

At a Glance

Project title

The Software Services and Systems Network

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Scope

The rapid evolution of information and communication technology (ICT) means that the opportunities for new ways of computing and interacting are growing. One such opportunity is developing innovative systems through the composition of software services, available over widely distributed infrastructures. Those services have the power to provide utility to users in a much more dynamic and flexible way than is possible with traditional software technology. However, service-oriented systems and their corresponding software services require fundamental changes to the way software is developed, deployed and maintained. Software that constitutes a serviceoriented system is no longer owned by on single organization but distributed and shared amongst many organizations. This distributed ownership opens up a whole range of research challenges, including the design, evolution, adaptation and quality assurance of service-oriented systems.

While many organisations across Europe are investigating some of these challenges, so far there has been little or no concerted effort to explore challenges that cut across different research disciplines.

S-Cube, the Network of Excellence on Software Services and Systems, has set out to address that situation by bringing together researchers from various disciplines such as to exploit synergy and learning effects across traditional research boundaries. For example, the software engineering discipline has acquired a huge body of knowledge on how to build and test traditional software systems. However, the distributed ownership of service-oriented systems implies that information required to build and test those systems might not be completely available during design-time, or – if available - can quickly become out-dated. Thus, many development activities need to be extended to run-time. This is where researchers working on self-adaptive computing infrastructures (such as used in grid and cloud computing) bring in their expertise to develop service-oriented systems that are more dynamic and autonomous. Researchers from service-oriented computing provide new languages and protocols to more dynamically and automatically compose and adapt software services. Finally, researchers from the business process management discipline contribute their understanding of how complex networks of organisations can work together to achieve joint goals via shared and distributed ownership of software systems.

Advances

To align and bring together the involved disciplines and co-existing, yet disparate, research themes, S-Cube pursues dedicated research and integration activities within the network. Those activities have led to results which are expected to have a sustainable impact on Europe's research in service-oriented systems.



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Figure 1: The S-CUBE Integrated Research Framework:



The most important integration results of S-Cube include:

- S-Cube Integrated Research Framework (IRF): The IRF guides S-Cube's research activities and ensures the integration of research results. The framework provides a clear separation of concerns and thus allows handling the complexity involved in aligning and integrating research activities of diverse disciplines. Figure 1 provides a high-level view on the framework.
- S-Cube Knowledge Model (KM): The S-Cube KM is a continuously updated on-line encyclopaedia and reference library for the Internet of Services, and is available via the S-Cube web portal at http://www.s-cube-network.eu/km. The network realised that the communities involved in S-Cube will not always be able to agree on a common terminology, so the KM is designed to provide interrelated and contextual definitions so researchers can translate between the vocabularies of the various research communities involved in this research.
- S-Cube Virtual Campus (VC): The S-Cube VC provides an online space facilitating the sharing of knowledge in the software services and systems community at http://www.s-cube-network.eu/vc. The VC provides a collection of learning modules, which provide teaching material based on the research themes of S-Cube. The material is intended to be used during lectures (such as S-Cube's joint master programme) but can also be employed for self-study.

The most important research results of S-Cube include:

- S-Cube Life-Cycle Model: The S-Cube life-cycle model defines the relevant activities for adaptation and evolution of service-oriented systems and integrates those into a coherent framework. Figure 2 presents the major activities and phases prescribed by the life-cycle model. In contrast to more traditional life-cycle models, the S-Cube life-cycle model considers the specifics of service-oriented systems, particularly concerning their dynamic adaptation during run-time.
- S-Cube Quality Reference Model (QRM): The S-Cube QRM provides a consolidated taxonomy of quality attributes for service-oriented systems, resulting from a thorough analysis of quality models used in software engineering, grid computing, business process management and service-oriented computing. Figure 3 presents the top-level structure of the QRM. The quality reference model can serve as a central access point to understanding the relevant quality attributes of service-oriented systems and how these are related to each other. The S-Cube QRM is accessible through the Knowledge Model via http://www.s-cube-network.eu/km/qrm.
- Quality Prediction and Proactive Adaptation: Ideally, during run-time the service-oriented system predicts the degradation of quality and thus imminent failures and thus can apply counter-measures to prevent the actual occurrence of failures. Such proactive adaptation addresses key drawbacks of more conventional reactive adaptation approaches. S-Cube's researchers have formed the Quality Prediction Working Group to work on novel approaches for proactive adaptation and to understand how those approaches could mutually benefit from each other. The results are available at http://www.s-cube-network.eu/qp.

Positioning in global context

During the course of the network, S-Cube has placed an emphasis on raising the awareness about its research activities and results in the outside world. This was achieved through intense dissemination activities as reported below.

- A significant number of high-quality chapters, articles and papers were published in books, international journals, conference and workshop proceedings. S-Cube members gave presentations across the world to disseminate their research and that of the network.
- Two books were edited and published by S-Cube members:
 - · Service Research Challenges and Solutions for the Future Internet: Towards Mechanisms and Methods for Engineering, Managing, and Adapting Service-Based







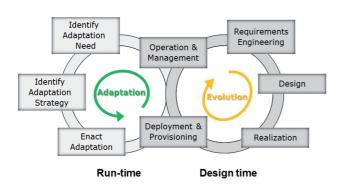
Systems. M. Papazoglou, K. Pohl, M. Parkin, and A. Metzger, (Eds.), Springer, 2010.

- Service Engineering European Research Results. S. Dustdar, F. Li (Eds.), Springer,
- · International conferences, including Service-Wave, ICSOC and BPSC, have been co-organized by S-Cube. ServiceWave is the leading EU conference on Future Internet and services systems, while ICSOC is the premier international conference on service-oriented computing.
- S-Cube members have co-organized many workshops, including thematic workshops to target industry and specialised communities on Services, Energy and Ecosystems, Engineering Service-Oriented Applications and Business Systems Management and Engineering.
- The organisation of the annual Service and Software Architectures, Infrastructures and Engineering (SSAIE) Summer School has brought together students from many countries to receive high-quality training from representatives from academia and industrial partners, such as IBM, Ericsson and BOC.
- · S-Cube members lead several of the SSAIE Collaboration Working Groups (CWGs) and contributed to the Future Internet Conference and Assembly (FIA).

Further, the S-Cube consortium was extended by taking on board 17 associate members (including China), leading to fruitful collaborations, research results and creating awareness about S-Cube activities and outcomes.

Finally, S-Cube achieved awareness by positioning itself through the ETP NESSI and its Industry Advisory Board, which includes representatives from Engineering Ingegneria Informatica (Italy), HP (UK), IBM Research (Israel), SAP (Germany), Siemens (Germany), and Thales (France).

Figure 2: The S-Cube lifecycle model:



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Target users / sectors in business and society

As a network of excellence, the results of S-Cube are targeted at

- researchers and research communities by providing 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** benefitting from S-Cube results (e.g., through the joint International Masters in Service Engineering (IMSE), the SSAI summer school on service-oriented computing, the S-Cube Virtual Campus, and the S-Cube Knowledge Model);
- developers and software engineers by having access to research results allowing for the more efficient development and evolution of serviceoriented systems that need to operate in a highlydynamic environment;
- service providers (in their role of service integrators) by understanding how to build composed services that are adaptive and context-aware, leading to improved user satisfaction due to better addressing user needs and dynamically responding to varying user contexts;
- · industry (large enterprises and SMEs) by providing 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 through knowledge exchange, networking, and collaboration (such as the methodology for use case definition defined within S-Cube).

Overall Benefits for business and society

The Future Internet will emerge through the convergence of software services, 'things' (network enabled devices and sensors), content, and communication networks. The Future Internet is expected to become the key infrastructure, essential to our future society and economy.

In the vision of the Future Internet, software services and service-oriented systems are expected to play a key role as an enabling technology and core building block. These services and systems will provide the correct level of abstraction from hardware and software entities, extending from business functions to data storage, processing and networking, devices and content. Ultimately, current service-oriented systems are expected to evolve into Future Internet Applications, operating on federated, open and trusted platforms, exploit-





ing the Internet of Content, Internet of Things and the Networks of the Future.

Future Internet Applications will exhibit an unprecedented level of dynamism, stemming from the need to adapt to broad, changing contexts and requirements. S-Cube has achieved a fundamental understanding of how to engineer adaptive service-oriented systems. S-Cube's research results thus provide an excellent foundation for future research on Future Internet Applications.

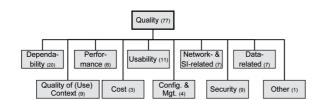
Achievements

Overall, S-Cube has achieved the following important outcomes and results.

Joint Research Results

- Joint Publications, including over 200 articles and papers and book chapters, as well as 2 books edited by S-Cube members (see http://www.scube-network.eu/results).
- The S-Cube Life-cycle Model (see Figure 2).
- The S-Cube Quality Reference Model (see Figure 3).

Figure 3: S-Cube Quality Reference Model



Integration Results

- The *S-Cube Integrated Research Framework* (see above and Figure 1).
- The S-*Cube Knowledge Model* (see http://www.s-cube-network.eu/km).
- The *S-Cube Virtual Campus* (see http://www.s-cube-network.eu/vc).
- Bonding of research staff and joint supervision: During the course of the project, S-Cube researchers strengthened their joint research and integration activities by using S-Cube's dedicated mobility programme. In addition, a high number of partners were involved in jointly supervising PhD students leading to a number of jointly supervised PhD theses.
- Collaborations: In addition to setting up intensive collaborations with 17 associate members, S-Cube members have actively contributed to shaping ETP NESSI's Strategic Research Agenda, and they have strengthened direct links with industry, e.g., through S-Cube's Industrial Advisory Board.

Spreading of Excellence Results

- Organisation of conferences and workshops, such as ServiceWave, ICSOC, and BPSC (see http://www.s-cube-network.eu/events).
- The organisation of the annual SSAIE *summer school on service-oriented computing* (see http://www.summersoc.eu/).
- Setting up the Erasmus Mundus *International Master on Service Engineering* program, IMSE (see http://www.erasmusmundus-imse.eu/).



