

Practical Challenges with Web Service Evolution: A Review of Literature and Current Industry Practices

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Abstract. Service-oriented Systems often rely on integrating software systems that are developed by independent parties and that evolve independently. In this paper we identify the key challenges with web service evolution such as backward and forward compatibility, serving and testing multiple concurrent versions, version specific documentation and communicating future changes. Following an appropriate strategy to overcome these challenges will enable web service publishers to iterate their services as required while minimizing the impact on existing consumers of the services. To understand and deal with these challenges, we performed a systematic review of the existing literature on web service evolution and investigated three real world web services. Based on our findings, we discussed the challenges and opportunities for future work to address the challenges.

Keywords: Web Service, Evolution, Versioning, SOA, SOAP, REST

1 Introduction

Web services offer a web-based communication mechanism between two software systems, commonly known as web service publishers and consumers. W3C defines web services as follows [1]:

“A Web Service is a software application identified by a URI [IETF RFC 2396], whose interfaces and binding are capable of being defined, described and discovered by XML artifacts and supports direct interactions with other software applications using XML based messages via Internet-based protocols.”

However, in today's technology, a web service is not limited to XML format and apply to a more generic context as defined in Wikipedia: [2]:

“A web service is a method of communication between two electronic devices over the World Wide Web. A web service is a software function

provided at a network address over the web or the cloud, it is a service that is “always on” as in the concept of utility computing.”

For example, a geographical mapping web service may be consumed by many different kinds of consumers such as: real-estate listing web sites, local business search portals, transit information web sites, etc.

To carry out the actual communication, a web service may follow a protocol. Of the many protocols that are in use today [3], two popular protocols are:

- Simple Object Access Protocol or **SOAP** web services
- Representational State Transfer or **RESTful** web services

Due to their historical usage, the term “web service” is often interpreted as SOAP. However, throughout this paper, unless otherwise specified, we have used this term to represent a web based communication method between two software systems irrespective of their actual implementation details. The findings mentioned in this paper are based on SOAP and REST based services due to their relative popularity over the other types.

1.1 SOAP Web Services

SOAP was designed in 1998 by Winer et al. and is currently maintained by the World Wide Web Consortium [4]. In brief, SOAP is an XML based protocol to communicate structured data and necessary headers between the consumers and publisher of a web service.

A SOAP web service is composed of one or more operations or methods. SOAP XML messages are used for communication between a consumer of the web service and its methods. The structure a SOAP service and its messages can be described using an accompanying XML based Web Services Description Language (WSDL) file. In addition to providing a structured definition of the service, these WSDL files can be automatically parsed by code-generators to provide the consumers with an easy-to-integrate interface.

1.2 RESTful Web Services

Being an XML based protocol, SOAP messages are often verbose. On the other hand, RESTful web services provide a lightweight and flexible approach, and gained popularity with the rise of cloud computing [5].

The term Representational State Transfer (REST) was introduced by Roy Fielding [6] and is used interchangeably as RESTful web service or Web API. In brief, REST is an implementation for web services where user defined “resources” are created, accessed, modified and deleted utilizing the various features of the HTTP stack such as caching, security, layering and different request methods (GET, POST, PUT, DELETE etc.), and content types.

The scope of this paper is limited to only the evolutionary aspects of web services. On this topic, the remainder of this paper is organized as follows: in

the next section we discuss the motivation behind this research followed by our research questions. Then, we discuss the research method and findings in Sections 4 and 5 respectively. Finally, we summarize the key challenges and future work opportunities with evolving web services in Section 6.

2 Motivation

Web services, like other software systems, need to evolve to stay on top of bugs and ever changing requirements. For example, between May 15th to 22nd of 2013, the Facebook Web Service team saw 238 new bugs, resolved 211 bugs and fixed 24 bugs [7]. However, often times web services are used by an unknown number of consumers, and the web service publishers have little control over them. Updating a web service can be tricky in such a situation since a breaking change may upset the existing consumers. To be able to evolve in such a decoupled scenario, multiple versions of a service need to coexist which poses both technical and business challenges on multiple fronts. At a conceptual level, Figure 1 shows the different parts of a web service that need to deal with evolution:

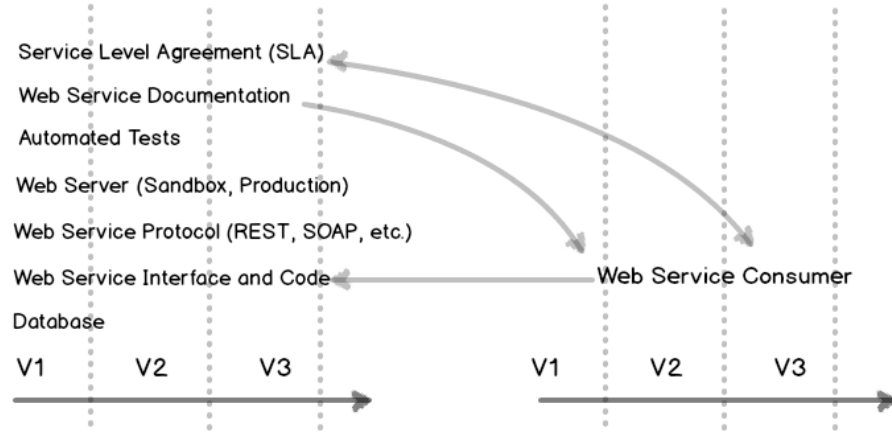


Fig. 1. Different Parts of an Evolving Web Service

Figure 1 shows the different parts of a web service that need to cope with the changing requirements for its evolution from $V1 \rightarrow V2 \rightarrow V3$. However, there is a little to no standard approach to tackle these parts of an evolving web service. The motivation for this research stems from the need to improve this situation.

3 Research Questions

To better understand the challenges related to web service evolution we have focused on the following list of research questions:

- Why do web services need to evolve?
- How to evolve the web services?
- What are the key challenges for evolving web services?

Focusing on these questions helped us identify gaps of the currently available techniques for evolving web services. Using this as a background, innovative future work can be carried out to fill these gaps and simplify web service evolution.

4 Research Method

We have performed a Systematic Literature Review to extract information from the published articles following [8]. We have also analyzed three real-world web services to find out the answers to the research questions based on industry examples. In this regard, we have limited our research to two high level sources as follows:

- Published articles from the academia and the industry
- Real world web services

4.1 Systematic Literature Review

Kitchenham et al. defines systematic review as follows [8]:

“A form of secondary study that uses a well-defined methodology to identify, analyse and interpret all available evidence related to a specific research question in a way that is unbiased and (to a degree) repeatable.”

We have carried out a systematic review because it helped us examining and summarizing the relevant work from the existing literature. To this regard, we have identified relevant papers from the following sources: IEEEExplore, ACM Digital library, Google Scholar, CiteSeer library, ScienceDirect, and SpringerLink.

To identify the relevant papers from these sources we have performed keyword searches. As mentioned in [9], keywording is a two step process, 1) extracting keywords from reading the abstracts and, 2) combining keywords from different papers. At step 1, we initially searched for the papers containing the terms “web service”. We have seen repeated mentions of the terms Service Oriented Architecture or SOA, SOAP, Web API and REST to denote similar concepts in these papers. In addition to this, we have expanded the word “evolution” with its commonly used English synonyms. At step 2, we combined the keywords and formed the following pseudo search query:

(“Web Service” OR SOA OR SOAP OR RESTful OR “Web API”)
AND (evolve OR evolution OR versioning)

We searched the aforementioned sources using this query in the title, abstract and keywords of the published articles. However, the sources offer different search capabilities and attempts were made to tune the queries based on the capabilities of a source. For example, only article titles were searched on Google Scholar and SpringerLink as they don’t allow search in abstracts at the time of writing this paper. We found the following number of matches from the sources including duplicates:

Source	Fields Searched	Number of Matches
IEEEExplore	Title, Abstract	224
Google Scholar	Title	130
ACM Digital Library	Title, Abstract	235
ScienceDirect	Title, Abstract, Keywords	54
SpringerLink	Title	15

From the search results, we performed a primary screening and selected 22 papers after reading the abstracts. Then, for the remaining articles, we read the full paper as long as it was found relevant, i.e. only if it contained topics about the evolution of web services. The resulting list is composed of [8] [9] [10] [11] [12] [13] [14] [15] [16] [5] [17] [18] [19].

In the next section, we list and discuss our findings from these selected papers in light of the research questions.

4.2 Analysis of Real World Web Service Evolution

In addition to looking at the published articles, we have also analyzed real world web services to examine their approaches to deal with evolution. A comprehensive review of all the real world web services is beyond the scope of this research. However, we selected the following web services as they are evolving with a large number of existing consumers using different evolution approaches:

- Google Maps
- Twitter API
- Facebook Graph API

The triangulation of the findings from the systematic literature review and the analysis of real world services provide a broader insight than each method itself.

5 Research Findings

5.1 Systematic Literature Review

Why Do Web Services Evolve? In this section, we have listed the drivers behind web service evolution as discussed in 3 of the selected papers. To begin with, in [10] Treiber et al. provided a list of changes related to web services with their interdependencies. To identify the source and impact of a change, they categorized the stakeholders into four roles:

- **web service provider**, is responsible for planning and conception of the service
- **developer**, implements the planned service
- **service integrator**, integrates with external web services and
- **user**, actually uses the integrated application.

The stakeholders take part in driving changes to a web service. The authors identified the following types of changes in a web services: Interface, Implementation, Quality of Service (QoS), Usage, Requirement, Service-level Agreement (SLA), Pre and post conditions, and Feedback. In line with [10] Lublinsky also pointed out that a new version may be required primarily because of changes in its interface, schema of the message payload or in its implementation. In [13], Laskey identified the key reasons for changes between versions as: a) service description changes, b) changes in functions, c) changes in the interaction mechanics, and d) change of known pre and post conditions. These changes would require new versions of the service as well as accompanying any explanation of the specific changes.

In addition to the types of changes discussed above, Borovskiy et al. identified some drivers behind web service evolution from the perspective of an enterprise [11]. They categorized two classes of change drivers:

- **Intrinsic change drivers**: Poor design, Poor implementation quality
- **Extrinsic change drivers**: Market drivers, Differentiation drivers, Business requirement drivers, Operational process drivers, Legislative regulatory drivers, User related drives

A change on a web service impacts one or more of the stakeholders. Treiber et al. pointed out that, the change drivers are also interdependent on each other [10]. For example, when a web service **provider** decides to change the **interface**, the **developer** needs to write the changed interface and its **implementation**. If the changed interface is not backward compatible, and the service **integrator** needs to modify the integration. The new interface and implementation may instigate a change its **QoS**, since it may improve or degrade the performance. The changes may improve or degrade the **QoS** and impact the **end user**.

How to evolve the web services? Now that we have listed the drivers behind web service evolution, next we present the different approaches to tackle web service evolution based on 6 of the selected papers.

Versioning: Lublinsky compared between multiple approaches of implementing evolving web services based on different dimensions as follows [12].

- **Units of versioning**: One approach to version a service is to apply a single version to all its methods that can be deployed as a group. Another approach is to version individual methods or operations of the service as they change, this confines the change to only specific methods and provides a finer grained

- versioning. However, deployment of such versioned methods are complicated and requires the consumer to specify a version for each method of the service.
- **Service version life-cycle considerations:** Lublinsky suggests adjusting the life-cycle of versions based on the actual need. Too many versions require more maintenance while too few versions leave the consumers a smaller time window to upgrade since each version has a shorter life-cycle.
 - **Version deployment/access approaches:** When deploying versioned services, Lublinsky compares between multiple versions deployed on the same endpoint vs. each version deployed on its own endpoint. Lublinsky favors the latter approach as it doesn't need intermediate routers and provides better scalability and loose coupling between versions.

A versioning scheme is required to identify and use a specific version. In [13] Laskey discussed versions in terms of identifiable resources, that can have multiple versions and are modified by applying new versions to the original one.

To identify a specific version of a resource, Leskey suggests using a unique identifier with an accompanying explanation of how to interpret it. The versioning identifiers should be used consistently. In addition to this, the author also recommends specifying a policy describing compatibility between the versions as shown in the following example:

“A versioning scheme for a service may include a generic policy, such as any succeeding version identified as 1.j will be backward compatible with any 1.i previous version in the sense that results are identically generated in version 1.j for functionality that existed in previous 1.i versions.”

To locate each version, the author provided the following example URL based scheme: *http://a.b.c/services1/20080601/* , where *service1* is the name of the resource and *20080601* is the date based version identifier. Given this URL scheme, the author suggests the service descriptions to dereference the URL and provide necessary details about the version so that the versioning information is transparent to the consumers.

From these versioning related papers, we identify the following **Deployment Challenges** for evolving web services:

- Should multiple versions be deployed under a separate or a single endpoint?
- Should a version apply to a whole service or to the individual methods?
- How many versions need to be deployed at any given time?
- How to identify and interpret a version?

Implementation: Once an appropriate evolution and versioning strategy is selected, the required changes need to be implemented. Next, we discuss the implementation approaches as suggested in the literature from the perspective of two levels, **1) protocol level** and **2) application level**.

Protocol Level Implementation: Since web services typically follow protocols such as SOAP, REST, etc., protocol level support for evolving web services would allow for uniform standards. In [14] Wilde proposed a conceptual framework for SOAP web services where consumers can be forward compatible in a managed way.

At its core, the framework includes open and extensible XML schemas so the consumers of old version can work with the schema in a newer version. To achieve this, the framework recommends using a set of custom extensions to the XML schema. These extensions can be as simple as XML tags such as `mustUnderstand`, `mayIgnore` or some complex ones to suit the specific use case in hand. To communicate their actual usage, an accompanying guideline on their processing rules need to be provided so that the consumers of the web service can attain a predictable level of “graceful degradation” as the service evolves.

Using a similar approach but instead of arbitrary custom tags to extend the schema, Fang et al. provides a concrete list of six XML nodes to create a version-aware service model for SOAP web services [15]. They introduced extensions to WSDL and UDDI [20] to tackle evolving web services. The six XML nodes are: **1) version name, 2) version description, 3) startTime of the version, 4) endTime of the version, 5) alias such as (new, current etc) of the version name and, 6) original version that preceded it.**

Using these tags, a consumer can find and register for a target version through a service registry. When a new version is released, a registered consumer gets notified about the change and can self update if the changes are backward compatible.

In [16] Leitner et al. provided an alternative approach to transparently handle multiple versions of SOAP web services using their framework called VRESCo. At its core, VRESCo builds a graph of the versions showing predecessor relations as shown in Figure 2:

For each version, VRESCo uses a free-form tag to identify it. The version tag and associated meta information from the WSDL file of each version is stored in VRESCo’s database. So, when new versions are released, it can analyze to see if the changes are backward compatible. To route a consumer request to the right version, the versions of a service are deployed behind a proxy. Based on a “selection strategy” specified by the consumer (e.g. always use latest, always use stable, fix version, etc.) the proxy can then automatically select the desired version. For compatible updates, this approach off-loads the consumer at the expense of an additional proxy layer.

In addition to the protocol level evolution support for SOAP web services, Mangler et al. showed a solution for RESTful web services in [5]. They introduced a description language called RIDDl for RESTful web services to support service composition and evolution.

RIDDl adds XML based descriptions to RESTful web services. Using RIDDl, service evolution is expressed through a chain of adapters, where the output of a service matches with the input of its preceding version. From this XML dec-

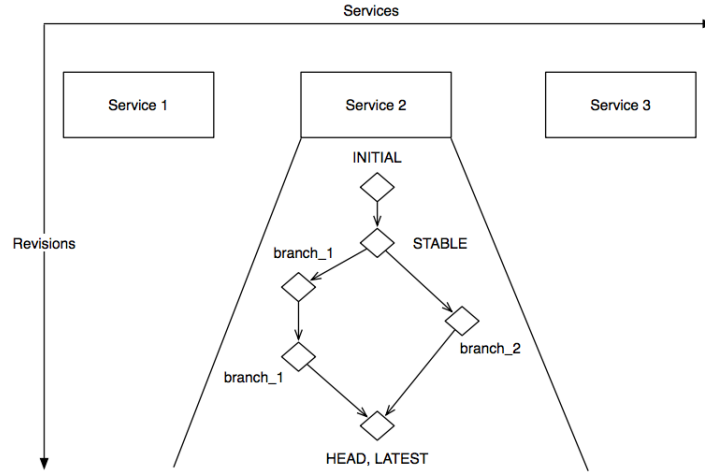


Fig. 2. VRESCo Service Version Graph, source: [16]

laration of the chain, it is possible to merge the inputs and outputs from each adapter to create a full description of a specific version.

From these different approaches, we have identified the following challenges with evolving web services:

- **Implementation Challenge:** How to provide protocol level support for versioning?
- **Communication Challenge:** How to automatically notify the consumers about the changes?

Application Level Implementation: Following from the protocol level implementation approaches discussed in the previous section, we have presented the application level solution approaches in this section.

Kaminski et al. presented a design technique for evolving web services from the perspective of the source code implementation [17]. They identified some key requirements for their design such as: **a) backward compatibility, b) common data store, c) no code duplication, d) untangled versions, e) unconstrained evolution, and f) a visible mechanism.**

With these requirements laid out, they proposed a design technique called “Chain of Adapters” for the implementation of evolving web services. Figure 3 shows a high level view of the design.

In essence, the design technique can be described as follows: To start with, a web service can be developed as usual. Then, the interface of the web service is duplicated under a namespace V1. An implementation of this interface is created in the same V1 namespace that performs necessary translations on the data and delegates the methods to the original web service. This produces a snapshot of the V1 service which can be published for its consumers.

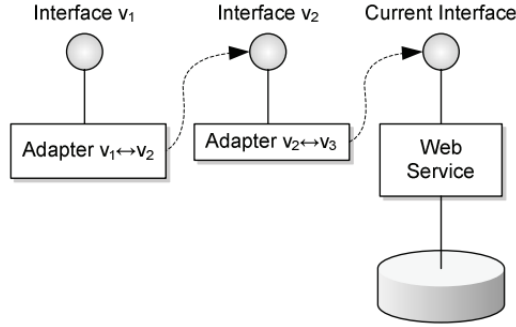


Fig. 3. Chain of Adapters structure, source: [17]

Now, to evolve to V2 of the service, the changes are made to the original web service. A compensating in a V1 \leftrightarrow V2 adapter is created to translate the V1 service to the changed web service. This V1 \leftrightarrow V2 adapter is the first of the “Chain of Adapters” to be used for evolution. Once the changes are complete, the interface of the original web service is duplicated into a the V2 namespace. In the same namespace, an implementation of this V2 interface delegates the calls to the original web service, while the V1 \leftrightarrow V2 adapter targets this new implementation. This way, a new snapshot for the V2 of the service is created.

As the service evolves, introducing new adapters for each version would produce a chain of such adapters to ensure backward compatibility and code reuse while being able to serve multiple concurrent versions.

The “Chain of Adapters” technique addresses their requirements, but they mentioned some caveats. For example, the adapters need to ensure all breaking changes are compensated, which may need for a separate data store when fields are removed from the datastore on subsequent versions. Also, this chain effectively connects all the versions, so a bug or its fix on one version may have impact on all the versions.

From this study, we have compiled the following list of **Implementation Challenges** for evolving web services:

- How to design and organize the code for evolving web services?
- How to fix defects that affect multiple versions?
- How to design the data storage for evolving web services?
- How to automatically test multiple versions of a web service?

Communication: A change in a web service may impact multiple stakeholders. So, it is important to communicate the changes and their impacts to the stakeholders as the service evolves. In this section, we have discussed 2 of the selected papers as they suggested ways to effectively communicate the evolution of web services.

In [18] Zou et al. presents a technique to generate consumer specific changelogs for evolving SOAP web services. The authors presented an approach where

a consumer specific changelog can be generated based on their usage pattern of the service. The approach is described below:

- **Service invocation monitoring:** A monitoring system tracks the usage pattern of each consumer to identify specific areas of interest for a consumer.
- **Service difference analysis:** The differences between two versions of a web service is analyzed by comparing their WSDL files.
- **Release note customization:** The release note can then be tailored for each consumer by using the data collected at step 1 and 2 to only include relevant changes per customer
- **Code release note linkage:** Using the customized release note from step 3, it is possible automatically inspect the consumer code and discover fragments of the code that need to change for the new version.

Aversano et al. provided an alternate approach to communicate changes in SOAP web services using a graphical way in [19]. To construct the graphical representation, the authors extracted meta information about methods and parameters for SOAP web services from the WSDL files. This meta information is then presented in a graph to visualize the service with its methods and parameters, and highlight changes between versions.

From these papers, we compiled the following list of **Documentation Challenges** of evolving web services:

- How to produce version specific documentation?
- How to generate changelog between versions?

5.2 Analysis of Real World Web Service Evolution

In this section we have listed our findings from the following real world evolving web services:

- **Google Maps:** Google Maps provides a web service for its consumers and updates the service to provide “new features, bug fixes and performance improvements” [21].
- **Twitter Web API:** Twitter provides a RESTful web service to interact with its data from third-party applications [22]. This web service is also evolving to fix bugs and introduce new features.
- **Facebook Graph API:** Facebook Graph API is the primary web service to retrieve and post data to Facebook [23]. The service evolves to support change/removal of functionality, backwards compatibility, Facebook product changes, and privacy and security related changes.

Versioning: Google Maps uses the following versioning policy [21]:

- **Experimental version:** With all the latest features, bug fixes and improvements. But this version is not guaranteed to be feature stable.

- **Release version:** From the the experimental version, every quarter, a feature stable version of the service is tagged as a “release” version. These release versions may receive bug fixes but the features remain stable.
- **Previously released or Frozen version:** Every time a new “release version” is tagged, the previously release version is “frozen”, so no new features or bug fixes are applied to ensure it remains completely feature stable.

Every time a new release version is tagged, the oldest version is retired. Google Maps guarantees the versions are backward compatible and automatically migrates the consumers using the oldest version to the following version.

On the other hand, the Twitter API had two versions at the time of writing this paper [22] and the old version was marked as deprecated. Once a version is released, future changes are made to the released version to provide new features and bug fixes. However, unlike Google Maps, new features are not always released under a new version name. Instead, the changes may be deployed under the same version name.

Unlike the previous approaches, Facebook Graph API uses a 90-day breaking change policy as follows: [23]

“Platform changes that would require a code change from developers (security and privacy changes excluded) will be announced at least 90 days before the change goes into effect.”

The service consumers, aka platform developers, can opt-in to migrate to a new release to get an early look on the impact of the breaking changes specific to their use case and take necessary actions within the 90-day period. All users are automatically migrated to the new version after this 90-day period.

From these different approaches, we compiled the following list of **Deployment Challenges** to evolving web services:

- How and when to migrate the consumers to a newer version?
- How and when to migrate the consumers that are using a retiring version?

Both Google Maps and Twitter web service users identify a desired version of the service in the URL. For example, to use the version 3.12 of Google Maps API, the following URL can be used <https://maps.googleapis.com/maps/api/js?v=3.12>. In absence of a version parameter, by default the experimental version of Google Maps is used.

Instead of a URL based versioning identifier, Facebook allows the consumers to enable the changes by pushing a button on the Facebook website. Once enabled, the users can make necessary changes before the 90-day period.

Documentation: Google Maps web service provides a human readable documentation of the service operations with examples for each version [24]. Since the API is publicly available, the users can run the example requests to produce live results by browsing the API endpoints on their browsers.

Twitter also publishes human readable API documentation for each version of the web service in their developer portal [22]. The portal includes an interactive web browser based console to let its users explore the service on the browser [25].

Similarly, the Facebook Graph API accompanies both a static HTML based and an interactive the API called “Graph API Explorer” [23].

From these examples, we have compiled the following list of **Documentation Challenges** of evolving web services:

- How to auto generate human readable usage examples of a web service?
- How to provide an interactive explorer for different versions a web service?

Communication: The real-world web services use multiple channels to communicate with the users. For example, Google Maps web service uses StackOverflow.com to collect code related questions from the users, an issue tracker to let the users report defects, and blogs and an email group to discuss changes [26].

Facebook also uses a developer portal, a StackOverflow channel and blogs to communicate with its users [27].

To communicate the past and upcoming web service changes, Twitter publishes a “Calendar of API Changes” on their developer portal [28]. In addition to this calendar, the portal also has developer blogs, a discussion forum and an issue tracker for its users.

From these communication patterns, we identified the following list of **Communication Challenges**:

- What communication channels should be used?
- If multiple channels are used, how to aggregate the data from multiple channels?

6 Discussion

In the previous sections, we have provided a list of different challenges in question formats related to evolving web services in 4 categories:

- Deployment Challenges
- Implementation Challenges
- Documentation Challenges
- Communication Challenges

These challenges are derived from our systematic review of the literature and analysis of three real world web services. We have also listed suggested approaches to tackle some of the problems. Even though the answers to these challenges rely on specific use-case of a web service, we recognize that these challenges are generic in nature. However, due to the lack of standard approaches to address these challenges, once a decision is made, it typically requires custom implementation to solve these general problems. Moreover, there is a lack of

tool support to aid the custom implementation efforts. We identify this lack of standards and tool support as an opportunity for innovative future work to simplify the evolution of web services.

7 Conclusion

Web services evolve for real world reasons, such as to produce business value, fix defects, adapt new technology and so on. However, there is little to no built-in support for evolving web services in the commonly used technologies of today. In this paper, we have listed the reasons that cause a web service to change, techniques to implement the change and the key challenges associated with the evolving web services from our systematic review of the literature and analysis of real-world web services. Understanding these challenges of an evolving web service helped us to identify some opportunities for innovative future work.

We have summarized our findings of the key challenges with evolutionary web services in four high level categories: a) Deployment, b) Implementation, c) Documentation and, d) Communication. For each of these categories, we have compiled a shortlist of challenges in question forms. This list of questions can be treated as a checklist for working on evolving web services. We have also discussed different approaches to solve some of the challenges from our review of the existing literature and industry practices. In our future work, we aim to reconcile and augment these fragmented solutions to provide a standard approach and tool support for evolving web services.

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