elements are molecules that are captured and transformed by active molecules representing procedures (functions, activities, etc.) in a single, atomic reaction as long as reactions are possible. As such, chemical computing is a self-evolving and self-coordinating process governing by actual and local conditions, a notable similarity to many adaptation and optimization requirements.

S-Cube envisioned *adaptive and self-optimizing services in a chemical framework* where the nature inspired mechanisms can yield higher level of autonomy while maintaining the power and efficiency of declarative programming and the clarity of mathematically well founded chemical calculus. Specifically, the following results have been achieved:

- As part of S-Cube research on service infrastructures the network has developed a *model for dynamic selection of services and adaptation* of service compositions based on availability and QoS attributes (e.g. [29]).
- S-Cube has developed *tools for chemical computing* in order to make it more usable (scheme interpreter, Java framework) and prototypes for interfacing these tools with concrete Web services (e.g. [30]).
- S-Cube integrated a *chemical engine into a service platform* for service selection and adaptation (e.g. [31]).

Further information:

➚ http://www.s-cube-network.eu/about-s-cube-pages/jra-2.3/

2.3 Integration of Education

Virtual Campus

The S-Cube *Virtual Campus* offers differentiated curricula in the field of software services and systems in connection with related research areas. The aim of the Virtual Campus is to foster the integration of research by providing a distributed and flexible e-learning environment and by supporting the joint Masters and PhD programs of S-Cube. In addition, the Virtual Campus will maintain the basis for further cooperation and integration in teaching in the service community and related communities.

The Virtual Campus also provides a collection of freely available learning modules, which provide teaching material based on the research themes of S-Cube. The material may be used during lectures (such as S-Cube’s joint master programme) but can also be employed for self-study.

Further information:

➚ http://www.s-cubenetwork.eu/vc

International Master in Service Engineering (IMSE)

The *International Master in Service Engineering* (IMSE) is a two-year Erasmus Mundus master programme in service engineering. It has been established with the aim of addressing the quickly growing need for new multi-disciplinary teaching programmes that are designed at the interface of software services and new globe-spanning business processes.

Further information:

- http://www.erasmusmundus-imse.eu/

2.4 Bonding of Research Staff

Bonding of Research Staff and Joint Supervision

During the course of S-Cube, the network researchers strengthened their joint research and integration activities by using S-Cube’s dedicated mobility programme. In addition, a high number of members were involved in jointly supervising PhD students leading to a number of jointly supervised PhD theses.

Further information:

- http://www.s-cube-network.eu/about-s-cube-pages/ia-2.1/

Summer School

The organisation of the annual Service and Software Architectures, Infrastructures and Engineering (SSAIE) Summer School has brought together students from all over Europe to receive high-quality training from representatives from academia and industrial partners, such as IBM, Ericsson and BOC.

Further information:

- http://www.summersoc.eu/

2.5 Community Outreach, Spreading of Excellence and Collaboration

Conferences and Workshops

S-Cube members organized or participated in the organization of over 40 high profile, international conferences, workshops, events sessions and summer schools including the two international leading conference series ICSOC and ServiceWave, as well as workshop series such as MONA+, PESOS, WESOA, SHARK, BSME, WAS4FI and many others.

Network members gave over 200 presentations at international conferences, EU related events, companies, and national research bodies, including 50 keynotes and invited talks at prominent international conferences and events.

Further information:

- http://www.s-cube-network.eu/events

Publications

S-Cube's research and integration results have been published in over 250 papers that appeared in international journals, books, conferences and workshops. A complete list of publications is available from the S-Cube web portal (see link below).

Three of S-Cube's publication highlights are:

- S-Cube members established a *Lecture Notes in Computer Science (LNCS) sub-line* together with 'Springer' to provide a shared dissemination channel for the results of the EC's FP7 research and development projects.
- S-Cube published a Springer book on *Service Research Challenges and Solutions for the Future Internet: Towards Mechanisms and Methods for Engineering, Managing, and Adapting Service-Based System* (see [1]). This book contains a series of surveys on the state of the art in each research area of S-Cube.
- S-Cube members edited the Springer book on *Service Engineering - European Research Results* (see [3]). This book covers the outcomes of the EC's SSAIE Service Engineering Collaborative Working Group (CWG).

Further information:

↗ http://s-cube-network.eu/refbase/
↗ http://www.springer.com/series/8680

IFIP Working Group on "Services-oriented Systems"

S-Cube members and collaborators have established a new *IFIP working group on Services-oriented Systems* (WG 2.14/6.12/8.10). IFIP is the International Federation of Information Processing. The new working group constitutes a joint effort of its technical committees TC2 (Software: Theory and Practice), TC6 (Communication Systems), and TC8 (Information Systems). This involvement of different technical committees is motivated by the multi-dimensional nature of services-based applications. Indeed, a major goal of the new working group is to organize and promote the exchange of information on both fundamental and practical aspects of service-based applications. The working group in particular aims to attract people from the different communities of relevance.

Further information:

↗ http://home.dei.polimi.it/baresi/ifip/

S-Cube Industrial Advisory Board

S-Cube members have actively contributed to *the Strategic [Industrial] Research Agenda (SRA)* of the European Technology Platform NESSI and co-organized sessions during NESSI Project Summit events.

Further, S-Cube has established and strengthened *direct and lasting links with industry*, specifically through S-Cube's *Industrial Advisory Board*, which provided very helpful recommendations on the alignment of S-Cube with industrial activities. The Industrial Advisory Board included members from Engineering Ingegneria Informatica (Italy), HP (UK), IBM Research (Israel), SAP AG (Germany), Siemens AG (Germany) and Thales (France). As tangible result of this industry alignment, S-Cube presented its results during dedicated industry workshops. The results presented are available in the form of a “shopping list” at the S-Cube web portal.

Further information:

- ↗ http://www.s-cube-network.eu/shopping-list

Use Case Methodology and Repository

In order to provide and to establish a *comprehensive and integrated approach for describing use cases*, S-Cube developed a methodology to capture significant information of use cases in a structured way. The methodology suggests an approach for describing and classifying use cases with the objective to make them comparable and reusable in the context of different projects, compiling use case business goals and domain assumptions for instance.

S-Cube created and hosted a *use cases repository* which furnishes use cases descriptions compliant to the proposed methodology. The driving aim behind the repository was to collect and to provide use case descriptions that are used, or going to be used, by EU-funded research projects. The repository includes use cases defined by S-Cube, as well as use cases published by other FP7 projects including NEXOF-RA, PLAY and ALERT. This repository also hosts the artefacts of the special session on “The Quest for Case Studies” organized by the ICSE 2012 Workshop PESOS.

Further information:

- ↗ http://s-cube-network.eu/use-cases
- ↗ http://www.s-cube-network.eu/pesos-2012

Collaboration with SSAIE and Future Internet (FIA) Projects

S-Cube collaborated with other EU projects in the SSAIE Collaboration Working Groups (CWGs). Most notably S-Cube members co-organized four CWGs, namely Service Engineering, Service Architectures, Use Cases, and Dissemination. In addition, S-Cube members significantly contributed to three other CWGs (QoS and SLAs, Repository, and Future Internet Assembly).

S-Cube participated in Future Internet Assembly (FIA) activities and was amongst the first projects to endorse the “Bled FIA declaration”.

Further information:

- ↗ http://s-cube-network.eu/collaboration
- ↗ http://www.future-internet.eu/publications/bled-declaration.html

3 Main Results

This section provides a comprehensive overview on results of S-Cube organised along the integration, the research and the spread of excellence activities performed in S-Cube. Due to its integrative nature, each of those activities (listed in the top row) contributed to more than one S-Cube objective (listed in the left column), outlined in Section 1 (see Table 3-1).

Contribution ++: strong +: medium	*Integrating Knowledge [and Re-sources]*[1]	*Integrating Communit-ies*	*Integration Framework*	*Engineering and Adap-tation Methodolo-gies*	*Realisation Mechani-sms*	*Spreading of Excel-lence*
1. Integration of Research Communities	++	++	++	++	++	+
2. Research on Engineer-ing and Adaptation Meth-odologies and Service Technologies	++	++	++	++	++	+
3. Integration of Education	++	+	+	+	+	++
4. Bonding of Research Staff	++	++	++	++	++	++
5. Community Outreach, Spreading of Excellence and Collaboration	++	+	+	+	+	++

Table 3-1: Contribution of S-Cube’s activities to S-Cube’s objectives

3.1 Integrating Knowledge

To foster the integration of research and to ensure alignment between the various related research disciplines, the S-Cube Knowledge Model was developed providing a method of capturing, managing and refining the knowledge produced by the network. The Knowledge Model allowed the collection, analysis and management of research within and outside of S-Cube and enabled the extraction and combination of the explicit, crosscutting knowledge required for collaborative research.

The main results achieved by the “integration of knowledge” activity are:

- The Knowledge Model includesover 450 terms and 723 definitions, which are publically available.
- The Knowledge Model integrates and synthesizes diverse definitions, terms, concepts and knowledge from different research communities.

[1] Please note that the integration of resources had been planned as part of the European Distributed Services Lab work in S-Cube. However, this work was closed in year one following the review recommendations.

- The Knowledge Model provides different ways of accessing its contents, e.g. browsing by alphabetical order or by research area, as well as searching.
- The Knowledge Model serves as reference point for the stakeholders addressed by S-Cube, i.e., researchers, students, software service developers and providers, and industry.
- The Knowledge Model gained wide acceptance among the network members, as well as external stakeholders (as visible by the accesses to the web pages).
- S-Cube's experience in establishing the Knowledge Model has been published and presented in different forums (see [32]).
- Since October 2010, S-Cube and HOLA![2] collaborate to employ the Knowledge Model to define a meta-data schema that provides the keywords attached to HOLA!'s Internet of Services Digital Library.

Further information:

➚ http://s-cube-network.eu/km/km-frontpage
➚ http://s-cube-network.eu/about-s-cube-pages/ia-1/

3.2 Integrating Communities

The integration of the different research communities in S-Cube was facilitated by (1) an intensive mobility programme which fostered the exchange of staff from all S-Cube members, (2) a systematic collection of use cases to illustrate and validate S-Cubes results, (3) the alignment with industry, specifically via the industrial advisory board, student internships with industry and S-Cube industry workshops.

Among others, the following results have been achieved:

- S-Cube researchers participated in over 105 research visits, covering a large variety of research subjects such as engineering, adaptation, and evolution of software-based applications. The exchange of staff obviously fostered the creation of effective communication channels and the creation of lasting collaborations among members.
- S-Cube established a structured approach for defining use cases for software-services and service-based applications. This approach was proposed to EU projects running concurrently to S-Cube with the aim of defining use cases unitarily. It has been adopted by at least three other FP7 projects. The use cases defined are hosted and made public via the S-Cube use case repository. Moreover, S-Cube members chaired the use cases working group session at the Collaboration Meeting promoted by the EU.
- S-Cube compiled a "shopping list" comprising results that are expected to be relevant for ICT industries and companies; an excerpt of these results was presented to researchers and decision makers from industry in specific workshops.

Further information:

➚ http://www.s-cube-network.eu/shopping-list

[2] http://www.holaportal.eu/node/12

- ↗ http://s-cube-network.eu/use-cases
- ↗ http://s-cube-network.eu/about-s-cube-pages/ia-2/

3.3 Integration Framework for Service-based Applications

The main goal of this activity was the definition and the validation of a coherent and holistic Integrated Research Framework (see Section 2.1) to foster the alignment of the research activities within S-Cube. Among others, the results include:

- The integration framework fostered the conceptual integration of principles, techniques, methods and mechanisms developed and extended in the various S-Cube research activities. Those results obviously have been widely published.
- The integration framework facilitated the definition of 24 concrete research challenges for the key building blocks of the framework and researched within S-Cube. In addition, patterns which characterize different types of users involved in the design and execution of software services and services-based systems have been identified and defined.
- By employing high level scenarios (see also Section 3.2) S-Cube members validated the end-to-end integration of S-Cube research results which in turn led to a continuous revision and improvement of the integration framework itself.
- The Integrated Research Framework and its building blocks were empirically validated such as demonstrators, experiments, and case studies. Overall, approximately 50 different validations have been executed and reported.
- The research framework and the use cases significantly facilitated the successful alignment of the short- and long-term research agendas of S-Cube members.

Further information:

- ↗ http://www.s-cube-network.eu/irf

3.4 Engineering and Adaptation Methodologies for Service-based Applications

The overall goal of this activity was to perform joint research and development for the next generation of engineering, adaptation, and quality assurance concepts, techniques and methods. Overall, the results achieved enable service integrators, services providers and other relevant stakeholders to compose, evolve, and adapt software services and service-based applications (detailed information on these objectives can be found in [1]). S-Cube’s results within this activity can be classified into the following three key areas.

S-Cube produced an integrated, coherent and comprehensive set of *principles, techniques and methods for engineering service-based applications*. Specifically and other than previous work, those results considered human-computer-interaction issues and the context of service-based applications. In more detail

- S-Cube developed a coherent life cycle for adaptable and evolvable service-based applications (e.g. [33, 34, 35]). This life-cycle was the first to fully incorporate adaptation (and specifically design-for-adaptation activities) into the system life-cycle and to incorporate guidelines for considering HCI and context aspects during design (e.g. [36, 37, 38]);

- S-Cube defined best practices to facilitate the migration of legacy systems to service-based applications (e.g. [39, 40, 41]).

Complementing the engineering techniques, S-Cube devised *novel principles, techniques and methods for cross-layer monitoring of service-based applications*. Those solutions – other than the ones before – address the multi-layer characteristics of service-based applications and are thus able to integrate and coordinate adaptations on different layers. In more detail

- S-Cube developed multi-level self-adaptation concepts and techniques for service-based applications (e.g. [14, 42, 43]), which consider HCI-aware monitoring and adaptation (e.g. [38, 44, 45]);
- In close interaction with the third key area of this activity (see below), S-Cube researchers created proactive adaptation and predictive monitoring techniques (e.g. [21, 24, 46]).

Finally, S-Cube produced new *concepts, principles and techniques for specifying, negotiating and assuring end-to-end quality provision and SLA conformance*. As major novelties this included performing quality assurance activities during run-time and leveraging those run-time techniques for online quality prediction and proactive negotiation. In more detail:

- S-Cube delivered an integrated end-to-end quality reference model (e.g. [47, 48, 49]) and a rich and extensible quality definition language (e.g. [50, 51, 52]);
- S-Cube developed techniques exploiting user and task models for automatic quality contract establishment (e.g. [36, 52, 53]), as well as techniques for proactive SLA negotiation and agreement (e.g. [54, 55, 56]).
- S-Cube researched and developed novel run-time quality assurance techniques, such as online testing and run-time verification (e.g. [57, 58, 59]). Based on those techniques and jointly with the second key area of this activity (see above), online quality prediction techniques have been devised, allowing to forecast service quality, thus enabling proactive adaptation of service-based applications (e.g. [58, 60, 61]).

Further information:

➚ http://s-cube-network.eu/about-s-cube-pages/jra-1

3.5 Realization Mechanisms for Service-based Applications

The major goal of this activity was to develop technologies, mechanisms and techniques for realizing QoS-aware and adaptable service-based applications. The collaborative research of this activity resulted in a stack of technologies and techniques. Both reflect the interdependencies of the service-based application layers and will enable the development of service-based applications according to the engineering principle and techniques as described in Section 3.4. S-Cube's results within this activity can be classified into the following three key areas.

The research work in this activity led to *developing models, notations and techniques for business transactions* and service networks, which are novel approaches towards allowing businesses to view their applications in terms of business relevant characteristics, rather than using exclusively IT metrics:

- S-Cube developed models and enabling technologies for business transactions (e.g. [26, 62, 63]) and service networks (e.g. [64, 65, 66]).
- S-Cube researchers identified interdependencies between the business process management, service compositions and service infrastructure, under consideration of QoS characteristics, adaptation, and monitoring (e.g. [13, 66, 67]) and created models for services, service compositions, and choreographies, including formal models, taking into account behavioural and QoS characteristics (e.g. [51, 68, 69]).

The resulting models for *QoS-aware and adaptable services and service compositions* are an additional advancement beyond existing approaches, comprising results in adaptation triggers and approaches, monitoring, analysis, and prediction of QoS characteristics, SLA and KPI violations:

- S-Cube defined adaptation triggers for service composition in SBAs. The approaches for identifying adaptation needs were closely related to monitoring of service compositions and their non-functional and QoS characteristics (e.g. [14, 70, 71]).
- S-Cube developed adaptation approaches for service compositions such as the use of fragments, aspect-orientation, service infrastructure adaptation, on-line testing and evolution of the business process (e.g. [72, 73]).
- The network proposed fragmentation as an approach for improving reusability of service compositions and choreographies, and for supporting adaptation of compositions (e.g. [24, 74, 75]) and models for context-aware service compositions (enabled by a framework for context-aware process evolution) and models for service compositions based on human-provided services and social media approaches (e.g. [37, 45 76, 77])
- S-Cube developed frameworks for multilevel and distributed service adaptation focusing on event logs analysis to support service execution and adaptation and to allow predicting violations of SLAs (e.g. [14, 49, 78]) and created a decision support for service adaptation by monitoring run-time service discovery, preventing runtime SLA violations (e.g. [18, 79,80]).

Moreover, S-Cube developed technologies for service provisioning, adaptation and monitoring, and incorporated them into approaches for *enabling self-* characteristics of an integrated service infrastructure*:

- S-Cube created novel approaches based on chemical model to build and adjust a new service infrastructure (e.g. [29, 30, 31]).
- S-Cube developed a SLA-based resource virtualization approach for on-demand service provision and execution (e.g. [81, 82]) and contributed enabling self-* characteristics of a service runtime environment incorporating both service registries and client components (e.g. [47, 83]).
- S-Cube created management and deployment approaches of services on Cloud infrastructures including both provisioning and adaptation (e.g. [82, 84]).

Further information:

➚ http://s-cube-network.eu/about-s-cube-pages/jra-2

3.6 Spreading of Excellence

S-Cube was aware that the long term integration of research requires enhancing synergies, pooling expertise in favour of clear strategic options that are the expressing of the needs and objectives of research identified in S-Cube not only in conjunction with S-Cube beneficiaries but also external communities. As a result, S-Cube members were highly committed to disseminating and creating awareness of S-Cube results. This involved dissemination activities within the academic and industrial research community, as well as communities of practitioners. In addition, this activity involved the set-up of a Virtual Campus on software services and systems, to ensure the uptake and awareness of S-Cube results already during university teaching and courses.

Results of the "spreading of excellence" activity include:

- **S-Cube Web Portal:** The web portal evolved to a valuable access point for research on software services research. 453 users (including members) have registered for the S-Cube Web Portal. At the time of reporting, the portal achieved a Google page rank of 6/10.

  Further information:

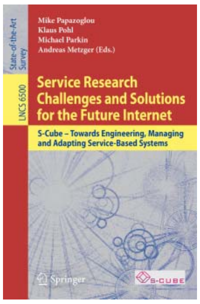
  ↗ http://www.s-cube-network.eu/

- **Publications**: Throughout the course of the network, S-Cube members published over 250 papers in international conferences, journals, and workshops. The complete list of papers is available on the S-Cube Web Portal (see link below). This includes over 30 journal papers published in journals such as IEEE Transactions on Software Engineering, ACM Transactions on Web, IEEE Software, Enterprise Information Systems, Automated Software Engineering, IEEE Internet Computing, Information and Software Technology Journal, Automated Software Engineering.

  Further information:

  ↗ http://www.s-cube-network.eu/refbase/

- **The S-Cube Book**: The book – titled "Service Research Challenges and Solutions for the Future Internet - S-Cube – Towards Engineering, Managing and Adapting Service-Based Systems" was devised in response to the evolution of the Internet from a source of information to a critical infrastructure that underpins economies and everyday life. It presents the foundations, vision, first results and future work in the area of software services as addressed by S-Cube in response to the challenges presented by the Internet of Services.



- **Service Engineering: European Research Results**: S-Cube members worked together on compiling a book to cover the outcomes of the EC's SSAIE Service Engineering Collaborative Working Group (CWG). The objective of the CWG was the development of a joint research agenda for the area of Service Engineering through collaboration in seven areas: the specification of services, service composition engineering, service engineering methodology, autonomic service adaptation, service testing and simulation, service governance techniques and engineering techniques for human provided services.

- **Springer LNCS: Service Science Subline:** To promote the discipline of Service Science, Management & Engineering, the S-Cube Network of Excellence together with Springer has created a *LNCS subline* providing a shared dissemination channel for the results of the EC’s FP7 research and development projects. Since the subline was conceived at the start of the S-Cube, it has been responsible for ten publications.

  Further information:

  ➚ http://www.springer.com/series/8680

- **International Leading Conferences:** S-Cube was strongly committed to the organization of premier research conferences. S-Cube co-organized ICSOC and ServiceWave, two international leading conferences on software services. ICSOC, the International Conference on Service Oriented Computing, is the leading forum to report and share progressive and guiding works in the domain of service oriented computing. ICSOC brings together experts from a multitude of disciplines, for instance, business process management, distributed systems, service science, and software engineering. The ServiceWave conference series established the premier European forum for researchers, educators and industrial practitioners to present and discuss the most recent innovations, trends, experiences and concerns in Software Services (or the “Future of the Internet of Services”) and related underlying network technologies.

- **Organization of Workshops and Conferences**: With the objective of offering opportunities to European researchers coming from academia, industry, and interested application communities to communicate problems, requirements and solutions within different areas, and to exchange working experiences, S-Cube members organized or participated in the organization of over 40 high profile, international conferences, workshops, sessions and summer schools including ICSOC and ServiceWave, as well as workshop series such as MONA+, PESOS, WESOA, SHARK, BSME, WAS4F, and industry workshops. S-Cube dedicated its last workshop, S-Cube@ICSE, to the presentation of its achievements and the discussion on future research challenges.

- **Presentations**: The S-Cube network members gave over 150 presentations at international conferences, EU related events, companies, and national research bodies. In addition, approximately 50 keynotes and invited talks were given at prestigious international conferences and events. The comprehensive list is attached to this document as Appendix 0.

- **IMSE Program**: S-Cube was aware of the quickly growing need for new multidisciplinary teaching programmes focussed on Service Engineering. Thus, S-Cube installed a new two-year Erasmus Mundus Master programme in Service Engineering, named the International Master in Service Engineering (IMSE). The marriage between the research-oriented Network of Excellence S-Cube and the educational programme IMSE was highly synergistic. IMSE is a perfect vehicle for sharing S-Cube’s scientific insights with the upcoming generation of new software service engineers. Additionally, the combination of the S-Cube Knowledge Model and the S-Cube Virtual Campus provides the knowledge backbone of IMSE: a virtual environment where scholars, lecturers and students share lecture slides, notes, articles, white papers, contacts, etc. Last, but not least, the SSAIE Summer School becomes an essential educational component in IMSE’s programme.

  Further information:

  ➚ http://www.erasmusmundus-imse.eu/

- **Collaboration with EC SSAIE Projects:** S-Cube strongly contributed to collaboration between EC funded projects (i.e., FP-6 and FP-7 projects), specifically by chairing and contributing to the SSAIE Collaboration Working Groups (CWGs). CWGs are considered by the EC as a main vehicle for achieving collaboration and durable links between European projects in the area of software and services. S-Cube participated in seven CWG working groups, and led three of them. In addition, S-Cube was among the projects that actively shaped the Future Internet Assembly (FIA) and endorsed the "Bled declaration".

  Further information:

  ➚ http://s-cube-network.eu/collaboration

- **Virtual Campus and Learning Packages**: The Virtual Campus offers differentiated curricula in the field of service-based computing in connection with distributed software development, e-business, e-government and e-learning applications. It aims to use a flexible combination of communication and collaboration technologies to encourage and facilitate knowledge exchange, news circulation, debate, feedback to support the interaction and dissemination in the community of Software Services and Systems. The Virtual Campus provides a wide collection of learning packages organized along the S-Cube Integrated Research Framework. In total, there is a collection of 42 Learning Packages covering 12 research topics. S-Cube's Virtual Campus is one of the primary long-lasting artefacts of S-Cube to be exploited to foster a European-wide professional learning society.

  Further information:

  ➚ http://s-cube-network.eu/vc

- **Collaboration with Industry (specifically NESSI)**: NESSI is the Networked European Software and Services Initiative and European Technology Platform (ETP) dedicated to Software and Services[3]. S-Cube established strong links with NESSI partners through various mechanisms. The members of S-Cube's Industrial Advisory Board were representatives from NESSI partner organizations. In addition, S-Cube collaborated with NESSI to organize sessions during NESSI Project Summit events. One major session was held at the NESSI Project Summit co-located with the Future Internet Assembly in Valencia, Spain.

  Further information:

  ➚ http://s-cube-network.eu/collaboration

- **Summer Schools:** Summer schools and training activities constitute an important means to spread excellence across communities. S-Cube has organized five summer school and training workshops of an international and interdisciplinary character. These workshops helped forge a new research community on Service Science Management and Engineering (SSME). Through the participation of distinguished experts and professionals from leading academic, research and industrial organizations in the SSAIE summer schools, the summer school promotes the exchange of ideas and helps participants — in particular young researchers and practitioners — to network and start new cooperative research projects.

[3] NESSI: http://www.nessi-europe.com/

Further information:

↗ http://www.summersoc.eu/

Figure 4: 5th Summer School on Service oriented Computing (June 27 - July 3, 2011)

4 Lessons Learned and Roadmap

S-Cube established a unified, multidisciplinary, vibrant research community conducting research on software services and service-based applications involving over 120 researchers and Ph.D. students from 16 full and 17 associated members.

In order to ensure high quality outcomes and to optimize its efficiency, S-Cube continuously reflected on the execution of its activities. Among others, S-Cube carried out self-assessments in order to scrutinize the efficiency and effectiveness of its activities and to ensure their alignment with the S-Cubes objectives. As a result, strongly supported by the reviewers’ recommendations, S-Cube’s activities have been reshaped and initially planned deliverables have been streamlined and adjusted.

4.1 Key Experiences and Lessons Learned

Lessons learned during the execution of S-Cube include:

- S-Cube was successful in establishing a research community for exchanging research ideas, integrating research results and for conducting joint research. In S-Cube, researchers identified and understood research challenges from the specific perspectives of different research communities, integrated a plethora of diverse views on research problems, and leveraged exciting research paradigms across the different research communities. Briefly, S-Cube facilitated significant synergies between the different research communities. The network’s joint programme of integration, research, and dissemination activities, as well as management structure, have proven to facilitate the establishment of a rich and long lasting integration of heterogeneous research communities. S-Cube’s researchers have established lasting bonds and will continue joint research beyond the end of the funding period of the network. In fact, several publications initiated within S-Cube will be finalised after the end of S-Cube.
- From its beginning, S-Cube enforced the differentiation between the engineering and the adaptation life-cycle. The different research communities brought in different and complementary skills. Together with a critical reflection on solutions outside of individual research communities this led to important improvements and thus significant progress from the state-of-the-art on adapting and engineering service-based applications. A key lesson learnt is that it has taken more time than expected to understand, to align and to integrate the different perspectives. The highest productivity of research was reached in year four and this momentum is still continuing. Thus, retrospectively a four year funding for a network of excellence appears too short.
- As planned in the description of work, S-Cube assessed and readjusted its joint programme of activities in the middle of the funding period. Equally important, very valuable external reviewer suggestions and S-Cube internal continuous analysis resulted in helpful streamlining of the joint programme of activities and re-adjustment of efforts. For example, the reduction of structural integrations and managerial work related to the Integrated Research Framework freed resources which have been much better spent in joint research activities. Without any doubt, those planned adjustments had a significant positive impact on the collaborations between S-Cube members and thus on the results achieved in S-Cube.
- S-Cube envisioned a Pan-European Distributed Lab to test, integrate, evaluate and benchmark relevant emerging service technologies. However, in the first year of

S-Cube it turned out that a decentralized approach much better fits the S-Cube needs. With support of the reviewers, the Pan-European Distributed Lab workpackage was consequently closed after year one. However, after achieving a joint understanding and an integration of research, a more comprehensive integration on a technical level would now foster and facilitated even tighter research integration and, especially, the validation of joint research results.

- The approach of paper-based deliverables (a compact introduction relates and summarizes publications attached to the deliverable) which was tried out in year one proved to be very effective. In fact, from year two all research deliverables have been delivered following this model. In year three and four even other workpackages (such as devoted to knowledge model and research framework validation) produced paper-based deliverables.
- The integration of principles, techniques and methodologies for engineering and adapting of software services and service-based applications significantly facilitated consistency and harmonization of S-Cubes research results. Especially during the first years, establishing a common reference framework was of topmost importance to enable effective collaborations between heterogeneous cross-workpackage and cross-layer approaches. The Integrated Research Framework fulfilled this goal, by providing researchers with a structured access to the S-Cube research challenges as well as research results.
- The creation of the Knowledge Model in terms of consolidating and reconciling overlapping definitions originated in different research areas gained a large benefit from S-Cube's mobility programme and physical meetings. The network's approach on scheduling regular face-to-face meetings allowed researchers to understand each other already during early phases of the network. Yet, S-Cube members realized early on that between the communities involved in S-Cube, it will not always be able to agree on a common terminology. So, the Knowledge Model did not force it but instead interrelated the various definitions such that people can translate between the vocabularies of the various communities. The meetings supported a shared understanding of the S-Cube's objectives, the development of joint research endeavours and the establishment of long lasting research relations.
- The integration of the Virtual Campus Learning Packages with iTunes University was considered by the S-Cube members as a promising direction to reach a large audience with the S-Cube material and to foster sustainability. This included the integration of the Learning Packages with iTunes University. The S-Cube research results can be discovered and downloaded free-of-charge using a plethora of devices and applications, e.g., iPhones, iPads, Apple TV clients, and iTunes on Windows and Mac OS X.
- S-Cube had the ambition to collect and exploit running examples based on real-world case studies. Getting industry involvement in terms of real world case-studies, real world workflows and process data, turned out to be a challenge in its own right, possibly due to the explorative nature of most work. However, S-Cube achieved to set up a repository of use cases, which has been adopted also by other networks.

4.2 Long-term Research Challenges and Roadmap

During the final months of S-Cube, S-Cube researchers and invited scientists have met to identify research challenges on engineering adaptive service-based applications relevant for the next five (maybe ten) years. Those research challenges constitute the S-Cube future Research Roadmap to be presented and discussed with a broader audience at the S-Cube workshop organized in conjunction with ICSE 2012 and published in the proceedings of that event (see [85, 86, 87, 88]). The research challenges are clustered along the S-Cube Integrated Research Framework (see Figure 1):

Service and software engineering: Research challenges related to engineering and design of software services and service-based applications include:

- Techniques and mechanisms for ensuring real-time service provisioning (considering cloud and mobile devices)
- Techniques to include human services and user-provided services in service compositions
- “Social” service models and techniques to support global software and service engineering
- Migration of existing service engineering techniques and processes to incorporate design-for-adaptation activities
- Concepts and techniques for retrieving and updating service descriptions exploiting the notion of linked services
- Principles and techniques to ensure that design activities remain efficient and effective despite increased “design-for-adaptation” needs
- Situational methods and (executable) modeling languages allowing to combine practices (method chunks) for software/service engineering

Service technology foundations: Research challenges related to the service technology stack, including service infrastructures (such as grids and clouds), service composition & coordination, and business process management & service networks include:

- Techniques for adaptable autonomous heterogeneous and “social” business processes
- Adaptation patterns for service compositions based on quality attributes
- Exploiting cloud solutions (IaaS, PaaS, SaaS) for service coordination
- Formal languages and composition (“orchestration”) approaches
- Novel architectural styles (beyond SOA & RESTful)
- Techniques for reasoning about and analyzing properties that emerges due to the interaction of services and organizations
- Employing nature-inspired computing as unconventional paradigms for service and infrastructure adaptation

Multi-layer and mixed-initiative monitoring and adaptation: Research challenges related to monitoring and adapting software services and service-based applications across the whole technology stack, considering triggers from the context of the system and supporting automated and human-in-the-loop adaptation include:

- Decentralized models and techniques to monitor and predict service quality issues
- Assurances for adaptation

- Approaches for retrieving and analyzing context information to support individuals in performing the right adaptation decisions in user-centric systems
- Techniques for combining and cross-correlating observations, predictions and events from different sources and provided by different techniques

Online service quality prediction for proactive adaptation: Research challenges related to assessing and predicting service quality during run-time to proactively respond to imminent problems and issues include:

- Leveraging large event streams towards prediction
- Techniques for IaaS performance prediction beyond traditional workload prediction
- Metrics, techniques and tools for measuring the accuracy of online quality predictions
- Concepts, models and algorithms for quality prediction of heterogeneous (real-world and IT) service-based applications
- Differentiating and correlating short-time predictions (for adaptation) with long-term predictions (for evolution)
- Concepts and factors relevant for contextualizing accuracy

5 Who can benefit from S-Cube

The S-Cube members have identified potential stakeholders and relevant S-Cube results from which those stakeholders can benefit. Among others, various business and society stakeholders can benefit from S-Cube as follows:

- **Researchers and Research Communities**: S-Cube’s research results provide an understanding of open, multi-disciplinary research to be addressed for the Future Internet and a baseline of novel techniques and methods for service engineering and adaptation, e.g., through the S-Cube integrated research framework.
- **Students**: The S-Cube results provide a solid baseline to train European students in the relevant areas for service-based applications, including software engineering, business processes, service-based computing and cloud computing. Students benefit from S-Cube results, e.g., through the joint International Masters in Service Engineering (IMSE), the SSAI summer school on service-based computing, the S-Cube Virtual Campus (see Section 3.6), and the S-Cube Knowledge Model (see Section 3.1).
- **Developers and Software Engineers:** The research results provided by S-Cube support developers and software engineers in in developing and advancing service-based applications required to operate in highly-dynamic environments more efficiently.
- **Service Providers and Service Integrators:** S-Cube provided knowledge on how to build and maintain composed services that are adaptive and context-aware. This knowledge supports service providers and integrators in improving their user satisfaction by better addressing user needs and dynamically responding to varying user contexts.
- **Industry (Large enterprises and SMEs):** S-Cube provided a catalogue of techniques and methods that can be transferred to industry (such as the quality reference model, knowledge model with key terminology, and learning packages).
- **EU Projects:** S-Cube supported knowledge exchange, networking, and collaboration (such as the methodology for use case definition defined within S-Cube). The potential expected impact is related to the increasing of the availability of up-to-date information about novel trends in technology and techniques for services systems influencing the way systems can be built and planned.

Overall, S-Cube has contributed to a fundamental understanding of how to engineer adaptive service-based applications. S-Cube’s research results thus provide a solid and sustainable foundation for future research on service-based applications, especially for what concerns so called Future Internet Applications, which are considered key to our future business and society. Future Internet Applications constitute an evolution of current service-based applications into systems operating on federated, open and trusted platforms, exploiting the Internet of Content, Internet of Things and the Networks of the Future.

6 Potential impact of S-Cube Results

In conjunction with the FP7 project SEQUOIA[4], the potential socio-economic impact of S-Cube’s research, integration and spreading of excellence activities has been assessed. This assessment was performed by a team of experts in the socio-economic fields, through the use of a structured questionnaire, dedicated focus group sessions, and direct interviews addressed to Call 1 and Call 5 projects representatives. The methodology used for the assessment of 30 projects as well as the results are reported in a SEQUOIA deliverable[5]. It thus complements the self-assessment as presented in 0 of this report.

According to the assessment, S-Cube is confirmed to be one of the five projects (out of 30) that scored highest in terms of potential socio-economic impacts. A deeper analysis of the socio-economic impacts S-Cube, together with that of the other four projects, is presented in the SEQUOIA deliverable D3.2: “Best Practices Report”.

Below is a summary of the economic, social, scientific and technological impact on direct and indirect beneficiaries of S-Cube for the assessment exercise performed jointly with SEQOUIA at the end of S-Cube[6].

6.1 Economic Impact

In terms of socio-economic impact, the network outcomes will produce different benefits on stakeholders: improve the quality of the service, reach more users, improve scalability, expand the range and the typologies of research activities and services made available to research communities, better target users’ needs, increment the optimization of resources, improve efficiency and obtaining well trained and educated graduates.

Due to its very nature as an NoE, S-Cube did not identify a commercial exploitation of its outputs and has not drafted a Business Plan (cf. 0). However, as mentioned in Section 3.2, S-Cube members have provided a “shopping list[7]” of digestible results that directly address industrial researchers and thus may foster the uptake of those results into industrial trials.

With reference to the sustainability plan of the network output, S-Cube integrated 17 associate members (from an academic context) and has jointly submitted over 20 project proposals. S-Cube expects to realise the most substantial economic impact of its outputs five to ten years after the end of the project which is the typical time-span for research to show impact in practice (see [4]).

Using different use cases in different sectors, such as wine production, automotive, eHealth and eGovernment, S-Cube has provided indications that various economic impacts on stakeholders can be expected, including improving the quality of business process and modelling languages, increasing the revenues of services providers, infrastructure providers, industry and SMEs.

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[4] SEQUOIA Project: http://www.sequoiaproject.eu/

[5] SEQUOIA Deliverable 3.1 – Call 1 and Call 5 Project Assessment Report: http://www.sequoiaproject.eu/index.php/documents/doc_download/43-deliverable-31

[6] Please note that parts of the text have been provided by SEQUOIA.

6.2 Social Impact

The sectors on which the network will have the more impact in general are eLearning, ICT support for efficient transport and ICT industry in general. In terms of eLearning, the S-Cube Virtual Campus will be a central access point for training and education material on service-based applications. With reference to transport and mobility, the S-Cube results will be exploited in the FI PPP project Finest[8]. The network will promote awareness for novel techniques and methods, specifically on adaptive services and applications for the ICT industry in general.

S-Cube contributes to the fulfilment of some of the 2020 European Digital Agenda's goals. S-Cube is mostly related to the political goal "Increase ICT related Services demand". But it will also work towards the fulfilment of some other goals: "Increment eCommerce", "Increase interoperability at a more general level", "Creation of content and borderless services" and "Creation of a united market". The network will have, in fact, an impact on all the aspects related to services and commerce.

In terms of scientific production, the outputs are very positive. On the S-Cube website 304 documents (including articles, proceedings and reports) are available in the Literature Database, and links to original documents are provided even if open access is not fully guaranteed. The knowledge produced by the network has been shared and diffused not only through publications and training activities but also thanks to several exchange initiatives. In fact, S-Cube members gave over 200 presentations, organised 105 exchange initiatives and established joint teaching courses (Virtual Campus modules). Finally, knowledge diffusion used also the training channel, which is in accordance with the identification of students and postgraduates as important beneficiaries of the network. Not only have training courses been organised, but the network has also organised an online training course and a summer school.

During its life, S-Cube sponsored a high number of PhD and post-doctoral scholarships, thereby determining a positive benefit deriving from the potential exploitation of the resulting highly-trained students by the new economy. In the future, the network expects to have an impact on employment rate in various territories because it is training new professionals that will be competitive on the labour market. The network will not have a high impact on working routine. The main impact regarding this aspect regards the way the researchers work: they will benefit from more awareness for the need of cross-disciplinary work, a better integration with other European researchers and richer collaborations and a wider access to research results. This will certainly have positive impacts on their research work.

S-Cube has a positive impact in terms of social capital and researchers networking. The number of new partnership agreements with other universities, research centres, enterprises or public bodies is an important indicator. The organisms of these new agreements have become associate members of S-Cube. Another indicator of the importance of research networking made by S-Cube is the number of new project proposals submitted thanks to the participation in the network. The network has also been in contact with the NESSI project, which aims at uniting a community of over 430 organisations from industry and academia in order to promote the Internet of Services through complementary activities Therefore, we can consider that S-Cube has developed a large research network, which has a very positive impact on the social capital of its members/participants. Moreover, considering that one of the objectives of S-Cube is to elaborate joint research agendas and roadmaps, the members have taken many

[8] http://www.finest-ppp.eu/

contacts with policy makers in the field of the Internet of Services. A white paper on the S-Cube vision has also been produced, and published as part of the S-Cube Book (see [1]).

7 S-Cube Members and Responsibilities

7.1 S-Cube Contacts and Members

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7.2 Network Management

S-Cube's Network Coordinator and Scientific Coordinator were responsible for an efficient operational and strategic network management. The responsibilities included, amongst others, the overall coordination, monitoring and supervision of the integration and joint research activities. The S-Cube activities were organized and managed by one activity leader each. Figure 5 depicts the activity responsibilities of the scientific director and the network coordinator, as well as the S-Cube members that acted as activity leaders.

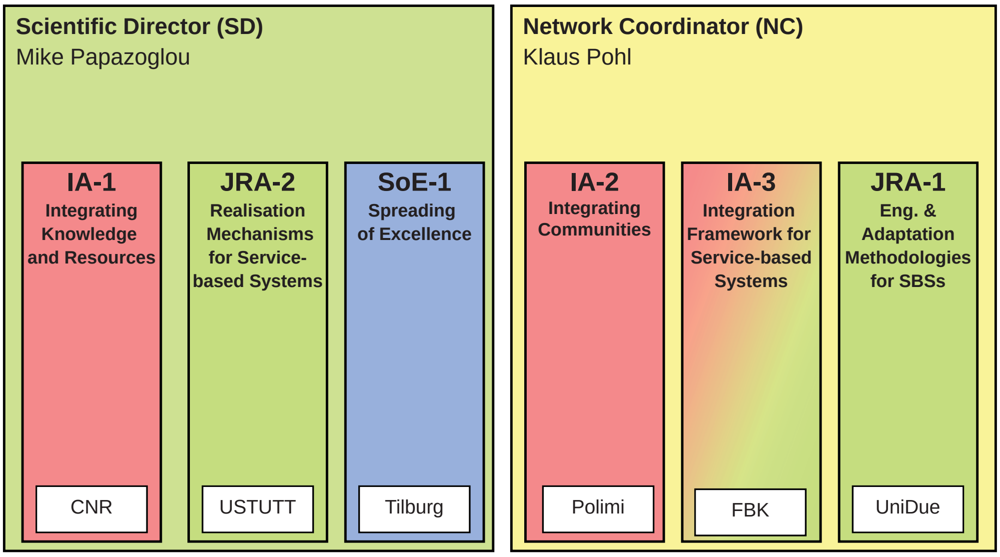

Figure 5: Scientific Director and Network Coordinator Responsibilities

The activities of S-Cube were broken down into workpackages, each organized and managed by a workpackage leader. The workpackage leaders were, amongst other, responsible for the technical and operational coordination and supervision of the work related to their workpackage and assessed its key performance indicators associated to the milestones and deliverables. Figure **6** shows the S-Cube member organisations acting as workpackage leaders.

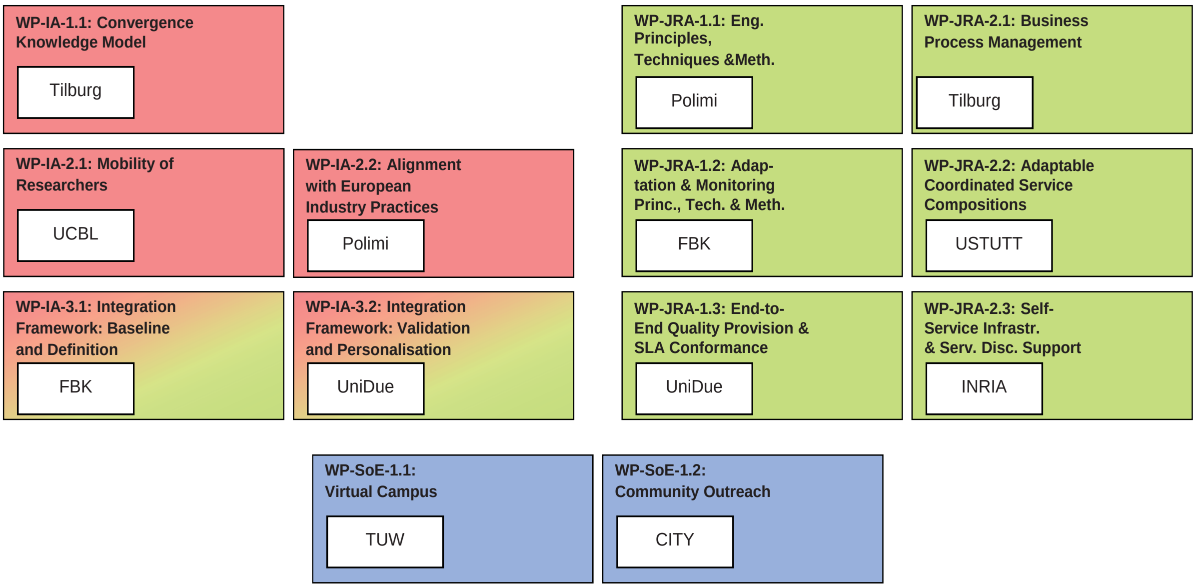

Figure 6: Workpackage Responsibilities

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