

# A Knowledge-based Framework for Dynamic Semantic Web Services Brokering and Management

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## Abstract

*The concept of automating Web services, specifically the brokering activities, is an active research topic. We need a comprehensive and overarching framework that handles the discovery, differentiation, negotiation and selection processing within the context of workflow management, and addresses the issues related to Virtual Organizations. The goal is to add semantics to Web services to endow them with capabilities currently lacking in the literature, but necessary for their successful deployment in future systems.*

*This paper references how such a framework, called the KDSWS Framework, addresses in an integrated end-to-end manner, the life-cycle of activities involved in brokering and managing Semantic Web Services. The following issues are addressed: semantic specification of services' capabilities; brokering the services, workflow management, resource management, interoperability and evolution of the Virtual Organization.*

## 1. Introduction

The relatively new concept of *Web services* is important to both e-Business and e-Government in that applications may exchange functionality and information over the Internet. Web services standards provide XML-based protocols to find publicly-registered services, to understand their purpose and operation, to negotiate and agree upon usage charges and Quality-of-Service commitments, and to invoke the services within the context of Internet-based workflow coordination of these services.

This paper references the Knowledge-based Dynamic Semantic Web Services (KDSWS) Framework [1] that addresses, in an integrated end-to-end manner, the life-cycle of activities involved in preparing, publishing, requesting, discovering, selecting, configuring, deploying, and delivering Semantic Web Services. In particular, the following issues are addressed: 1) semantic specification of services capabilities including quality of

service, trust, and security; 2) brokering the services that are available to fulfill a request 3) workflow management; and 4) resource management, interoperability and evolution of the Virtual Organization (VO).

Brokering, or matchmaking, involves services advertising themselves to a broker, and the broker handling queries about the available services and mediating the results for the requestor [2]. Brokering activities involve discovering available services that match the request, differentiating between the discovered services, negotiating with the top-ranked services, and finally selecting the services that best meet the request.

“Semantic Web Services” (SWS) is the term that describes our research approach. We view “Web services” as services that use little or no semantic markup, and have little of the enhanced capability described in this paper. Semantic Web technology, on the other hand adds semantic and process oriented information, together with heuristics and constraints that can be used to coordinate the activities of the VO.

Section 1 has introduced the topic, while Section 2 discusses the problem space and some of the drawbacks and issues associated with existing approaches. The Knowledge-based Dynamic Semantic Web Services Framework is presented in Section 3. Section 4 presents a methodology to broker Web services within the KDSWS framework. Section 5 presents our conclusions and suggests areas for future research.

## 2. Related Work

In order for the various protocols involved in delivering Web services, as shown in [3], to achieve an end-to-end solution involves linking the many disparate protocols and technologies, despite the fact that they are all still based on the XML foundation. The nuances of these various technologies still need to be mediated to some level to be truly interoperable. These approaches do not specify aspects regarding repositories and agents.

As mentioned, Semantic Web Services attempt to address the shortcomings of Web services with respect to automation, and OWL-S is being established as a primary

specification for this endeavor. However, recent research [2, 4, 5] has documented several shortcomings attributed to OWL-S.

Current research suggests syntactic, semantic and pragmatic types of brokering, or semiotic brokering to reflect all three. Syntactic brokering uses the structure or format of a task specification to match a requester with a service provider, semantic brokering uses the request's meaning and information content to match with the meaning of the offered services of the provider [6], and pragmatic[7] involves using the context of the interaction to broker services.

Current approaches to differentiate Web services utilize Service Level Agreements (SLA) [8] and Quality of Service (QoS) [9] attributes to further rank the match of the request to the providers and their services beyond service discovery. Negotiation within the Web services arena involves setting both the negotiation strategy and process via the following architectures: "fully delegated" where the negotiation service executes most of the negotiation, "interoperable messaging adapter" where the negotiation service acts a message broker with possible mapping between the messages, and "process management" where the negotiation service enforces the rules agreed by the partners while separating the decision making and from the negotiation process itself [10]. See Kim [10] for a concise summary of approaches and issues with Web services negotiation.

### 3. KDSWS Framework

The KDSWS Framework proposes to deliver a comprehensive and integrated end-to-end solution to dynamically broker SWS. The framework positions itself as an enterprise-scale foundation to ultimately provide VOs with the interfaces necessary to interoperate via Semantic Web Services using, and quickly adapt to, the plethora of prevailing technologies and protocols.

Like the Web Services Modeling Framework (WSMF) [11], ontologies and mediation are an integral part of this framework, and are manifested in the mapping and heuristics. The structure and design of the components target, or map to, ontological implementations such as OWL and OWL-S, albeit with potential extensions to facilitate the additional functionality. A primary function of the heuristics is to enhance the mappings ability to dynamically mediate between disparate components.

This framework has similar guiding principles, with respect to incorporating knowledge and providing a 'protocol-independent' (vs. language-independent) conceptual base, to those found in [4]. However, this framework approaches the solution spaces from a different perspective by placing more emphasis on a total

enterprise solution and by providing a 'way-forward' via a guiding methodology as to how to use the structures.

As shown in Figure 1, the framework is comprised of the KDSWS Processes, KDSWS Specification, and KDSWS Functional Architecture. Note that underlines denote components specified in the diagrams and that the elements that are relevant to this discussion are highlighted in green with dashed outlines.

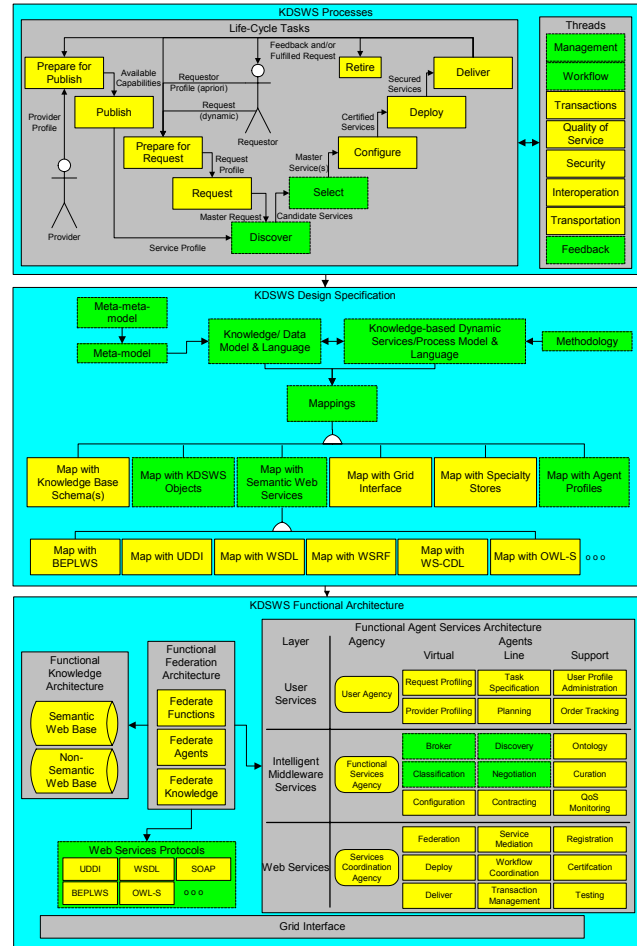


Figure 1. KDSWS Framework

The KDSWS Processes layer is segregated into Tasks and Threads; such segregation provides the ability to specify behavior based on the context of where an operation is invoked. Tasks are well-delineated steps to deliver functionality via Web services, and the brokering activities involve the Discover and Select tasks. For additional context designation, threads are defined as layers of functionality that the tasks use to deliver the services. For this discussion, we address the issues related to Management, Workflow, and Feedback.

The KDSWS Design Specification allows the enterprise-wide data and processes needs to be stipulated

for the KDSWS Processes, as well as for the backend, middleware and user services, which provides a comprehensive (by addressing backend, middleware, and user needs as well as the end-to-end issues) and integrated (by addressing both data and process needs) solution. The data aspects are captured in the meta-model and are modeled by the Knowledge/Data Model and Language (KDM/KDL) [12]. The process aspects are captured in the methodology and are modeled by the Knowledge-based Dynamic Services/Process Model and Language (KDSPLM/L) [1]. This ‘meta-model/process’-based approach enables an extensible framework that provides a macro-level shell to plug-in different approaches to the facets of the Web services life-cycle (e.g., negotiation, policy management, etc.) yet still provides enough structure to guide implementations.

The elements contained in the meta-model come from various sources such as the WSMF, OWL-S and Sheth [13]. The meta-model focuses on developing the ‘building blocks’ (i.e., constraints, preferences, profiles, capabilities, etc.) versus focusing on the higher-level and visible, finished products like a service, a profile, or request on which some approaches place their primary attention. This ‘building block’ approach makes the framework components composable, reusable and extensible. The meta-model distinctly defines resource-based (e.g., service, agent, protocol) and process-based (e.g., task, thread, event) classes in order to clarify the concepts involved in delivering Web services functionality.

The Mappings is a superclass of all mappings to ensure consistency across the methods to bridge the KDL/KDSPL to other technologies and standards. The mapping to other KDSWS objects (both KDL and KDSPL) enables the aggregation of the ‘building blocks’ to be defined by rules versus relationships. Because the rules are much easier to change, the framework is much more flexible in adapting to change. This rules-based approach facilitates the dynamic generation of the framework’s profiles (e.g., requestors, providers, situations, services, etc.) in order to drive the matchmaking of a request to service(s). By combining the rules with events, the framework allows the dynamic adjustment of the process to address the ‘static process declaration’ issue by having certain conditions invoke specific behavior.

The profiles of the various agents are embedded throughout the KDSPL. The mapping to agent profiles identifies the points where agents are specified and organizes into a profile that contains the responsibilities of the agent within a given context. From this profile, the specification for a given agent can be engineered into a working component.

The KDSWS Functional Architecture’s functional emphasis originates from the need to embed the purpose, behavior and relations within the specification via such items as the goals argument. The Functional Agent Services Architecture (FASA’s) virtual agents specify agents’ aggregation and coordinate the activities of other agents. Line agents are involved in work specifications and delegate support functions to other agents (support agents). The Intelligent Middleware Services layer is supported by the Functional Services Agency whose agents include line agents that receive the task specification and plan from the User Agency, and search for appropriate Internet-based web services that can accomplish the tasks [14].

Protocols are an essential backbone for Web services that establish the expected means to communicate between end-points. There are numerous protocols (see [3]) used to support Web services, some of which are mature but most of still emerging at varying levels of maturity. Semantic expansions to these protocols will likely be necessary to take full advantage of the expanded functionality in this framework.

#### 4. Managed Brokering Methodology

The processes in the methodology shown in Figure 2 are select portions of the KDSWS Methodology’s Discover and Select tasks set within the Management, Workflow and Feedback Threads. The discussion below walks through the methodology to exemplify the framework’s managed approach to brokering. Space does not permit to explain how this methodology is specified in the KDL or KDSPL, but see [1] for more details.

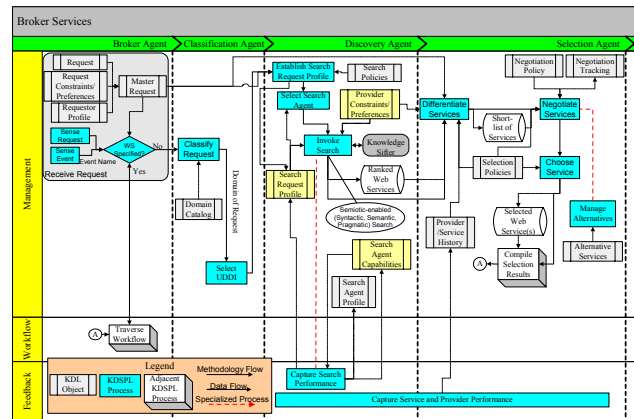


Figure 2. Brokering Methodology

The Broker Agent is the agent designated as owning these processes, while the Traverse Workflow process controls the overall flow to iterate through the services that are potentially reflected within a workflow context.

The first activity is to enact the Receive Request process that determines if the Master Request is 'profiled' (needs to be brokered using a semantic profile of the request) or if it explicitly specifies a Web service in the WS Specified? process. If the Master Request is specified, then other services within the workflow are checked to see if they need to be brokered. Otherwise, the Broker Agent commences the brokering activity by delegating the Classification Agent to handle the Classify Request process in order to establish the domain-specific UDDI to use. Multiple registries and ontologies are required because each domain possesses characteristics unique to its own environment.

Next, the Discovery Agent handles the Establish Search Request Profile process which uses the Master Request and Search Policies (e.g., priorities and process) that the VO, requestor and provider wish to establish for the interaction. For example, the VO might prefer price to be deemed more important than availability, and the provider might invoke different approaches to the search depending on the level of specificity of the request. Since multiple search devices are available, the Select Search Agent process uses the Search Request Profile to determine which search vehicle can best handle the request and the policies set forth. In this case, Knowledge Sifter [15] is selected because it handles the syntactic, semantic and pragmatic types of brokering. Once the search resource is selected, the Invoke Search process is started where the Search Request Profile and Provider Constraints/ Preferences provide more information to Knowledge Sifter in order for it to deliver more accurate results.

Because our methodology focuses on learning capabilities of agents, the Capture Search Performance process captures the measurement of performance and accuracy of the results in Search Agent Capabilities, and uses these measurements to refine the Search Request Profile for future searches.

The Selection Agent rounds out the brokering activity by first invoking the Differentiate Services process to perform a finer-grain ranking of the services than the search agent performed. Provider/Service History provides the SLA along with other characteristics such as reputation [9] to this process, while Selection Policies provide the priorities placed on the QoS parameters (e.g., price, availability, turnaround). The Capture Service and Provider Performance process feeds knowledge and activity into the Provider/Service History.

The Negotiate Services process uses the Negotiation Policy (e.g., negotiation strategy, rules and parameters) and Negotiation Tracking (e.g., previous negotiation activity and progress within current negotiation process). This process involves a buyer, seller, and a potential marketplace in a potentially very ornate process that is

beyond this discussion. This approach also uses the 'process management' type of negotiation as suggested in [10]; however, the approach can be altered as necessary. A particular facet that is yet to be worked out is the timing issues between reaching a negotiated agreement in this brokering activity and when the workflow is actually executed.

The Choose Service dynamically applies the selection priorities within the Selection Policies in order to determine the Web service that best matches the request. The Manage Alternatives process continually monitors for potential options in the case that profiled services may not meet the request exactly, but may be acceptable. Because of the workflow needs to be traversed, the interim Selected Web Service(s) need to be collected and stored via the Compile Selection Results process. Here the potentially heterogeneous results are also mediated with the overall activity into a consistent and usable form by downstream configuration activities. Meanwhile, the flow returns to deal with services potential still left to be brokered within the workflow.

## 5. Conclusions

In order to accelerate the introduction of new concepts and systems, we need approaches which automate the entire Web services life-cycle and address the issues related to Virtual Organizations. This paper presents an agent-based approach to managing the brokering of Semantic Web Services for use within a Virtual Organization, and is part of a larger methodology, called the KDSWS Framework. The framework provides a formal model-based approach to implementing Web services that specifies the modeling, specification, design, implementation and deployment of systems composed of SWS. The goal of the framework is to support the automatic discovery, composition, execution and management of Web services for the Virtual Organization in a protocol-independent manner.

The framework provides a comprehensive solution because it addresses the backend specification for federating enterprise resources, agents and knowledge repositories. It is integrated because the data and process specifications are created using the same foundation - the KDM/KDL. Interoperability is facilitated by the integrated design space and mediation structures. The framework is knowledge-based because it uses heuristics to associate the knowledge to objects and services, and captures usage context as well. This rules-based approach facilitates the dynamic profiling of resources as well as quick adaptation to the rapidly changing Web services standard and protocol base. The term 'semantic' denotes the knowledge-based semantic specification of

the relevant features and functions provided by the Web Service.

In order to address the multitude of issues in this area, we propose the KDSWS Framework as a way to combine three important, and inter-related, viewpoints:

- The KDSWS Process viewpoint addresses issues related to workflow, transaction-control, security, and interoperation in the form of “threads”. The delineation between the resource-based and process-based classes in the meta-model provides crisper concepts for the framework to specify tighter designs.
- The KDSWS Design Specification viewpoint models objects, relationships, constraints, heuristics, and processes using the KDM/KDL and extensions KDSPM/KDSPL to handle special features of Semantic Web Service specifications. The advantage provided by a separate and integrated specification is the VO can adjust to a constantly changing protocol base more rapidly by developing the mappings from the consistent base versus having to recode the affected interfaces.
- The KDSWS Functional Architecture provides an agent-based architecture to implement systems via composable Semantic Web Services. The architecture includes Functional Architectures for knowledge represented in repositories, federation policy, rules, agents, Web service protocols, and agent services to manage various aspects of deploying Semantic Web Services.

This research is still at an abstract level, and an implementation of the framework is planned where the facets of the research can be matured. Future work for the framework includes creating a modeling facility for the unique approach of the methodology that integrates the meta-model.

Finally, our research indicates that the KDSWS semantic modeling techniques and methodology, when applied to service-oriented systems exemplified by Semantic Web Services, helps to address the plethora of issues needed to successfully deploy them in real-world applications. The semantically-enabled workflow and feedback processes provide a managed approach to the dynamic delivery of Web services. The multiple viewpoints help to isolate and identify important issues and the mappings from viewpoint to viewpoint assure that the structures, operations, and constraints are properly mapped and preserved.

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