INTEGRATION ARCHITECTURES BASED ON SEMANTIC WEB SERVICES: FAD OR MODEL FOR THE FUTURE?

Findings of a Comprehensive SWOT Analysis

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Abstract: Web services brought about a revolution by taking a remarkable step toward seamless integration of distributed software components. The importance of Web services as a cornerstone of service-oriented integration architectures is recognized and widely accepted by experts from industry and academia. Current Web service technology, however, operates at the syntactic level and, hence, requires human interaction to a large extent. Semantic Web services pledge the automation of core Web service tasks, such as discovery, selection, composition, and execution, thus enabling interoperation between systems and keeping human intervention to a minimum. Within the scope of this work, we discuss the capabilities of integration architectures based on Semantic Web services as well as relevant environmental factors. The discourse is based on the findings of a SWOT analysis that was conducted in early 2007. In order to best assess the relevance and applicability of integration architectures based on Semantic Web services in an organisational context, particular importance was attached to differences in the viewpoints of practitioners and researchers.

1 INTRODUCTION

Many enterprises employ multiple mission-critical, best-of-breed application systems from different vendors with different technologies and platforms (Hohpe and Woolf, 2005). They chose the best vendor for every operational area and connected the products via the interfaces they provided. This approach, however, normally leads to highly complex systems. Nevertheless, until recently, this strategy was considered a silver bullet when assembling business software.

Together with mergers and acquisitions, reorganizations, and leadership changes, which also cause significant impact on IT infrastructures, best-of-breed solutions lead to extreme heterogeneity. Obviously, the operation of such patchworks is extremely complex and costly. The maintenance of numerous vendor relations and the necessity of specific know-how usually are not justifiable. However, the integration of application systems within organizations and across organizational boundaries is essential to realize competitive advantages. Even if just a few critical systems cannot share their data effectively, they create information bottlenecks that often require human intervention to be solved. Only with properly deployed integration architectures can organisations focus their efforts on their value-creating core competencies.

Web services brought about a revolution by taking a remarkable step toward seamless integration of distributed software components. The importance of Web services as a cornerstone of service-oriented integration architectures is recognized and widely accepted by experts from industry and academia. Current Web service technology, however, operates at the syntactic level and, hence, still requires human interaction to a large extent. Semantic Web services (SWS) pledge the automation of core Web service tasks, such as discovery, selection, composition, and execution, thus enabling interoperation between systems and keeping human intervention to a minimum (McIlraith et al., 2001; Fensel and Bussler, 2002; Terziyan and Kononenko, 2003).

However, with respect to SWSs, there seems to be a gap between research trends and industrial needs (Sollazzo, 2002). Within the scope of this work, we discuss the capabilities of integration architectures based on SWSs as well as relevant environmental factors. The discourse is based on the findings of a SWOT analysis that was conducted

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within the scope of a Delphi study (Bachlechner, 2007). In order to best assess the relevance and applicability of integration architectures based on SWSs in an organisational context, particular importance was attached to differences in the viewpoints of practitioners and researchers.

In section 2, we describe the design of the underlying analysis. While sections 3 and 4 present and discuss the results of the SWOT analysis in detail, we conclude with a summary of major findings in section 5.

2 APPROACH

The underlying Delphi study was conducted at the University of Innsbruck in early 2007. The main goal of the study was to collect and quantify the opinions of clearly defined groups of practitioners and researchers on the potential of SWSs as basis for integration architectures that enable organisations to link their data processing systems efficiently. It was expected that an understanding of the relevance and applicability of SWS-based integration architectures would help to align future research efforts with industry needs effectively. Another goal was to make participating experts from academia and industry more sensitive to the progress and focus of SWS research in general.

2.1 Survey Design

Within the scope of the study, the participating experts were provided with two questionnaires. The first questionnaire contained open-ended questions designed to capture the experts' views concerning factors potentially affecting the relevance and applicability of SWS-based integration architectures. The responses from the first round were aggregated into groups and classified by the unique issues that best summarized their contents. The second questionnaire was based on the responses from the first round. The participants were asked to review the aspects identified in the first round and rank them on structured bipolar rating scales ranging from 1 to 5, with 1 representing *Strong Disagreement* and 5 representing *Strong Agreement*. Two rounds were expected to be sufficient to attain a first impression concerning the opinions of the experts.

The Delphi study consisted of four parts, structured and formalized in a way that allowed for various analyses: a SWOT analysis, a requirements analysis, an analysis of expected effects, and a technology roadmap. Within the scope of this work, we focus exclusively on the results of the SWOT analysis. Its purpose was twofold: firstly, it was used to compare SWS-based integration architectures and traditional approaches with respect to their capabilities; secondly, it was used to collect information on relevant environmental factors.

2.2 Questionnaire

The SWOT analysis helped to assess the relevance and applicability of integration architectures based on SWSs by analyzing their strengths, weaknesses, opportunities, and threats. With regard to SWS-based integration architectures, we wanted to know the strengths and weaknesses that people with industrial and academic backgrounds associate with them. What makes them better than or inferior to traditional approaches? What external factors drive or restrict their use?

The questions stated within the scope of the SWOT analysis read as follows:

- Where do you see the strengths of integration architectures based on SWSs?
- Where do you see the weaknesses of integration architectures based on SWSs?
- What factors do you think will drive the use of integration architectures based on SWSs in the future?
- What factors do you think will restrict the use of integration architectures based on SWSs in the future?

2.3 Expert Panel

The candidates were selected from academia and industry in similar proportion. Repeated involvement at major conferences and publication in at least one of the relevant fields were two of the main criteria used to find suitable representatives of the target population. The candidates were exclusively people involved in at least one of the major international conferences related to SWSs and associated technologies, enterprise integration architectures and middleware solutions, and book authors or members of widely recognized initiatives active in at least one of the related research fields.

The 38 experts who participated in both rounds of the study were from all parts of the world and affiliated with major universities and enterprises. While 21 of the experts had academic backgrounds, 17 had industrial ones. These numbers correspond well with Clayton's (1997) recommendation for an adequate panel size. The expertise of the participants in the area of research was gathered to evaluate their technical qualification for the study. The expertise distribution grouped by backgrounds is shown in Figure 1. The scale ranged from 1 to 5, with 1 representing *Novice* and 5 representing *Expert*. None of the participants ranked in the lowest category.

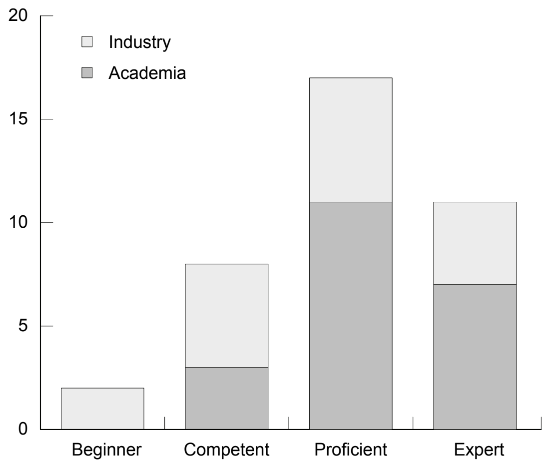

Figure 1: Expertise distribution.

2.4 Survey System

Web-based surveys provide capabilities far beyond those available for any other type of self-administered survey technique. They can be designed in ways that facilitate a dynamic interaction between respondents and the survey system, which is of particular interest for Delphi studies (Dillman, 2004). Web surveys offer enormous potential for conducting research. However, it always must be kept in mind that a survey corresponds to a level of technical sophistication that makes it possible for most users to respond. Within the scope of the development of the survey system, programming and design steps were taken to minimize the differences across respondents caused by different operating systems, Web browsers, and screen configurations.

3 RESULTS

In the following, we discuss the results of the SWOT analysis. The respondents rated up to 40 statements with respect to each of the questions stated within the scope of the SWOT analysis. The respondents were free to leave statements unrated or to check a *No Comment* box. The most important statements from respondents with either academic or industrial backgrounds are presented in tabular form. Statements are defined as *Most Important* if the mean of their ratings is greater than or equal to 4 (i.e., on average, the experts at least agreed to the statement). The most controversial statements comparing the two groups of respondents are illustrated by means of net diagrams. The five statements in which the difference of the means of the two groups of respondents is maximal are defined as *Most Controversial*.

3.1 Strengths

Tables 1 and 2 list the most important strengths of integration architectures based on SWSs from either an academic or an industrial perspective. Improved service discovery capability and facilitated interoperability are the most important strengths, according to both groups of respondents.

From an academic point of view, improved mediation between services, enhanced process and term definitions, and the formalization of systems also play key roles. From respondents with an industrial viewpoint, improved mediation between services and enhanced process and term definitions got average ratings of only 3.86 and 3.67, respectively. Interestingly, the formalization of systems is also among the most controversial statements with regard to strengths of integration architectures based on SWSs. This is due to the fact that respondents with industrial backgrounds gave the statement an average rating of 3.40 which is significantly lower than the one of respondents with academic backgrounds.

Table 1: Most important strengths from an academic perspective.

	Mean
Improved service discovery capability	4.24
Facilitated interoperability	4.20
Improved mediation between services	4.10
Enhanced process and term definitions	4.06
Formalization of systems	4.00

Table 2: Most important strengths from an industrial perspective.

	Mean
Facilitated interoperability	4.36
Improved service discovery capability	4.33
Facilitated reuse of services	4.07
Improved service composition capability	4.00

The facilitated reuse of services and improved service composition capability also are among the most important strengths of SWS-based integration architectures from an industrial point of view. The facilitated reuse of services, with an average rating of 3.95, also is quite important from an academic point of view.

Figure 2 shows the most controversial strengths of SWS-based integration architectures comparing the two groups of respondents. Respondents with industrial backgrounds perceive the goal-based paradigm as a clear strength, with an average rating of 3.93, while respondents with academic backgrounds consider the statement rather neutral, with an average rating of 3.16. Conversely, respondents with academic backgrounds perceive the formalization of systems, compliance with business and legal rules, improved service choreography capability, and facilitated system upgrades as key strengths, while respondents with industrial backgrounds rate them only slightly above average.

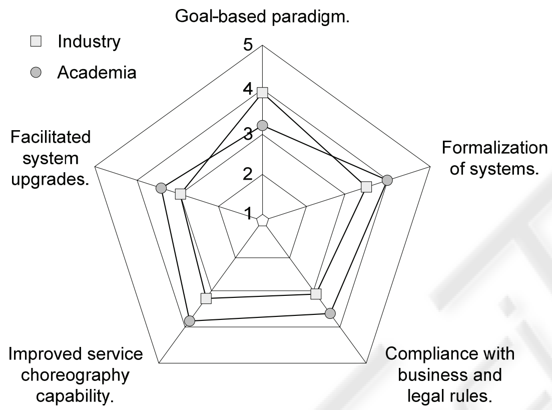

Figure 2: Most controversial strengths.

3.2 Weaknesses

Tables 3 and 4 list the most important weaknesses of integration architectures based on SWSs from academic and industrial perspectives. The use of immature technologies and the description overhead are the most important weaknesses, according to both groups of respondents.

Respondents with academic backgrounds perceive high initial start-up costs, the lack of agreement on the description depth, and high system complexity as particularly important weaknesses. Interestingly, the lack of agreement on the description depth and the high system complexity both also are among the most controversial statements. This is due to the fact that respondents with industrial backgrounds rated them with average scores of 3.31, significantly lower than the respondents with academic backgrounds. The high initial start-up costs also are not perceived as a very serious weakness by the respondents with industrial backgrounds. The statement got an average rating of only 3.54 from practitioners. High service development costs, unsatisfactory support of change management, and the labour-intensive service specification also are among the most important weaknesses from an academic viewpoint. The labour-intensive service specification with an average rating of 3.92, also plays a key role for experts with an industrial point of view. The unsatisfactory support of change management and the high service development costs with average ratings of 3.58 and 3.17, respectively, play only minor roles for practitioners.

For respondents with industrial backgrounds, the facts that SWS-based integration architectures have not yet been adopted and that software engineers are not ontology experts represent additional, and particularly important, weaknesses. With average ratings of 3.68 and 3.89, respectively, both also are relevant for researchers.

Table 3: Most important weaknesses from an academic perspective.

	Mean
High initial start-up costs	4.42
Lack of agreement on description depth	4.38
Use of immature technologies	4.26
High system complexity	4.21
Description overhead	4.16
High service development costs	4.05
Unsatisfactory support of change management	4.05
Labour-intensive service specification	4.05

Table 4: Most important weaknesses from an industrial perspective.

	Mean
Use of immature technologies	4.23
Not yet adopted	4.15
Software engineers are not ontology experts	4.08
Description overhead	4.00

While respondents from both groups agree on weaknesses such as the use of immature technologies, description overhead, and labour-intensive service specification, there also are some controversies. Figure 3 shows the most controversial weaknesses of integration architectures based on SWSs comparing the two groups of respondents.

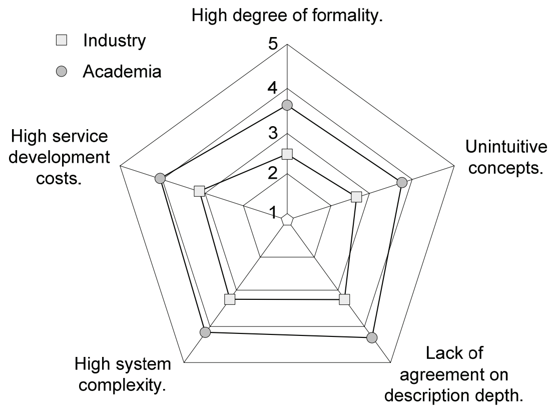

Figure 3: Most controversial weaknesses.

Respondents with academic backgrounds rate the high degree of formality, unintuitive concepts, and high service development costs as rather important weaknesses. From an industrial perspective, these aspects are rated only slightly above average. Instead, respondents with industrial backgrounds perceive as a key weakness the fact that integration architectures based on SWSs have not yet been adopted. Furthermore, the lack of a dominant design seems to be a serious issue from an industrial viewpoint, while it does not seem to be relevant for researchers. However, the latter controversies are not among the top five.

3.3 Opportunities

Tables 5 and 6 list the most important factors driving the use of integration architectures based on SWSs from either an academic or an industrial perspective. The need for service interoperability and the availability of business cases, compliant middleware implementations and effective tools are the most important driving factors, according to both groups of respondents.

Interestingly, the factors that are perceived to drive the use of integration architectures based on SWSs differ significantly between the two groups of respondents. Proven cost-effectiveness, a compelling value proposition, and increasing dynamics of cooperation are among the most important factors driving the use of integration architectures based on SWSs, according to the respondents with academic backgrounds. With an average rating of 3.69, proven cost-effectiveness is a significantly less important factor for respondents with industrial backgrounds. The difference of the means is large enough to make it the most controversial statement with respect to factors driving the use of SWS-based integration architectures. Increasing dynamics of cooperation and the compelling value proposition, with average ratings of 3.73 and 3.80, respectively, are only slightly less important from an industrial point of view than from an academic viewpoint. Researchers also attach particular importance to such factors as the increasing support from standardization bodies and the proliferation of services. From the point of view of practitioners, with average scores of 3.69 and 3.77, respectively, both are less important.

Preceding agreement on standards, buy-ins from large integration players, potential savings, and increasing dynamics of systems are among the most important factors driving the use of SWS-based integration architectures from the point of view of respondents with industrial backgrounds. Interestingly, increasing dynamics of systems also is among the most controversial statements with regard to driving factors. This is due to the fact that respondents with academic backgrounds rated the statement with an average score of 3.58, significantly lower than the respondents with academic backgrounds. The other factors, preceding agreement on standards, buy-ins from large integration players, and potential savings, with average ratings of 3.95, 3.68, and 3.74, respectively, are significantly less important from the perspective of a researcher as compared to that of a practitioner.

Table 5: Most important opportunities from an academic perspective.

	Mean
Availability of business cases	4.42
Proven cost-effectiveness	4.33
Availability of compliant middleware implementations	4.21
Increasing dynamics of cooperation	4.16
Availability of best practices	4.16
Need for service interoperability	4.05
Compelling value proposition	4.05
Increasing support from standardization bodies	4.00
Availability of effective tools	4.00
Proliferation of services	4.00

Factors such as the availability of integrated development environments and methodologies also play key roles for SWS-based integration architectures from an industrial viewpoint. However, while the availability of methodologies, with an average rating of 3.84, is only slightly less important for respondents with academic backgrounds, the availability of integrated development environments got an average rating of only 3.68.

Table 6: Most important opportunities from an industrial perspective.

	Mean
Need for service interoperability	4.46
Preceding agreement on standards	4.33
Availability of effective tools	4.31
Buy-in from large integration players	4.25
Potential savings	4.18
Increasing dynamics of systems	4.18
Availability of business cases	4.15
Availability of compliant middleware implementations	4.15
Availability of integrated development environments	4.15
Need for effective collaboration	4.08
Need for flexible integration	4.08
Availability of methodologies	4.00

Practitioners also perceive the needs for effective collaboration and flexible integration to be important drivers regarding the use of integration architectures based on SWSs. Researchers, however, merely are in accord with respect to the need for flexible integration. It got an average rating of 3.95. With respect to the importance of the need for effective collaboration, participants with academic backgrounds are less confident. The average rating is only 3.68.

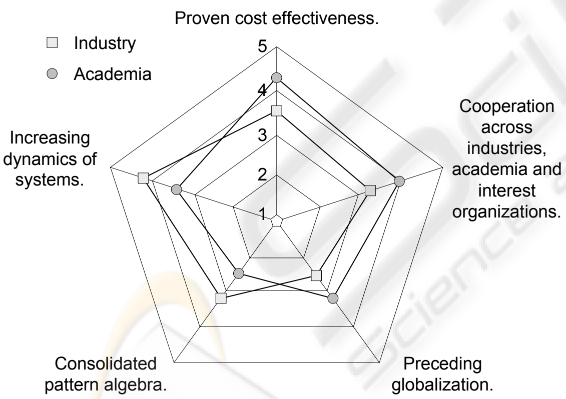

Figure 4: Most controversial opportunities.

Figure 4 shows the most controversial factors driving the use of integration architectures based on SWSs comparing the two groups of respondents. From an academic point of view, cooperation across industries, academia and other interest organizations, as well as preceding globalization, play much more important roles than they do for participants with an industrial viewpoint. In contrast, the consolidated pattern algebra is perceived as an important opportunity only from practitioners.

3.4 Threats

Tables 7 and 8 list the most important factors restricting the use of integration architectures based on SWSs from academic and industrial perspectives. Interestingly, not a single factor is among the most important ones for both groups.

The difficulty in describing semantics and the unavailability of convincing case studies are by far the most important restricting factors for researchers. With average ratings of 3.69 and 3.58, respectively, both are significantly less important for practitioners. However, despite the clear difference regarding the average means, neither statement is among the most controversial. From an academic point of view, the increasing complexity, unproven cost-effectiveness, high costs, failure to reach critical mass, and limited consideration of business needs play key roles with respect to factors restricting the use of SWS-based integration architectures. With scores of 3.85 and 3.77, respectively, the average ratings of practitioners regarding the limited consideration of business needs and unproven cost-effectiveness are quite in accord with those of the researchers. The other factors, increasing complexity, failure to reach critical mass, and high costs, with average ratings of 3.62, 3.54, and 3.33, respectively, are significantly less important from the perspective of a practitioner as compared to that of a researcher. Finally, respondents with academic backgrounds attach particular importance to the lack of skilled developers as well as the lack of integration into middleware technologies. From respondents with an industrial viewpoint, they got average ratings of 3.69 and 3.83, respectively.

By far, the lack of effective tools is the most important factor restricting the use of integration architectures based on SWSs for practitioners. With an average rating of 3.94, the lack of effective tools also is quite important from an academic point of view. Still, quite important factors from an industrial perspective are the lack of industrial commitment and the limited interest of vendors. Interestingly, respondents with academic backgrounds rate both statements with average scores of 3.35 and 3.17, respectively, only slightly above average. Due to the large differences of the means, both statements are among the most controversial with respect to factors restricting the use of SWS-based integration architectures. The difficulty to catalyze the market and the fact that the dominant vendors use their own technology also play major roles with respect to restricting factors from an industrial point of view.

From the perspective of researchers, both are of lower importance than for practitioners, with average scores of 3.77 and 3.61, respectively.

Table 7: Most important threats from an academic perspective.

	Mean
Difficulty of describing semantics	4.39
Unavailability of convincing case studies	4.22
Increasing complexity	4.11
Unproven cost-effectiveness	4.11
High costs	4.06
Failure to reach critical mass	4.06
Limited consideration of business needs	4.06
Lack of skilled developers	4.00
Lack of integration into middleware technologies	4.00

Table 8: Most important threats from an industrial perspective.

	Mean
Lack of effective tools	4.23
Lack of industrial commitment	4.08
Limited interest of vendors	4.08
Market does not understand values and capabilities	4.00
Difficulty of catalyzing the market	4.00
Dominant vendors use own technology	4.00

The two groups of respondents regard quite different aspects of the threats to integration architectures based on SWSs as important.

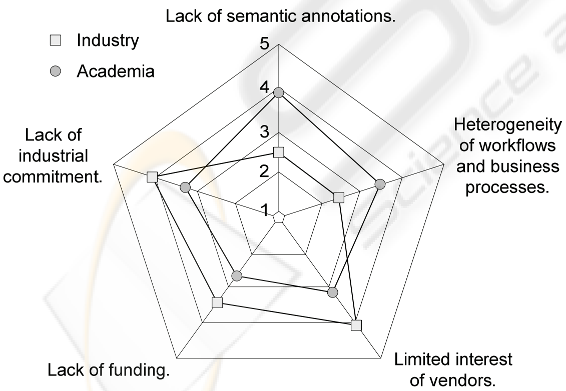

Figure 5: Most controversial threats.

Figure 5 shows the most controversial factors restricting the use of SWS-based integration architectures comparing the two groups of respondents. From an academic point of view, the lack of semantic annotations and the heterogeneity of workflows and business processes play much more important roles than they do for experts with an industrial point of view. In contrast, the lack of funding is perceived as an important threat only from respondents with industrial backgrounds.

4 DISCUSSION

So far, we have shown that there are several more or less agreed capabilities of integration architectures based on SWSs. They were called strengths and weaknesses. We also described environmental factors relevant to the use of SWS-based integration architectures. The factors that drive the use of SWS-based integration architectures were called opportunities. We also mentioned threats that describe factors restricting the use of integration architectures based on SWSs. Throughout this work, we assigned opinions either to people with academic or with industrial backgrounds. The former also were called researchers and the latter practitioners. The analysis was characterized by a continuous comparison of hypothetical SWS-based integration architectures and traditional integration approaches.

At the end of the day, it is the practitioners who decide about the adoption of integration architectures in industry. Researchers are supposed to deliver technologies meeting the requirements of the practitioners. The perceived strengths of SWS-based integration architectures are worth knowing, but the weaknesses are what researchers have to focus on. The weaknesses are the limitations, faults, or defects that keep an approach, such as an integration architecture, from achieving its purpose. The same applies to the environmental factors. Exploiting opportunities is desirable, but countering threats is essential. Focusing on the weaknesses and threats ultimately helps to find an answer to the question whether SWS-based integration architectures are a fad or a model for the future.

Researchers and practitioners agree that SWS-based integration architectures reduce interoperability problems and facilitate enterprise integration by improving such selected SWS usage activities as discovery, mediation, and composition. Enhanced process and term definitions, as well as explicit definitions of service conditions and functionalities based on ontologies, allow for a better understanding of the used systems. It also is agreed that the use of immature technologies currently is one of the most important weaknesses of integration architectures based on SWSs. One of the key problems regarding evolving or immature technologies, particularly within highly complex systems, is that no one understands the risks that come with their use.

Weaknesses that are perceived as important, such as the lack of agreement on description depth, description overhead, and the labour-intensive service specification, allude to one and the same issue. There is a need to focus on this within the scope of the research on SWS frameworks. It may be reasonable to depart from the idea that generic frameworks work for all SWS applications. It seems important to find the right balance between the satisfaction of high knowledge requirements and the avoidance of description overhead. Sivashanmugam et al. (2003) discuss the description of Web services based on shared ontologies.

Interestingly, the costs incurred by setting up and maintaining SWS-based integration architectures are perceived as a weakness by researchers rather than by practitioners. Nevertheless, there is no doubt that the cost-effectiveness of SWS-based integration architectures needs to be proved. Making disparate systems share information cost-effectively is a key problem for companies, and represents billions of euros in technology spending, with a high percentage of worldwide IT budgets dedicated to enterprise integration projects. De Brujin et al. (2005) describe a SWS framework that aims at enabling flexible and cost-effective integration.

Unlike researchers, practitioners perceive a lack of industrial commitment and only limited interest of vendors. Furthermore, practitioners are aware that the market principally does not understand the values and capabilities of integration architectures based on SWSs. This explains why it is difficult to catalyze the market and why dominant vendors use their own technologies. Interestingly, researchers also are aware of this situation and know that their consideration of business needs is limited. The unavailability of convincing case studies and best practices can be viewed as a direct consequence of the lack of target group orientation.

5 CONCLUSIONS

With respect to many aspects, the picture of integration architectures based on SWSs looks quite different from an academic point of view than from an industrial viewpoint. We hope that this discourse helps to take a first step toward closing the gap between research trends and industrial needs and, subsequently, to exploit the full potential of SWSs within the scope of integration architectures. However, more could be done in this area. Additional studies that address further issues would be valuable to make more accurate conclusions. For instance, it would be interesting to evaluate specific SWS frameworks with respect to their relevance and applicability for integration architectures. Furthermore, based on the results of this work, best practices that define the configuration of an SWS-based integration architecture, could be formulated for specific organisational environments.

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