A Research Agenda for Service-Oriented Architecture

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ABSTRACT

It is clear that Service-Oriented Architecture (SOA) is having a substantial impact on the way software systems are developed. However, although significant progress is being made in several fronts, current efforts seem to evolve in many directions. There is danger that important research needs will be overlooked, while other efforts will focus on issues of peripheral long-term significance in practice. As a research community that has gone through a substantial "growth spurt" we find ourselves facing a great opportunity and challenge: to better channel our research efforts, we should attempt to reflect upon our progress to date and recognize how our efforts and results build on each other, and to identify—and potentially prioritize—the areas that we still need to investigate. The purpose of this work is to provide a long-term consensus SOA research agenda, classified into research issues pertaining to the business, engineering and operation aspects of service-oriented systems, plus a set of cross-cutting aspects. An additional goal is to assemble an international research group to analyze the current state of the practice and current research initiatives in SOA and create a community of interest around SOA research to share results and ideas on how to improve SOA adoption and the development of service-oriented systems.

Categories and Subject Descriptors

D.2.10 [**Design**]: Service-Oriented Systems — service-oriented architecture, design guidelines.

D.2.11 [**Software Architectures**]: Service-Oriented Architecture (SOA) — SOA as an architectural style and pattern for systems development.

D.2.12 [**Interoperability**]: Systems Integration — SOA as an enabler for systems interoperability, use of standards for systems interoperability.

General Terms

Management, Design, Standardization.

Keywords

SOA, service-oriented architecture, service-oriented systems, service orientation, systems interoperability, SOA research.

1. BACKGROUND

Over the past decade we have witnessed a significant growth of software applications that are delivered in the form of services utilizing the network infrastructure. These services are available either on corporate Intranets or on the Internet, and are delivered either on open or on proprietary network protocols. This approach to systems development is commonly referred to as service-oriented architecture (SOA), SOA-based systems, or service-oriented systems.

The initially slow but gradually increasing adoption of service-oriented systems is supported by both the technical and the business community. From a technical perspective, service-oriented systems are an approach to software development where services provide reusable functionality with well-defined interfaces; a service infrastructure enables discovery, composition and invocation of services; and applications are built using functionality from available services. From a business perspective, service-oriented systems are a way of exposing legacy functionality to re-mote clients, implementing new business process models by utilizing existing or third-party soft-ware assets, reducing the overall IT expenditures while potentially increasing the potential for innovation through software investments [2]. From either perspective, and despite their initially slow adoption and the conflicting standards proposed to support them, service-oriented systems are becoming the de-facto approach to bridging the gap between business models and software infrastructure and flexibly supporting changing business needs [11].

A group of European researchers has identified a list of research challenges in service-oriented computing (SOC) with a goal similar to that of this project: to provide the means for consolidating and streamlining current SOC research efforts, as well as prioritizing important gaps [12]. While the results of this work are important and compatible with the results of this project, they focus largely on the development and operations of service-oriented systems. Another European group has identified a set of research challenges as preparation to the development of the "Software and Services Challenge" [5]. The results of this work are also interesting, but are more long term. Our proposed taxonomy of research issues takes a step back and identifies issues that would help an organization make decisions on SOA adoption, create a SOA strategy, and then develop, deploy and operate service-oriented systems.

2. APPROACH

The project started with an extensive literature review on topics related to SOA, with the purpose of identifying the state of the practice, plus multiple interviews with practitioners and researchers to identify both enablers and barriers of SOA adoption. This literature review included multiple case studies of successful SOA adoption. Most of these case studies, even though mostly vendor-sponsored and product-specific, all had a theme in common: a strong link between business strategy and SOA adoption. With this in mind, we created a service-oriented system development lifecycle that supports the strategic approach to SOA adoption shown in the case studies. Then, we identified areas of SOA research necessary to fill in the gaps and developed a draft agenda that was validated with a diverse community at seven international workshops and one international panel. A final report with our findings is scheduled for publication this year.

3. RESULTS

3.1 Overview of the SOA Research Framework

In an ideal service-orientation adoption setting, an organization develops a service strategy that takes into account the organization's business drivers, context and application domain. In order to execute the service strategy, the organization has to generate plans to achieve the goals and objectives outlined by the strategy. Finally, the execution of these plans require business, engineering and operations decisions to be made, taking into consideration cross-cutting concerns such as governance, social and legal issues, stakeholder management, and training and education. These relationships are shown in Figure 1.

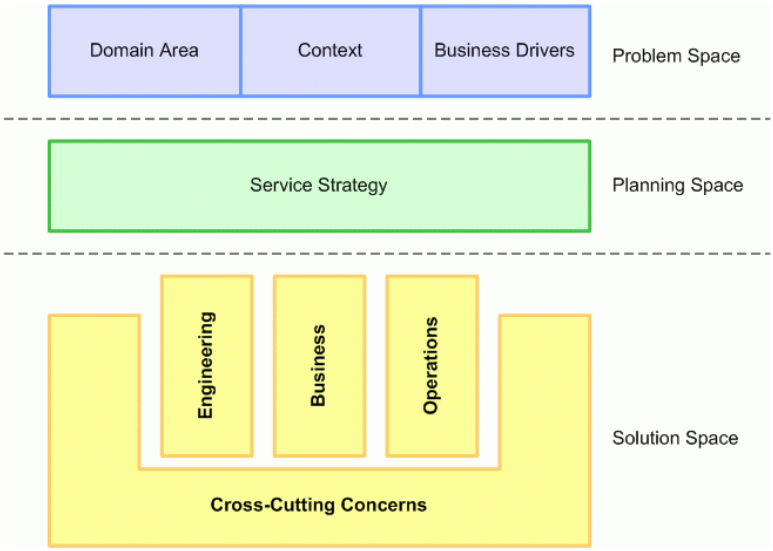

Figure 1. Overview of the SOA Problem and Solution Space

Problem Space: The problem space corresponds to the characteristics of the organization that is going to adopt SOA, as well as the problems that SOA is expected to address. The problem space shapes and places constraints on the strategy, but can also enable its execution. The elements of the problem space become the drivers for the strategy.

Planning Space: An SOA strategy should be stated as the way in which SOA is going to address the organization's business drivers for SOA adoption. A service-oriented environment is iterative, to the point that the term "perpetual beta" is being used to indicate the dynamism of this environ-ment in order to respond to required business agility. The organization's SOA strategy may change over time due to changes in the problem space or to information provided by data collected during Evaluation/Optimization, as shown in Figure 2.

Solution Space: In the solution space the SOA plans are executed to produce a service-oriented system. During the execution of the plans, changes or wrong assumptions about SOA technology may invalidate the plans and cause the organization to reformulate their SOA strategy, as shown in Figure 2. Once the service-oriented system is deployed, measurements are gathered to support any metrics designed to test the effectiveness of the SOA strategy and the system itself. This data will help to optimize the SOA strategy, if needed, and also help to plan for the next iteration, once again reflecting the dynamic nature of service-oriented environments.

3.2 SOA Framework Phases, Activities and Indicators

A strategic approach to SOA adoption requires an iterative approach to systems development that reflects the strong link between business strategy and development strategy. Figure 3 shows a proposed software development lifecycle for service-oriented systems, where each pass through the lifecycle corresponds to an iteration in Figure 2. The development phases are listed across the top and the activities that are carried out to develop the service-oriented system during these phases are on the left, along with indicators to evaluate the effectiveness of the service-oriented system against the SOA adoption goals. The main differences with other iterative development frameworks, such as the IBM Rational Unified Process (RUP) , are the emphasis on

activities to establish and analyze the relationship with business goals at the beginning of the cycle, the emphasis on evaluation at the end of the cycle, and the specification/review of business objectives at the end of the cycle as well so that the requirements for each iteration follow business objectives.

3.3 SOA Research Taxonomy

The development of a service-oriented system requires business, engineering and operations decisions to be made, as well as other cross-cutting decisions. Our taxonomy of research topics, shown in Figure 4, is divided into these decision areas. The research topics correspond to areas where additional research is needed to support a strategic approach to service-oriented systems development.

The complete final report will provide the rationale, current efforts, and challenges and gaps for each of the research topics identified in the taxonomy. Below we list examples of selected topics from each of the four primary areas of the taxonomy. Greater detail as well as an annotated bibliography for the sources of information will be included in the final report.

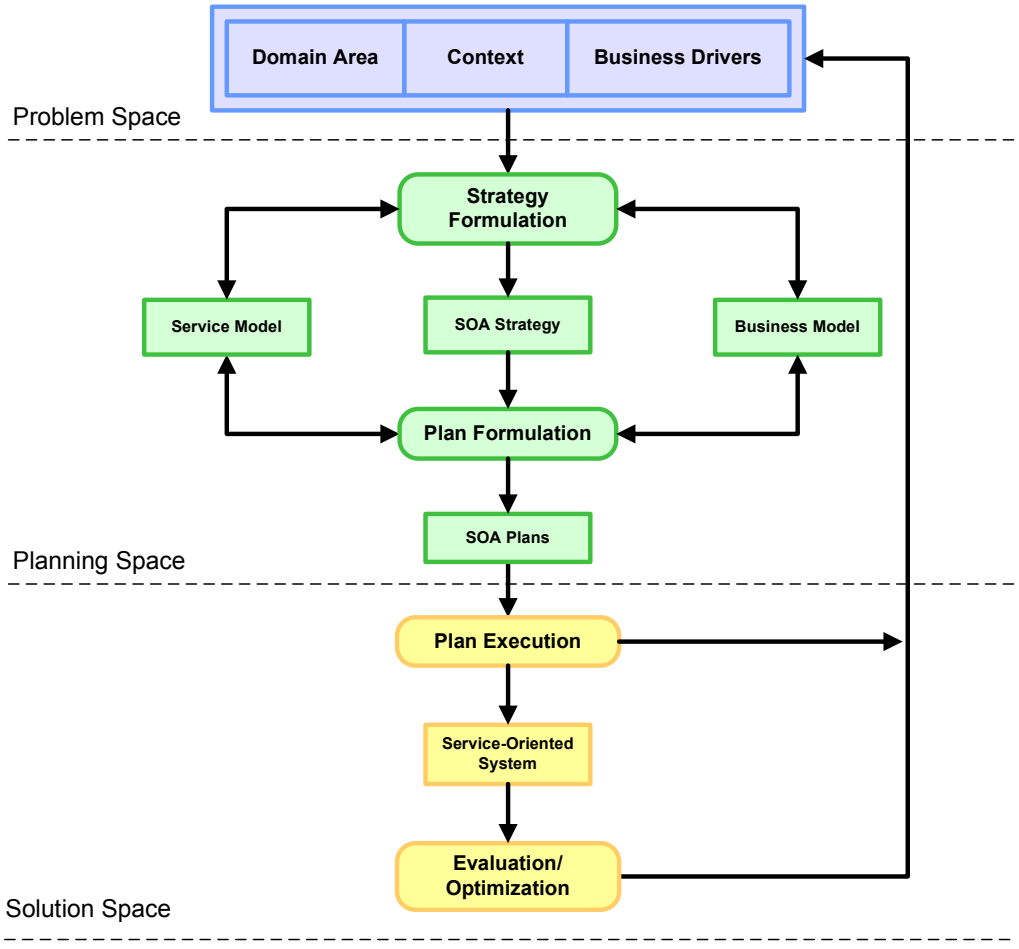

Figure 2. Expanded View of the SOA Problem and Solution Space

3.3.1 Example of a Business Topic: Business Case for SOA

Rationale: In general, there is recognition that SOA adoption can provide business agility, adaptability, legacy leverage, and integration with business partners. Given these goals, an important criterion for making business decisions concerns the amount of investment that is required for SOA adoption and the projected payoff over a certain period of time.

Current Efforts: There is current work that identifies the business value of SOA adoption in various industries, as indicated by references such as

- Tilley et al discuss the business value of Web Services when used for enterprise application integration or business-to-business (B2B) commerce [14].
- Brandner et al claim enhanced integration capabilities of its core banking system through the use of Web services [3]. There are several other Australian, US, and Finnish success stories in the banking industry.
- Pujari discusses the pros and cons of self-service technology, potentially enabled by SOA technologies, in the Canadian B2B industry [13].

- Linthicum has written several articles on the subject, including one in which he proposes a formula for calculating the relative value of SOA adoption [9].

PHASES	P1: Analysis	P2: Positioning	P3: Assessment	P4: Planning	P5: Construction	P6: Transition	P7: Production
ACTIVITIES							
A1: Business Objectives Specification	+++	++	+				++
A2: Business Intelligence and Information Gathering		+++	+	++	+		
A3: Risk Analysis	++		+++	+++	++	+	
A4: Prototyping				++	+		
A5: Implementation				+	+++	++	
A6: Integration					++	+++	++
A7: Adoption						++	+++
A8: Maintenance					+	+	++
A9: Management						++	+++
INDICATORS							
I1: Financial Indicator Measurements	++		+	+++			
I2: Technology Indicator Measurements			+	++	++	+	++
I3: User Rating Measurements						++	+++
I4: Compliance Indicators	+			++	+	++	+++

Figure 3. Mapping Between Phases, Activities and Indicators

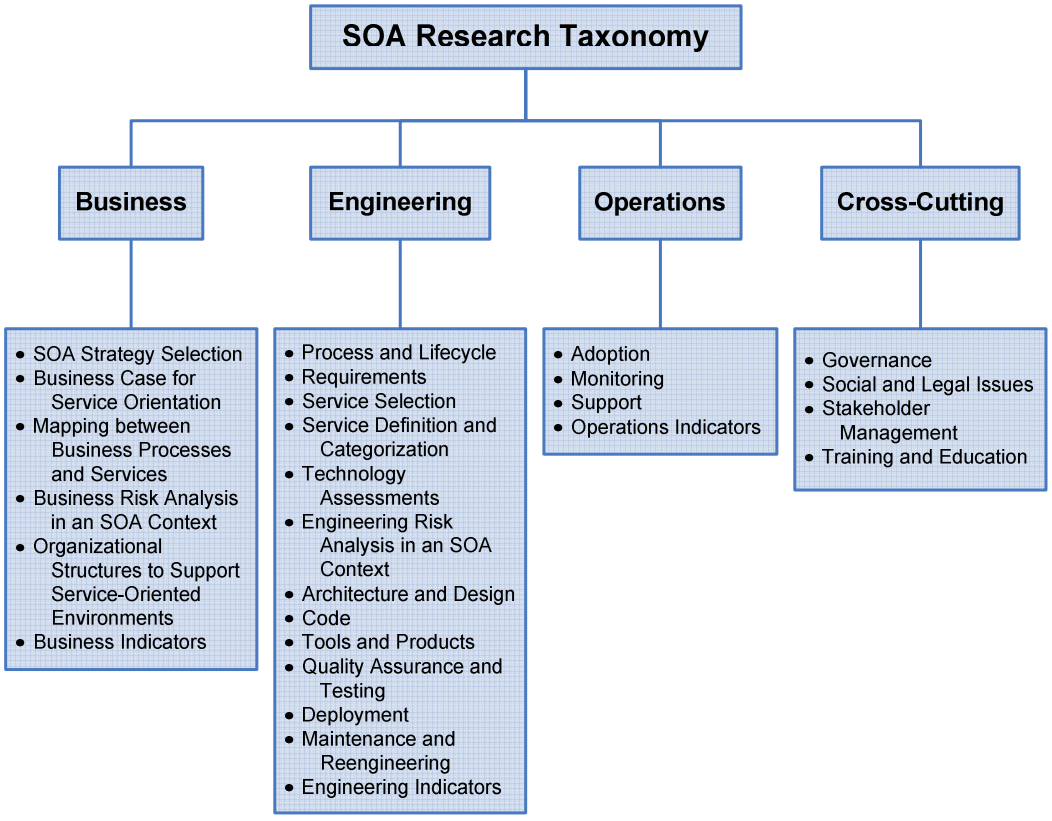

Figure 4. SOA Research Taxonomy

There are other case studies and articles that provide anecdotal evidence of the business value of SOA adoption—many of these studies are sponsored by vendors or co-authored with vendors. The problem is that these are examples of point solutions that are all so different that it is difficult to make valid generalizations across organizations. A comprehensive framework for

understanding the business value of SOA has not yet been developed.

Challenges and Gaps: The largest gap in this area is that more vendor-neutral data needs to be gathered. Current efforts have focused on individual case studies and there have not been rigorous analyses that can be generalized. This triggers another important question that has to do with the nature of the data that needs to be gathered. How does an organization measure common benefits associated to SOA adoption, such as business agility, legacy leverage or increased interoperability? An important research focus would be to gather data from both success stories and failures, find commonalities, and start to develop a framework for calculating the business value of SOA adoption.

3.3.2 Example of an Engineering Topic: System Testing

Rationale: In an SOA environment, system testing means end-to-end testing. The problem is that in SOA environments, systems components are distributed, deployed on heterogeneous platforms, and often not even available.

Current Efforts: The market for testing tools for SOA environments (mainly for Web Services) is growing. Tools are available to perform testing at multiple levels—from business processes to messages—as well as testing for qualities such as availability, performance, and security. However, most testing tools are incapable of building composite interdependent tests across technology platforms, languages and systems. Also, most testing tools assume control over all elements of the service-oriented system. Sometimes client developers typically only have access to interfaces (e.g. WSDL description files in the case of Web Services) and lack access to code. This has triggered some research into use of gray-box testing, which is appropriate when there is limited knowledge.

Challenges and Gaps: The challenges in system testing are driven by the distributed, heterogeneous nature of service-oriented systems components and a growing market of third-party services which means that there is not a single owner of the complete system. This triggers some interesting research topics such as

- Dynamic testing in distributed, heterogeneous environments
- Service certification
  - What does a certification process look like?
  - What can be certified?
- Enhanced service repositories that provide test cases for services
  - How are test cases specified?
- Test-aware interfaces for service consumers to test services
  - Given that providers would need to have test instances of services, how are these test services specified and how do service consumers become aware of their existence?

We also need to recognize that it is not always possible to do end-to-end testing. In such cases, interesting research topics are

- Simulation of service-oriented system environments
- Best practices for exception handling

3.3.3 Example of an Operations Topic: Service-Level Agreements

Rationale: A service-level agreement (SLA) is a formal and bilateral contract between service provider and consumer to specify the requirements and uses of specific services. An SLA is essential for establishing trust between service providers and service consumers. In a growing third-party service market, the establishment of SLAs can be used to differentiate and select from various available services, help service providers anticipate demand and plan their resource allocation accordingly, and can be used a mechanism for risk mitigation.

Current Efforts: There is a perceived need for standardization, specification and guidance for using SLAs in a SOA context. Web Service Level Agreements (WSLA) is a specification and reference implementation by IBM that provides detailed SLA specification requirements for enabling the monitoring of SLA compliance, how these requirements are addressed in the WSLA specification, and a WSLA monitoring framework that allows monitoring of SLAs at runtime [6]. CBDi provides basic guidance on how to approach SLAs from a service consumer and a service provider perspective at a higher level than WSLA [4]. Given that most SLAs are based on specifying the required quality of service (QoS) for a service, an active research area is modeling and implementing various QoS attributes in service-oriented and dynamic environments.

Challenges and Gaps: An important contribution to SOA adopters would be the creation of a generic and standardized framework for SLA management across enterprises as well as across vari-ous lines of business inside an organization. This would involve providing appropriate automation and support for mapping contractual service level agreements to standard and actionable implementations and the monitoring and management of service level at runtime. In the area of QoS, more work needs to be done in understanding QoS of composite services, especially when lower level services in a composite service are provided by different providers.

3.3.4 Example of a Cross-Cutting Topic: SOA Governance

Rationale: An InfoWorld 2007 SOA Trend Survey indicates that lack of governance is the main inhibitor for SOA adoption (50%). Effective SOA governance requires rules that define roles and responsibilities, define appropriate use of standards, make explicit the expectations of a diverse set of stakeholders, provide for SLAs and monitor compliance through metrics and automatic recording and reporting.

Current Efforts: A number of organizations such as IBM, AgilePath and Software AG have developed sophisticated models of SOA governance. These models focus mostly on relationship to corporate enterprise architecture, use of registries, SOA lifecycle management, defining and monitoring SLAs, and defining and analyzing metrics on policy enforcement, effectiveness of services and use of services. A number of tools have also begun to automatically incorporate metrics and aspects of governance and research efforts have begun to identify roles and responsibilities [7, 8].

Challenges and Gaps: Most efforts to define and implement governance are still vendor-driven and guided by the governance aspects that can be automated by their tools. As with the business

case for SOA, most case studies are anecdotal and idiosyncratic. An interesting research topic would be to establish an abstract model for SOA governance and its variations within different domains. A starting point could be the establishment of SOA governance elements, similar to what has been done at Hartford Inc. and the creation of a template, similar to some work done by Burton Group [1, 10].

4. RESULTS AND FUTURE WORK

Engineering challenges are significant if SOA is to be used in "advanced ways", such as semantic services, dynamic discovery and composition, and real time applications. The main challenges for enterprise applications are related to business and operations, and not engineering. As third-party services become the new business model, there needs to be support for service-level agreements, runtime monitoring, end-to-end testing involving third parties, pricing models for third-party services, and service usability from a design and an adoption perspective.

There are some areas where non-vendor surveys, studies and experiments are needed to produce more concrete guidance, rather than additional basic research. Some examples of these areas are SOA governance, business case for SOA adoption, ROI for SOA adoption, and development processes and practices for SOA-based development.

We also found several topics in which there is significant research in academia, such as semantics, but no support from industry to test ideas in real scenarios. There needs to be more collaborative research between industry and academia to create real practices.

The next steps for this project are to create a final report with the complete findings and to start establishing a community of interest around the SOA research agenda.

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