Reference Architecture Foundation for Service Oriented Architecture Version 1.0

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Abstract:

This document specifies the OASIS Reference Architecture Foundation for Service Oriented Architecture (SOA-RAF). It follows from the concepts and relationships defined in the OASIS Reference Model for Service Oriented Architecture. While it remains abstract in nature, the current document describes the foundation upon which specific SOA concrete architectures can be built.

The focus of the SOA-RAF is on an approach to integrating business with the information technology needed to support it. These issues are always present but are all the more important when business integration involves crossing ownership boundaries.

The SOA-RAF follows the recommended practice of describing architecture in terms of models, views, and viewpoints, as prescribed in the ANSI[1]/IEEE[2] 1471-2000, (now ISO[3]/IEC[4] 42010-2007) Standard. The SOA-RAF is of value to Enterprise Architects, Business and IT Architects as well as CIOs and other senior executives involved in strategic business and IT planning.

The SOA-RAF has three main views: the *Participation in a SOA Ecosystem* view which focuses on the way that participants are part of a Service Oriented Architecture ecosystem; the *Realization of a SOA Ecosystem* view which addresses the requirements for constructing a SOA-based system in a SOA ecosystem; and the *Ownership in a SOA Ecosystem* view which focuses on what is meant to own a SOA-based system.

[1] American National Standards Institute

[2] Institute of Electrical and Electronics Engineers

[3] International Organization for Standardization

[4] International Electrotechnical Commission

Status:

This document was last revised or approved by the SOA Reference Model TC on the above date. The level of approval is also listed above. Check the "Latest Version" or "Latest Approved Version" location noted above for possible later revisions of this document.

Technical Committee members should send comments on this specification to the Technical Committee's email list. Others should send comments to the Technical Committee by using the "Send A Comment" button on the Technical Committee's web page at http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=soa-rm.

For information on whether any patents have been disclosed that may be essential to implementing this specification, and any offers of patent licensing terms, please refer to the Intellectual Property Rights section of the Technical Committee web page http://www.oasis-open.org/committees/soa-rm/ipr.php.

The non-normative errata page for this specification is located at http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=soa-rm.

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1 Introduction

Service Oriented Architecture (SOA) is an architectural paradigm that has gained significant attention within the information technology (IT) and business communities. The SOA ecosystem described in this document occupies the boundary between business and IT. It is neither wholly IT nor wholly business, but is of both worlds. Neither business nor IT completely own, govern and manage this SOA ecosystem. Both sets of concerns must be accommodated for the SOA ecosystem to fulfill its purposes.[5]

The OASIS Reference Model for SOA **[SOA-RM]** provides a common language for understanding the important features of SOA but does not address the issues involved in constructing, using or owning a SOA-based system. This document focuses on these aspects of SOA.

The intended audiences of this document and expected benefits to be realized include non-exhaustively:

- Enterprise Architects - will gain a better understanding when planning and designing enterprise systems of the principles that underlie Service Oriented Architecture;
- Standards Architects and Analysts - will be able to better position specific specifications in relation to each other in order to support the goals of SOA;
- Decision Makers - will be better informed as to the technology and resource implications of commissioning and living with a SOA-based system; in particular, the implications following from multiple ownership domains; and
- Users/Developers - will gain a better understanding of what is involved in participating in a SOA-based system.

1.1 Context for Reference Architecture for SOA

1.1.1 What is a Reference Architecture?

A reference architecture models the abstract architectural elements in the domain of interest independent of the technologies, protocols, and products that are used to implement a specific solution for the domain. It differs from a reference model in that a reference model describes the important concepts and relationships in the domain focusing on what distinguishes the elements of the domain; a reference architecture elaborates further on the model to show a more complete picture that includes showing what is involved in realizing the modeled entities, while staying independend of any particular solution but instead applies to a class of solutions.

It is possible to define reference architectures at many levels of detail or abstraction, and for many different purposes. A reference architecture is not a concrete architecture; i.e., depending on the requirements being addressed by the reference architecture, it generally will not completely specify all the technologies, components and their relationships in sufficient detail to enable direct implementation.

1.1.2 What is this Reference Architecture?

There is a continuum of architectures, from the most abstract to the most detailed. This Reference Architecture is an abstract realization of SOA, focusing on the elements and their relationships needed to enable SOA-based systems to be used, realized and owned while avoiding reliance on specific concrete technologies. It is therefore at the more abstract end of the continuum, described in [TOGAF v9] as a “foundation architecture”. It is nonetheless a *reference* architecture as it remains solution-independent. It is defined therefore as a *Reference Architecture Foundation*, because it takes a first principles approach to architectural modeling of SOA-based systems.

While requirements are addressed more fully in Section 2, the SOA-RAF makes key assumptions that SOA-based systems involve:

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[5] By *business* we refer to any activity that people are engaged in. We do not restrict the scope of SOA ecosystems to commercial applications.

- Use of resources that are distributed across ownership boundaries;
- people and systems interacting with each other, also across ownership boundaries;
- security, management and governance that are similarly distributed across ownership boundaries; and
- interaction between people and systems that is primarily through the exchange of messages with reliability that is appropriate for the intended uses and purposes.

Even in apparently homogenous structures, such as within a single organization, different groups and departments nonetheless often have ownership boundaries between them. This reflects organizational reality as well as the real motivations and desires of the people running those organizations.

Such an environment as described above is an *ecosystem* and, specifically in the context of SOA-based systems, is a **SOA ecosystem**. This concept of an ecosystem perspective of SOA is elaborated further in Section 1.2.

This SOA-RAF shows how Service Oriented Architecture fits into the life of users and stakeholders, how SOA-based systems may be realized effectively, and what is involved in owning and managing them. This serves two purposes: to ensure that SOA-based systems take account of the specific constraints of a SOA ecosystem, and to allow the audience to focus on the high-level issues without becoming over-burdened with details of a particular implementation technology.

1.1.3 Relationship to the OASIS Reference Model for SOA

The OASIS Reference Model for Service Oriented Architecture identifies the key characteristics of SOA and defines many of the important concepts needed to understand what SOA is and what makes it important. The Reference Architecture Foundation takes the Reference Model as its starting point, in particular the vocabulary and definition of important terms and concepts.

The SOA-RAF goes further in that it shows how SOA-based systems can be realized – albeit in an abstract way. As noted above, SOA-based systems are better thought of as dynamic systems rather than stand-alone software products. Consequently, how they are used and managed is at least as important architecturally as how they are constructed.

1.1.4 Relationship to other Reference Architectures

Other SOA reference architectures have emerged in the industry, both from the analyst community and the vendor/solution provider community. Some of these reference architectures are quite abstract in relation to specific implementation technologies, while others are based on a solution or technology stack. Still others use middleware technology such as an Enterprise Service Bus (ESB) as their architectural foundation.

As with the Reference Model, this Reference Architecture is primarily focused on large-scale distributed IT systems where the participants may be legally separate entities. It is quite possible for many aspects of this Reference Architecture to be realized on quite different platforms.

In addition, this Reference Architecture Foundation, as the title illustrates, is intended to provide foundational models on which to build other reference architectures and eventual concrete architectures. The relationship to other industry reference architectures for SOA and related SOA open standards is described in Appendix E.

1.1.5 Expectations set by this Reference Architecture Foundation

This Reference Architecture Foundation is not a complete blueprint for realizing SOA-based systems. Nor is it a technology map identifying all the technologies needed to realize SOA-based systems. It does identify many of the key aspects and components that will be present in any well designed SOA-based system. In order to actually use, construct and manage SOA-based systems, many additional design decisions and technology choices will need to be made.

1.2 Service Oriented Architecture – An Ecosystems Perspective

Many systems cannot be completely understood by a simple decomposition into parts and subsystems – in particular when many autonomous parts of the system are governing interactions. We need also to understand the context within which the system functions and the participants involved in making it function. This is the ***ecosystem***. For example, a biological ecosystem is a self-sustaining and dynamic association of plants, animals, and the physical environment in which they live. Understanding an ecosystem often requires a holistic perspective that considers the relationships between the elements of the system and their environment at least as important as the individual parts of the system.

This Reference Architecture Foundation views the SOA architectural paradigm from an ecosystems perspective: whereas a system will be a capability developed to fulfill a defined set of needs, a SOA ecosystem is a space in which people, processes and machines act together to deliver those capabilities as services.

Viewed as whole, a SOA ecosystem is a network of discrete processes and machines that, together with a community of people, creates, uses, and governs specific services as well as external suppliers of resources required by those services.

In a SOA ecosystem there may not be any single person or organization that is really "in control" or "in charge" of the whole although there are identifiable stakeholders who have influence within the community and control over aspects of the overall system.

The three key principles that inform our approach to a SOA ecosystem are:

- a SOA is a paradigm for *exchange of value* between independently acting *participants*;
- participants (and stakeholders in general) have legitimate claims to *ownership* of resources that are made available via the SOA; and
- the behavior and performance of the participants are subject to *rules of engagement* which are captured in a series of policies and contracts.

1.3 Viewpoints, Views and Models

1.3.1 ANSI/IEEE 1471-2000::ISO/IEC 42010-2007

The SOA-RAF uses and follows the IEEE “Recommended Practice for Architectural Description of Software-Intensive Systems” **[ANSI/IEEE 1471] and [ISO/IEC 42010]**. An architectural description conforming to this standard must include the following six (6) elements:

1. Architectural description identification, version, and overview information
2. Identification of the system stakeholders and their concerns judged to be relevant to the architecture
3. Specifications of each viewpoint that has been selected to organize the representation of the architecture and the rationale for those selections
4. One or more architectural views
5. A record of all known inconsistencies among the architectural description’s required constituents
6. A rationale for selection of the architecture (in particular, showing how the architecture supports the identified stakeholders’ concerns).

The standard defines the following terms[6]:

Architecture

The fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution.

[6] See http://www.iso-architecture.org/ieee-1471/conceptual-framework.html for a diagram of the standard’s Conceptual Framework

Architectural Description

A collection of products that document the architecture.

System

A collection of components organized to accomplish a specific function or set of functions.

System Stakeholder

A system stakeholder is an individual, team, or organization (or classes thereof) with interests in, or concerns relative to, a system.

A stakeholder's concern should not be confused with either a need or a formal requirement. A concern, as understood here, is an area or topic of interest. Within that concern, system stakeholders may have many different requirements. In other words, something that is of interest or importance is not the same as something that is obligatory or of necessity **[TOGAF v9]**.

When describing architectures, it is important to identify stakeholder concerns and associate them with viewpoints to insure that those concerns are addressed in some manner by the models that comprise the views on the architecture. The standard defines views and viewpoints as follows:

View

A representation of the whole system from the perspective of a related set of concerns.

Viewpoint

A specification of the conventions for constructing and using a view. A pattern or template from which to develop individual views by establishing the purposes and audience for a view and the techniques for its creation and analysis.

In other words, a view is what the stakeholders see whereas the viewpoint defines the perspective from which the view is taken and the methods for, and constraints upon, modeling that view.

It is important to note that viewpoints are independent of a particular system (or solutions). In this way, the architect can select a set of candidate viewpoints first, or create new viewpoints, and then use those viewpoints to construct specific views that will be used to organize the architectural description. A view, on the other hand, is specific to a particular system. Therefore, the practice of creating an architectural description involves first selecting the viewpoints and then using those viewpoints to construct specific views for a particular system or subsystem. Note that the standard requires that each view corresponds to exactly one viewpoint. This helps maintain consistency among architectural views which is a normative requirement of the standard.

A view is comprised of one or more architectural models, where model is defined as:

Model

An abstraction or representation of some aspect of a thing (in this case, a system)

All architectural models used in a particular view are developed using the methods established by the architectural viewpoint associated with that view. An architectural model may participate in more than one view but a view must conform to a single viewpoint.

1.3.2 UML Modeling Notation

An open standard modeling language is used to help visualize structural and behavioral architectural concepts. Although many architecture description languages exist, we have adopted the Unified Modeling Language™ 2 (UML® 2) **[UML 2]** as the main viewpoint modeling language. Normative UML is used unless otherwise stated but it should be noted that it can only partially describe the concepts in each model – it is important to read the text in order to gain a more complete understanding of the concepts being described in each section..

Appendix B introduces the UML notation that is used in this document.

1.4 SOA-RAF Viewpoints

The RAF uses three views that conform to three viewpoints: *Participation in a SOA Ecosystem*, *Realization of a SOA Ecosystem*, and *Ownership in a SOA Ecosystem*. There is a one-to-one correspondence between viewpoints and views (see Table 1).

Viewpoint Element	**Viewpoint**		
	Participation in a SOA Ecosystem	*Realization of a SOA Ecosystem*	*Ownership in a SOA Ecosystem*
Main concepts covered	Captures what is meant for people to participate in a SOA ecosystem.	Captures what is meant to realize a SOA-based system in a SOA ecosystem.	Captures what is meant to own a SOA-based system in a SOA ecosystem
Stakeholders addressed	All participants in the SOA ecosystem	Those involved in the design, development and deployment of SOA-based systems	Those involved in governing, managing, securing, and testingSOA-based systems
Concerns addressed	Understanding ecosystem constraints and contexts in which business can be conducted predictably and effectively.	Effective construction of SOA-based systems.	Processes to ensure governance, management, security, and testing of SOA-based systems.
Modeling Techniques used	UML class diagrams	UML class, sequence, component, activity, communication, and composite structure diagrams	UML class and communication diagrams

Table 1 Viewpoint specifications for the OASIS Reference Architecture Foundation for SOA

1.4.1 *Participation in a SOA Ecosystem* Viewpoint

This viewpoint captures what a SOA ecosystem is, as an environment for people to conduct their business. We do not limit the applicability of such an ecosystem to commercial and enterprise systems. We use the term business to include any transactional activity between multiple users.

All stakeholders in the ecosystem have concerns addressed by this viewpoint. The primary concern for people is to ensure that they can conduct their business effectively and safely in accordance with the SOA paradigm. The primary concern of decision makers is the relationships between people and organizations using systems for which they, as decision makers, are responsible but which they may not entirely own, and for which they may not own all of the components of the system.

Given SOA's value in allowing people to access, manage and provide services across ownership boundaries, we must explicitly identify those boundaries and the implications of crossing them.

1.4.2 *Realization of a SOA Ecosystem* Viewpoint

This viewpoint focuses on the infrastructure elements that are needed to support the construction of SOA-based systems. From this viewpoint, we are concerned with the application of well-understood technologies available to system architects to realize the SOA vision of managing systems and services that cross ownership boundaries.

The stakeholders are essentially anyone involved in designing, constructing and deploying a SOA-based system.

1.4.3 *Ownership in a SOA Ecosystem* Viewpoint

This viewpoint addresses the concerns involved in owning and managing a SOA as opposed to using one or building one. Many of these concerns are not easily addressed by automation; instead, they often involve people-oriented processes such as governance bodies.

Owning a SOA-based system implies being able to manage an evolving system. It involves playing an active role in a wider ecosystem. This viewpoint is concerned with how systems are managed effectively, how decisions are made and promulgated to the required end points; how to ensure that people may use the system effectively; and how the system can be protected against, and recover from consequences of, malicious intent.

1.5 Terminology

The keywords “MUST”, “MUST NOT”, “REQUIRED”, “SHALL”, “SHALL NOT”, “SHOULD”, “SHOULD NOT”, “RECOMMENDED”, “MAY”, and “OPTIONAL” in this document are to be interpreted as described in **[RFC2119]**.

References are surrounded with **[square brackets and are in bold text]**.

The terms “SOA-RAF”, “this Reference Architecture” and “Reference Architecture Foundation” refer to this document, while “the Reference Model” refers to the OASIS Reference Model for Service Oriented Architecture”. **[SOA-RM].**

1.5.1 Usage of Terms

Certain terms used in this document to denote concepts with formal definitions and are used with specific meanings. Where reference is made to a formally defined concept and the prescribed meaning is intended, we use a **bold font**. The first time these terms are used, they are also hyperlinked to their definition in the Glossary that appears as Appendix B to the document. Where a more colloquial or informal meaning is intended, these words are used without special emphasis.

1.6 References

1.6.1 Normative References

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2 Architectural Goals and Principles

This section identifies the goals of this Reference Architecture Foundation and the architectural principles that underpin it.

2.1 Goals and Critical Success Factors of the Reference Architecture Foundation

There are three principal goals:

1. to show how SOA-based systems can effectively bring participants with needs (‘consumers’) to interact with participants offering appropriate capabilities as services (‘producers’);
2. for participants to have a clearly understood level of confidence as they interact using SOA-based systems; and
3. for SOA-based systems to be scaled for small or large systems as needed.

There are four factors critical to the achievement of these goals:

1. **Action**: an account of participants’ action within the ecosystem;
2. **Trust**: an account of how participants’ internal perceptions of the reliability of others guide their behavior (i.e., the trust that participants may or may not have in others)
3. **Interaction**: an account of how participants can interact with each other; and
4. **Control**: an account of how the management and governance of the entire SOA ecosystem can be arranged.

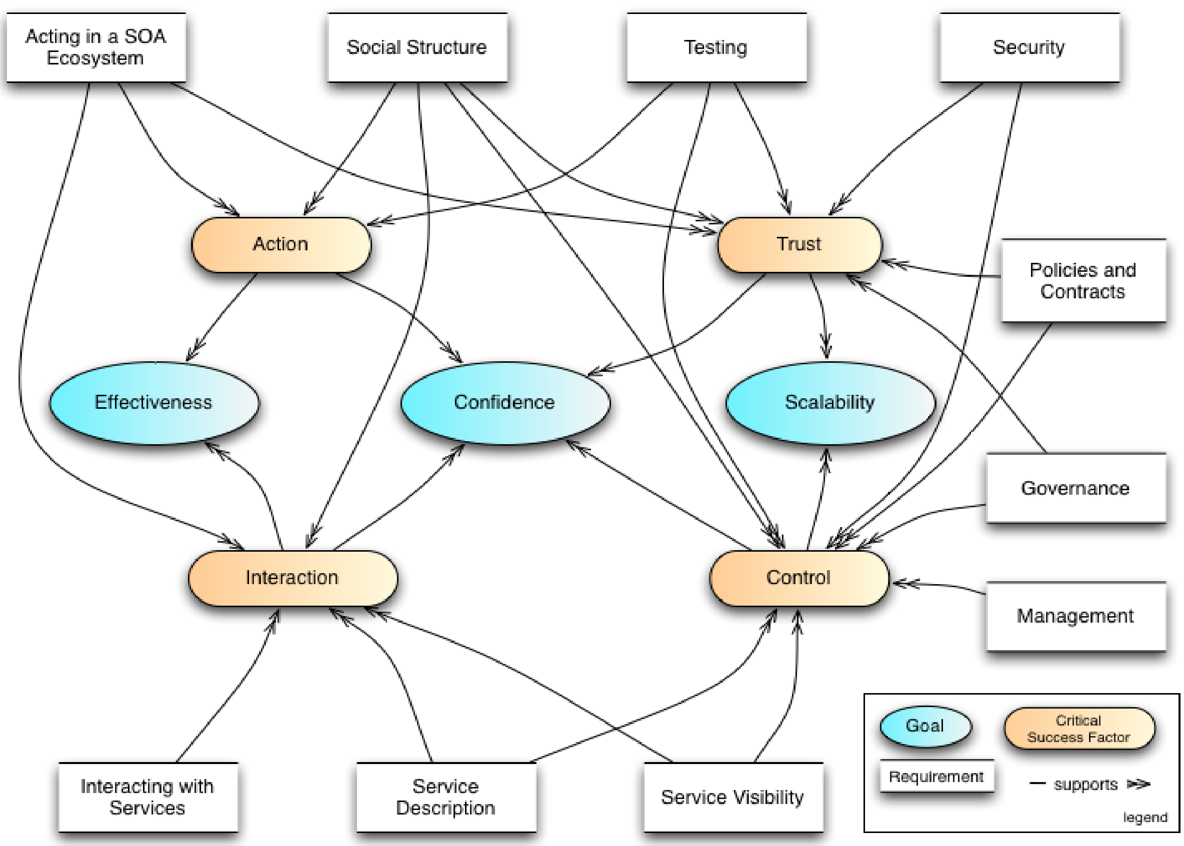

Figure 1 Critical Factors Analysis of the Reference Architecture

Figure 1 represents a Critical Factors Analysis (CFA) diagram demonstrating the relationship between the primary goals of this reference architecture, critical factors that determine the success of the architecture and individual elements that need to be modeled.

A CFA is a structured way of arriving at the requirements for a project, especially the quality attribute (non-functional) requirements; as such, it forms a natural complement to other requirements capture techniques such as use-case analysis, which are oriented more toward functional requirements capture. The CFA requirement technique and the diagram notation are summarized in Appendix B.

2.1.1 Goals

2.1.1.1 Effectiveness

A primary purpose of the SOA-RAF is to show how SOA-based systems ensure that participants can use the facilities of the system to meet their needs. This does not imply that every need has a SOA solution, but for those needs that can benefit, we look at what is needed to use the SOA paradigm effectively.

The key factors that govern effectiveness from a participant's perspective are actions undertaken– especially across ownership boundaries – with other participants in the ecosystem and lead to measurable results.

2.1.1.2 Confidence

SOA-based systems should enable service providers and consumers to conduct their business with the appropriate level of confidence in the interaction. Confidence is especially important in situations that are high-risk; this includes situations involving multiple ownership domains as well as situations involving the use of sensitive resources.

Confidence has many dimensions: confidence in the successful interactions with other participants, confidence in the assessment of trust, as well as confidence that the ecosystem is properly managed.

2.1.1.3 Scalability

The third goal of this reference architecture is scalability. In architectural terms, we determine scalability in terms of the smooth growth of complex systems as the number and complexity of services and interactions between participants increases. Another measure of scalability is the ease with which interactions can cross ownership boundaries.

2.1.2 Critical Success Factors

A critical success factor (CSF) is a property of the intended system, or a sub-goal that directly supports a goal and there is strong belief that without it the goal is unattainable. CSFs are not necessarily measurable in themselves. As illustrated in Figure 1, CSFs can be associated with more than one goal.

In many cases critical success factors are often denoted by adjectives: reliability, trustworthiness, and so on. In our analysis of the SOA paradigm however, it seems more natural to identify four critical concepts (nouns) that characterize important aspects of SOA:

2.1.2.1 Action

Participants' principal mode of participation in a SOA ecosystem is action; typically action in the interest of achieving some desired real world effect. Understanding how action is related to SOA is thus critical to the paradigm.

Action is, of course, pervasive in the ecosystem; and many models in the SOA-RAF address aspects of action. However, action is the central theme of the models labeled "Action in a Social Context" and "Action in a SOA Ecosystem".

2.1.2.2 Trust

The viability of a SOA ecosystem depends on participants being able to effectively measure the trustworthiness of the system and of participants. Trust is a private assessment of a participant's belief in the integrity and reliability of the SOA ecosystem (see Section 3.1.4).

Trust can be analyzed in terms of trust in infrastructure facilities (otherwise known as reliability), trust in the relationships and effects that are realized by interactions with services, and trust in the integrity and confidentiality of those interactions particularly with respect to external factors (otherwise known as security).

Note that there is a distinction between trust in a SOA-based system and trust in the capabilities accessed via the SOA-based system. The former focuses on the role of SOA-based systems as a *medium* for conducting business, the latter on the trustworthiness of participants in such systems. This architecture focuses on the former, while trying to encourage the latter.

2.1.2.3 Interaction

In order for a SOA ecosystem to function, it is essential that the means for participants to interact with each other is available throughout the system. Interaction encompasses not only the mechanics and semantics of communication but also the means for discovering and offering communication.

2.1.2.4 Control

Given that a large-scale SOA-based system may be populated with many services, and used by large numbers of people; managing SOA-based systems properly is a critical factor for engendering confidence in them. This involves both managing the services themselves and managing the relationships between people and the SOA-based systems they are utilizing; the latter being more commonly identified with governance.

The governance of SOA-based systems requires decision makers to be able to set policies about participants, services, and their relationships. It requires an ability to ensure that policies are effectively described and enforced. It also requires an effective means of measuring the historical and current performances of services and participants.

The scope of management of SOA-based systems is constrained by the existence of multiple ownership domains.

2.2 Principles of this Reference Architecture Foundation

The following principles serve as core tenets that guided the evolution of this reference architecture.

Technology Neutrality

Statement: Technology neutrality refers to independence from particular technologies.

Rationale: We view technology independence as important for three main reasons: technology specific approach risks confusing issues that are technology specific with those that are integrally involved with realizing SOA-based systems; and we believe that the principles that underlie SOA-based systems have the potential to outlive any specific technologies that are used to deliver them. Finally, a great proportion of this architecture is inherently concerned with people, their relationships to services on SOA-based systems and to each other.

Implications: The Reference Architecture Foundation must be technology neutral, meaning that we assume that technology will continue to evolve, and that over the lifetime of this architecture that multiple, potentially competing technologies will co-exist. Another immediate implication of technology independence is that greater effort on the part of architects and other decision makers to construct systems based on this architecture is needed.

Parsimony

Statement: Parsimony refers to economy of design, avoiding complexity where possible and minimizing the number of components and relationships needed.

Rationale: The hallmark of good design is parsimony, or “less is better.” It promotes better understandability or comprehension of a domain of discourse by avoiding gratuitous complexity, while being sufficiently rich to meet requirements.

Implications: Parsimoniously designed systems tend to have fewer but better targeted features.

Distinction of Concerns

Statement: Distinction of Concerns refers to the ability to cleanly identify and separate out the concerns of specific stakeholders in such a way that it is possible to create architectural models that reflect those stakeholders' viewpoint. In this way, an individual stakeholder or a set of stakeholders that share common concerns only see those models that directly address their respective areas of interest.

Rationale: As SOA-based systems become more mainstream and increasingly complex, it will be important for the architecture to be able to scale. Trying to maintain a single, monolithic architecture description that incorporates all models to address all possible system stakeholders and their associated concerns will not only rapidly become unmanageable with rising system complexity, but it will become unusable as well.

Implications: This is a core tenet that drives this reference architecture to adopt the notion of architectural viewpoints and corresponding views. A *viewpoint* provides the formalization of the groupings of models representing one set of concerns relative to an architecture, while a *view* is the actual representation of a particular system. The ability to leverage an industry standard that formalizes this notion of architectural viewpoints and views helps us better ground these concepts for not only the developers of this reference architecture but also for its readers. The IEEE Recommended Practice for Architectural Description of Software-Intensive Systems **[ANSI/IEEE 1471-2000::ISO/IEC 42010-2007]** is the standard that serves as the basis for the structure and organization of thisdocument.

Applicability

Statement: Applicability refers to that which is relevant. Here, an architecture is sought that is relevant to as many facets and applications of SOA-based systems as possible; even those yet unforeseen.

Rationale: An architecture that is not relevant to its domain of discourse will not be adopted and thus likely to languish.

Implications: The Reference Architecture Foundation needs to be relevant to the problem of matching needs and capabilities under disparate domains of ownership; to the concepts of "Intranet SOA" (SOA within the enterprise) as well as "Internet SOA" (SOA outside the enterprise); to the concept of "Extranet SOA" (SOA within the extended enterprise, i.e., SOA with suppliers and trading partners); and finally, to "net-centric SOA" or "Internet-ready SOA."

3 *Participation in a SOA Ecosystem* view

No man is an island
No man is an island entire of itself; every man
is a piece of the continent, a part of the main;
if a clod be washed away by the sea, Europe
is the less, as well as if a promontory were, as
well as any manner of thy friends or of thine
own were; any man's death diminishes me,
because I am involved in mankind.
And therefore never send to know for whom
the bell tolls; it tolls for thee.
John Donne

The OASIS SOA Reference Model defines Service Oriented Architecture as “a paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains” and services as “the mechanism by which needs and capabilities are brought together”. The central focus of SOA is “the task or business function – getting something done.”

Together, these ideas describe an environment in which business functions (realised in the form of services) address business needs. Service implementations utilize capabilities to produce specific (real world) effects that fulfill those business needs. Both those using the services, and the capabilities themselves, may be distributed across ownership domains, with different policies and conditions of use in force. The role of a service in the SOA context is to enable effective business solutions in a distributed environment. SOA is thus a paradigm that guides the identification, design, implementation (i,e. organization), and utilization of such services.

The *Participation in a SOA Ecosystem* view in the SOA-RAF focuses on the constraints and context in which people[7] conduct business using a SOA-based system. By business we mean any shared activity entered into whose **objective** is to satisfy particular **needs** of each person. The OASIS SOA RM defines SOA as “a paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains.” To put it another way, to effectively employ the SOA paradigm, the architecture must take into account the fact and implications of different ownership domains, and how best to organize and utilize capabilities that are distributed across those different ownership domains. These are the main architectural issues that the Participating in a SOA Ecosystem view tries to address.

The subsections below expand on the completely abstract reference model by identifying more fully and with more specificity what challenges need to be addressed in order to successfully accomplish SOA. Although this section does not provide a specific recipe, it does identify the important things that need to be thought about and resolved within an ecosystem context.

The people actively participating in a SOA-based system, together with others who may potentially benefit from the services delivered by the system, together constitute the **stakeholders**. The stakeholders, the system and the environment (or context) within which they all operate, taken together forms the **SOA ecosystem**. That ecosystem may reflect the SOA-based activities within a particular enterprise or of a wider network of one or more enterprises and individuals.Although a SOA-based system is essentailly an IT concern, it is nonetheless a system engineered deliberately to be able to function in a SOA ecosystem. In this context, a service is the mechanism that brings a SOA-based system capability together with stakeholder needs in the wider ecosystem. This is explored in more detail in Section 3.2.2 below.

Furthermore, this *Participation in a SOA Ecosystem* view helps us understand the importance of execution context – the set of technical and business elements that allow interaction to occur in, and thus business to be conducted using, a SOA-based system.

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[7] ‘People’ and ‘person’ must be understood as both human actors and ‘legal persons’, such as companies, who have rights and responsibilities similar to ‘natural persons’ (humans)

This section describes how a SOA-based system behaves when participants may be in different organizations, with different rules and expectations, and assumes that the primary motivation for participants to interact with each other is to achieve **objectives** –to get things done.

The dominant mode of communication within a SOA ecosystem is electronic, supported by IT resources and artifacts. The stakeholders are nonetheless people: since there is inherent indirection involved when people and systems interact using electronic means, we lay the foundations for how *communication* can be used to represent and enable action. However, it is important to understand that these communications are usually a means to an end and not the primary interest of the participants of the ecosystem.

Several interdependent concerns are important in our view of a SOA-ecosystem. The ecosystem includes stakeholders who are participants in the development, deployment and governance and use of a system and its services; or who may not participate but are nonetheless are affected by the system. **Actors** – whether stakeholder **participants** or delegates who act only on behalf of participants (without themselves having any stake in the ecosystem) – are engaged in **actions** which have an impact on the real world and whose meaning and intent are determined by implied or agreed-to semantics.

The main models in this view are:

- the **Social Structure in a SOA Ecosystem Model** introduces the key elements that underlie the relationships between participants and that must be considered as pre-conditions in order to effectively bring needs and capabilities together across ownership boundaries;
- the **Action in a SOA Ecosystem Model** introduces the key concepts involved in service actions, and shows how joint action and real-world effect are what is being aimed for in a SOA ecosystem..

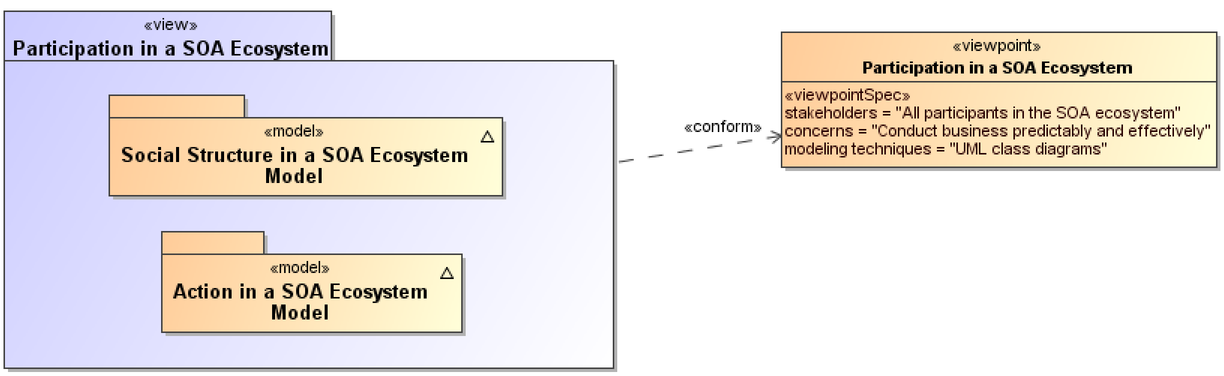


Figure 2 Model elements described in the Participation in a SOA Ecosystem *view*

3.1 Social Structure in a SOA Ecosystem Model

The actions undertaken by participants in a SOA ecosystem are performed in a *social context* that defines the relationships between the participants. That context is the social structure. In order to achieve success in SOA, the overall social structure in which the SOA effort is to be undertaken must be taken into consideration.Ownership boundaries and their implications can only be understood and addressed within the context of the larger social structure within which they exist and the nature of the relationships between the different participants in that structure.

The primary function of the Social Structure Model is to explain the relationships between an individual participant and the social context of that participant. The model also helps in defining and understanding the implications of crossing ownership boundaries. It is, for example, the foundation for understanding security, governance and management in the SOA ecosystem.

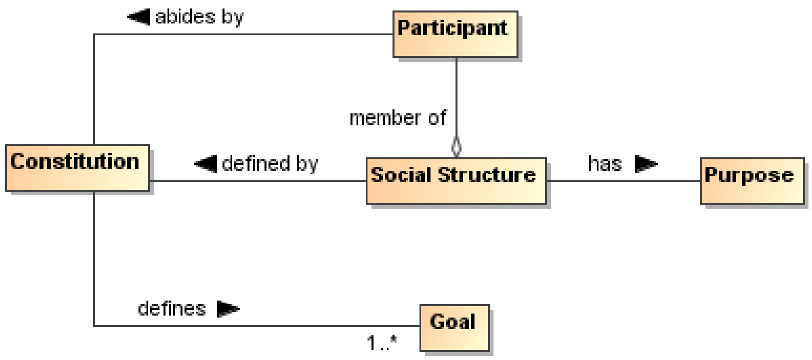


Figure 3 Social Structure

Social Structure

> A social structure[8] is a nexus of relationships amongst participants brought together for a specific purpose. (Social structures are sometimes referred to as social institutions.)

A social structure represents a collection of participants, but a collection that is brought together for a purpose. There may be a large number of different kinds of relationships between participants in a social structure. The organizing principle for these relationships is the social structure's purpose.

A social structure may have any number of participants, and a given participant can be a member of multiple social structures. Thus, there may be interaction among social structures, sometimes resulting in disagreements when the premises of the social structures do not align.

A social structure has a purpose – the overarching reason for which it exists. All social structures are established with implied or explicitly defined purpose. The purpose is usually reflected in specific goals laid down in the social structure's constitution or other 'charter'.

A social structure can take different forms. For example, an enterprise is a common kind of social structure that embodies a form of hierarchic organization; an online chat room represents a social structure of peers that is very loose. A market represents a social structure of buyers and sellers. The legal frameworks of entire countries and regions also count as social structures.

The RAF is concerned primarily with social structures that reflect relationships amongst **participants** in SOA ecosystems, notably:

- the enterprise social structure which is composed internally of many participants but that has sufficient cohesiveness to be considered as a potential stakeholder in its own right; and
- the peer group which governs relationship between participants within an ecosystem..

Enterprise

> An enterprise is a social structure with an identifiable leadership structure, and that has internally established goals that reflect a defined purpose. It can act as a participant within other social structures, including other enterprises and is represented by members of its leadership structure.

Peer Group

> A peer group is a social structure withno discernable leadership structure, that may or may not have internally established goals, but is identiable as the locus of interaction between participants with individual goals and who are considered peers of one another.

Many interactions between participants take place within social structures. Depending on the scale and internal structure of an enterprise social structure, these interactions may or may not cross ownership boundaries (an enterprise can itself be composed of sub-enterprises). However, interactions between participants within a peer social structure inherently cross ownership boundaries.

[8] Social structures are sometimes referred to as social institutions.

The nature and extent of the interactions that take place will reflect, often implicitly, degrees of trust between participants and the very specific circumstances of each participant at the time, and over the course, of the interactions. It is in the nature of an SOA ecosystem that these relationships are rendered more explicit and are formalized and form a central part of what the SOA-RM refers to as “Execution Context”.

Social structures involved in a particular interaction are not always explicitly identified. For example, when a customer buys a book over the Internet, the social structure that determines the validity of the transaction is often the legal framework of the region associated with the book vendor. Such legal jurisdiction qualification is typically buried in the fine print of the service description.

Constitution

> A constitution is a set of rules, written or unwritten, that spell out the purpose, goals, scope, and functioning of a social structure.

Every social structure functions according to rules by which participants interact with each other within the structure. In some cases, this is based on an explicit agreement, in other cases participants behave as though they agree to the constitution without a formal agreement. In still other cases, participants abide by the rules with some degree of reluctance – this is an issue raised later on when we discuss governance in SOA-based systems. In all cases, the constitution may change over time, in those cases of implicit agreement the change can occur quickly.

3.1.1 Participants, Actors and Delegates

Social structures have stakeholders, some of whom may be enterprises. They interact within the broad ecosystem. Actors operate within a system. The concept of Participant is particularly important as it reflects the hybrid role of both a Stakeholder (in the ecosystem), primarily concerned with expressing needs and seeing those needs fulfilled; and an Actor (in the System), directly involved with system-level activity. This hybrid role of Participant thus provides a bridge between the ecosystem and the system.

An actor can be either a **participant** (and thus also a stakeholder) – with a stake in the ecosystem; or a **delegate** (a human actor with no stake in the ecosystem or an automated agent), acting on behalf of a participant.

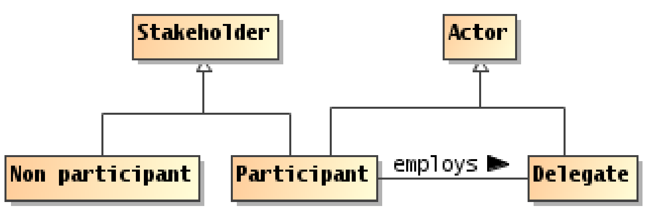


Figure 4 Actors, Participants and Delegates

Stakeholder

> A stakeholder in the SOA ecosystem is a person with an interest – a ‘stake’ – in the ecosystem.

Note: Not all stakeholders necessarily participate in the SOA ecosystem; indeed, the interest of non-participant stakeholders may be in realizing the benefits of a well-functioning ecosystem and not suffering unwanted consequences. They can not all or always be identified in advance but due account is often taken of such stakeholder types, including potential customers, beneficiaries, affected third parties, as well as potential “negative stakeholders” who might deliberately seek a negative impact on the ecosystem (such as hackers or criminals).

Actor

> An actor is a human or non-human agent capable of action within a SOA-based system.

Participant

> A participant is a person[9] who is both a stakeholder in the SOA ecosystem and an actor in the SOA-based system.

Delegate

> A delegate is an actor that is acting on behalf of a participant.

A delegate can be a person or an automated or semi-automated agent.

Many stakeholders and actors operate in a SOA ecosystem, including software agents that permit people to offer, and interact with, services; delegates that represent the interests of other participants; or security agents charged with managing the security of the ecosystem. Note that automated agents are always delegates, in that they act on behalf of a stakeholder.

In the different models of the RAF, actor is used when it is not important whether the entity is a delegate or a participant. If the actor is acting on behalf of a stakeholder, then we use delegate. This underlines the importance of delegation in SOA-based systems, whether the delegation is of work procedures carried out by human agents who have no stake in the ecosystem but act on behalf of a participant who does; or whether the delegation is performed by technology (automation). If the actor is also a stakeholder in the ecosystem, then we use participant.

In order for a delegate to act on behalf of another person, they must be able to act and have the authority to do so.

3.1.2 Roles in Social Structures

Social structures are abstractions: a social structure cannot directly perform actions – only people or automated processes following the instructions of people can actually do things. However, an actor may act on behalf of a social structure and certainly acts within a social structure depending on the roles that the actor assumes and the nature of the relationships betweent the concerned parties or stakeholders.

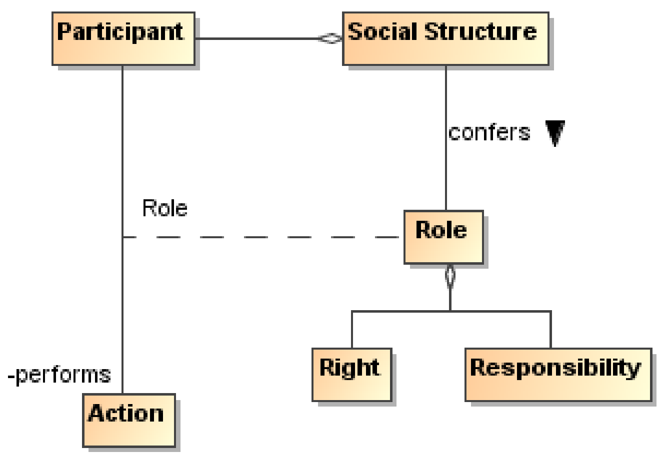


Figure 5 Role in Social Structures

Role

> A role is a type of relationship between a participant and the actions that participant may performs (or is allowed to perform) within a social structure.

A role is not immutable and is often time-bound. A participant can have one or more roles concurrently and may change them over time and in different contexts, even over the course of a particular interaction. One participant with appropriate authority in the social structure may formally *designate a role* for another

[9] Again, this can be a 'natural' or 'legal' person

participant, with associated rights and responsibilities, and that authority may even qualify a period during which the designated role may be valid.

Conversely, someone who exhibits qualification and skill may *assume a* role without any formal designation. For example, an office administrator who has demonstrated facility with personal computers may be known as (and thus assumed to role of) the ‘goto’ person for people who need help with their computers.

Although many roles are clearly identified, with appropriate names and definitions of responsibilities, it is also entirely possible to separately bestow rights, bestow or assume responsibilities and so on, often in a temporary fashion. For example, when a company president delegates certain responsibilities on another person, this does not imply that the other person has become company president. Likewise, a company president may bestow on someone else her role during a period of time that she is on vacation or otherwise unreachable, with the understanding that she will re-assume the role when she returns from vacation.

Authority

> Authority is the right or responsibility to act on behalf of an organization or another person.

Right

> A right is a predetermined permission conferred upon an actor that allows them to perform some action or assume a role in relation to the social structure.

Rights can be constrained. For example, sellers might have a general right to refuse service to potential customers but this right could be constrained so as to be exercised only when certain criteria are met.

Responsibility

> A responsibility is a predetermined obligation on a participant to perform some action or to adopt a stance or role in relation to other actors.

Responsibility implies human agency, which is why only participants, as opposed to all actors (who can be non-human agents) are concerned. even if the consequences of such responsibility can impact other (human and non-human) actors.

Rights, authorities, responsibilities and roles form the foundation for the security model as well as contributing to the governance model in the ‘Ownership in a SOA Ecosystem’ View of the RAF. Rights and responsibilities are similar in structure to permissions and obligations; except that rights and responsibilities are associated with participants as opposed to permissions and obligations which are associated with actions.

People will assume and perform roles according to their actual or perceived rights and responsibilities, with or without explicit authority. In the context of a SOA ecosystem, human abilities and skills are relevant as they equip individuals with knowledge, information and tools that may be necessary to have meaningful and productive interactions with a view to achieving a desired outcome. For example, a person who needs a particular book, and has both the right and responsibility of purchasing the book from a given bookseller, will not have that need met from the online delegate of that bookstore if he does not know how to use a web browser. Equally, just because someone does have the requisite knowledge or skills does not entitle them *per se* to interact with a specific system.

3.1.2.1 Service Roles

As in roles generically, a participant can play one or more of those roles inherent to the SOA paradigm in the SOA ecosystem, including as a service consumer, a service provider, a mediator, and so on, depending on the context. A participant may be playing a role of a service provider in one relationship while simultaneously playing the role of a consumer in another. Roles inherent to the SOA paradigm include Consumer, Provider, and Mediator.

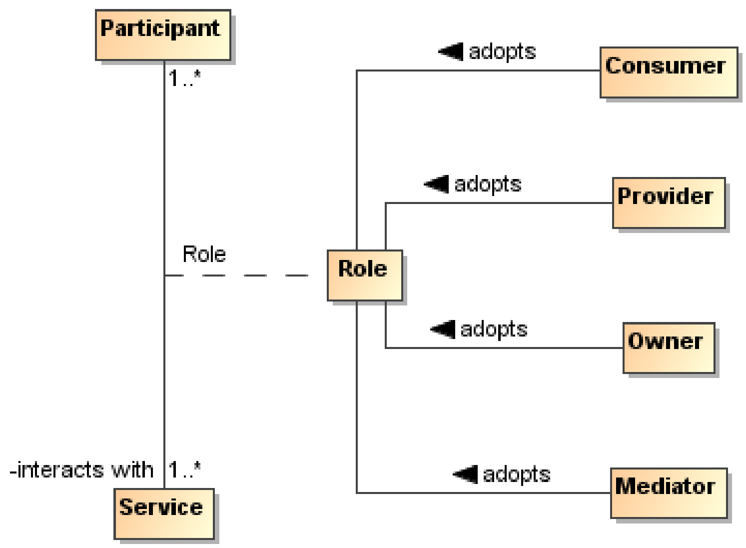


Figure 6 Participant Roles in a Service

Provider

A provider is a role assumed by a participant who is offering a service.

Consumer

A consumer is a role assumed by a participant who is interacting with a service in order to fulfill a need.

Mediator

A mediator is a role assumed by a participant to facilitate interaction and connectivity in the offering and use of services.

Owner

An owner is a role assumed by a participant who is claiming and exercising ownership over a service.

It is a common understanding that service interactions are typically initiated by service consumers, although this is not necessarily true in all situations. Additionally, as with service providers, several stakeholders may be involved in a service interaction supporting a given consumer.

The roles of service provider and service consumer are often seen as symmetrical, which is also not entirely correct. A consumer tends to express a ‘Need’ in non-formal terms: “I want to buy that book”. The type of ‘Need’ that a service is intended to fulfill has to be formalized and encapsulated by designers and developers as a ‘Requirement’. This Requirement should then be reflected in the target service, as a ‘Capability’that, when accessed via a service, delivers a ‘Real World Effect’ to an arbitrary user: “The chosen book is ordered for the user” It thus satisfies the need that has been defined for an archetypal user. Specific and particular users may not experience a need exactly as captured by the service: “I don’t want to pay that much for the book”, “I wanted an eBook version”, etc. There can therefore be a process of implicit and explicit negotiation between the user and the service, aimed at finding a ‘best fit’ between the user’s specific need and the capabilities of the service that are available and consistent with the service provider’s offering. This process may continue up until the point that the user is able to accept what is on offer as being the best fit and finally ‘invokes’ the service. ‘Execution context’ has thus been established. This is explored in more detail later on. Service mediation by a participant can take many forms and may invoke and use other services in order to fulfill such mediation. For example, it might use a service registry in order to identify possible service partners; or, in our book-buying example, it might provide a price comparison service, suggest alternative suppliers, different language editions or delivery options.

3.1.3 Resource and Ownership

3.1.3.1 Resource

A resource is generally understood as an asset: it has value to someone. Key to this concept in a SOA ecosystem is that a resource needs to be identifiable.

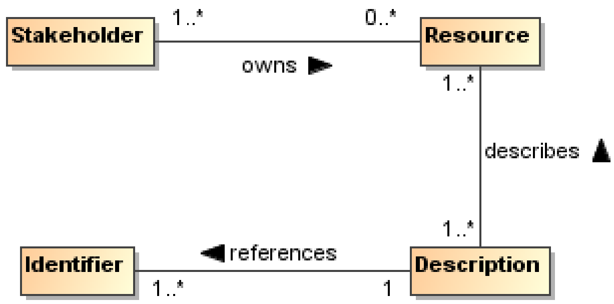


Figure 7 Resources

Resource

> A resource is any identifiable entity that has value to a stakeholder.

A resource may be identifiable by different methods but within a SOA ecosystem a resource must have at least one well-formed identifier that may be unambiguously resolved to the intended resource.

Codified (but not *implied*) contracts, policies, obligations, and permissions are all examples of resources as are capabilities , services, service descriptions, and SOA-based systems. An *implied* policy, contract, obligation or permission would not be a resource, even though it may have value to a stakeholder, because it is not an identifiable entity.

Identifier

> An identifier is any sequence of characters that may be unambiguously resolved to identifying a particular resource.

Identifiers typically require a context in order to establish the connection with the resource. In a SOA ecosystem, it is good practice to use globally unique identifiers; for example globally unique IRIs.

A given resource may have multiple identifiers, with different value for different contexts.

The ability to identify a resource is important in interactions to determine such things as rights and authorizations, to understand what functions are being performed and what the results mean, and to ensure repeatability or characterize differences with future interactions. The specific subset of individual characteristics that are necessary and sufficient in order to unambiguously identify a resource depends on the ecosystem and/or specific interactions within a system. However, in order to enable visibility and interaction in a SOA ecosystem, those resources that are important to a given SOA system must be *unambiguously* identifiable at any moment and in any interaction, many of which may not be predictable given the operation of systems across ownership boundaries. The way to achieve this is by using identifiers.

3.1.3.2 Ownership

Ownership is defined as a relationship between a stakeholder and a resource, where some stakeholder (in a role as **owner**) has certain claims with respect to the resource.

Typically, the ownership relationship is one of control: the owner of a **resource** can control some aspect of the resource.

Ownership

> Ownership is a particular set of claims, expressed as rights and responsibilities, that a stakeholder has in relation to a resource; It may include the right to transfer that ownership, or some subset of rights and responsibilities, to another entity.

To own a resource implies taking responsibility for creating, maintaining and, if it is to be available to others, provisioning the resource. More than one stakeholder may own different rights or responsibilities associated with a given service, such as one stakeholder having the responsibility to deploy a capability as a service, another owning the rights to the profits that result from charging consumers for using the service, and yet another owning the right to use the service.

A stakeholder who owns a resource may delegate some or all of these rights and responsibilities to others, but typically retains the responsibility to see that the delegated rights and responsibilities are exercised as intended. There may also be joint ownership of a resource, where the rights and responsibilities are shared.

A crucial property that distinguishes ownership from a more limited ***right to use*** is the right to transfer rights and responsibilities totally and irrevocably to another stakeholder. When a stakeholder uses a resource but does not own the resource, that stakeholder may not transfer the right to use the resource to a third stakeholder. The owner of the resource maintains the rights and responsibilities of being able to authorize other stakeholders to use the owned resource.

Ownership is defined in relation to the social structure relative to which the given rights and responsibilities are exercised. In particular, there may be constraints on how ownership may be transferred. For example, a government may not permit a corporation to transfer assets to a subsidiary in a different jurisdiction.

Ownership Boundary

> An ownership boundary is the extent of ownership asserted by a stakeholder over a set of resources and for which rights and responsibilities are claimed and (usually) recognized by other stakeholders.

In a SOA ecosystem, providers and consumers of services may be, or may be acting on behalf of, different owners, and thus the interaction between the provider and the consumer of a given service will necessarily cross an ownership boundary. It is important to identify these ownership boundaries in a SOA ecosystem, as successfully crossing them requires the elements identified in the following sections be addressed. Addressing the elements identified in the following sections is referred to in the OASIS SOA RM as establishing the execution context.

3.1.4 Trust and Risk

For an interaction to occur each actor must be able and **willing** to participate.

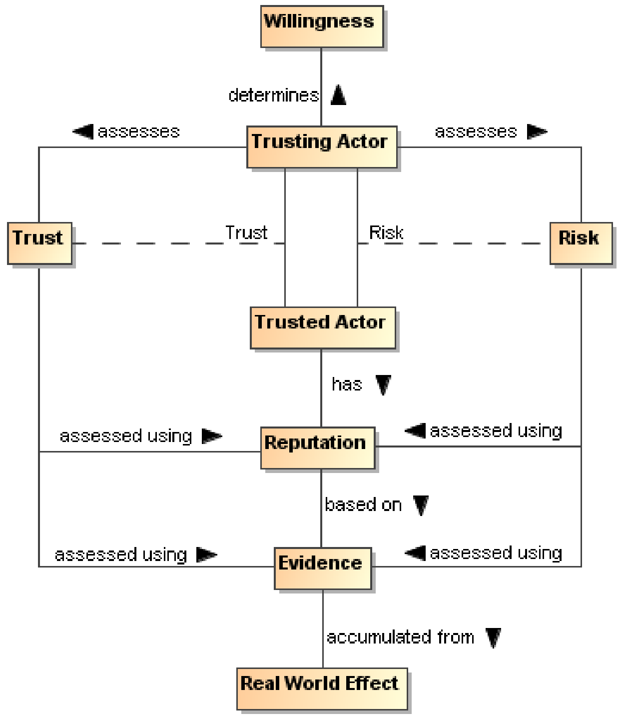


Figure 8 Willingness and Trust

Willingness

> Willingness is the internal commitment of a human actor to carry out its part of an interaction.

Willingness to interact is not the same as a willingness to perform requested actions, however. For example, a service provider that rejects all attempts to perform a particular action may still be fully willing and engaged in interacting with the consumer. Important considerations in establishing willingness are both **trust** and **risk**.

Trust

> Trust is a private assessment or internal perception of one participant that another participant will perform actions in accordance with an assertion regarding a desired real world effect.

Risk

> Risk is a private assessment or internal perception of the likelihood that certain undesirable real world effects will result from actions taken, or that the RWE might not meet certain criteria (e.g., performance), and the consequences or implications of such.

Trust is involved in all interactions – it is necessary for *all* the actors (consumers, providers, mediators) involved in a given interaction to trust each other at least to the extent required for continuance of the interaction. The degree and nature of that trust is likely to be different for each actor, most especially when those actors are in different ownership boundaries.

An actor perceiving risk may take actions to mitigate that risk. At one extreme this will result in a refusal to interact. Alternately, it may involve adding protection – for example by using encrypted communication and/or anonymization – to reduce the perception of risk. Often, standard procedures are put in place to increase trust and to mitigate risk.

Assessing Trust and Risk

The assessments of trust and risk are based on evidence available to the *trusting* participant. In general, participants will seek evidence directly from the *trusted* actor (e.g., via documentation provided via the service description) as well as evidence of the reputation of the trusted actor (e.g., third-party annotations such as consumer feedback).

Trust is based on the confidence that the trusting participant has accurately and sufficiently gathered and assessed evidence to the degree appropriate for the situation being assessed.

Assessment of trust is rarely binary. An actor is not completely trusted or untrusted. There is typically some degree of uncertainty in the accuracy or completeness of the evidence or the assessment. Similarly, there may be uncertainty in the amount and potential consequences of risk.

The relevance of trust to interaction depends on the assessment of risk. If there is little or no perceived risk, or the risk can be covered by another party who accepts responsibility for it, then the degree of trust may be less or not relevant in assessing possible actions. For example, most people consider there to be an acceptable level of risk to privacy when using search engines, and submit queries without any sense of trust being considered.

As perceived risk increases, the issue of trust becomes more of a consideration. For interactions with a high degree of risk, the trusting participant will typically require stronger or additional evidence when evaluating the balance between risk and trust. An example of high-risk is where a consumer's business is dependent on the provider's service meeting certain availability and security requirements. If the service fails to meet those requirements, the service consumer will go out of business. In this example, the consumer will look for evidence that the likelihood of the service not meeting the performance and security requirements is extremely low.

3.1.5 Policies and Contracts

As noted in the Reference Model, a **policy** represents some commitment and/or constraint promulgated and enforced by a stakeholder and that stakeholder alone. A **contract**, on the other hand, represents an agreement by two or more participants. Enforcement of contracts may or may not be the responsibility of the parties to the agreement but is usually performed by a stakeholder in the ecosystem (public authority, legal system, etc.).

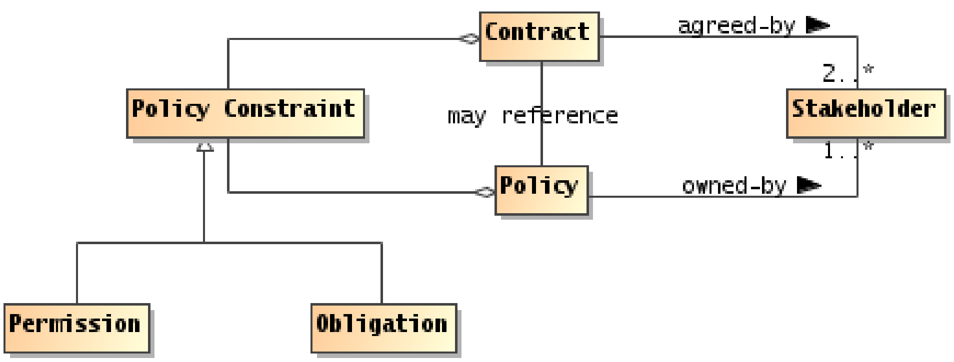


Figure 9 Policies and Contracts

Policy

> A policy is an assertion made by a stakeholder which the stakeholder commits to uphold and, if possible and necessary, enforce through stated constraints.

Policies can often be said to be about something – they have an object. For example, there may be policies about the use of a service. Policies have an **owner** – the stakeholder who asserts and takes responsibility for the policy. Note that the policy owner may or may not be the owner of the object of the policy. Thirdly, policies represent constraints – some measurable limitation on the state or behavior of the object of the policy, or of the behavior of the stakeholders of the policy.

Contract

> A contract represents an agreement made by two or more participants (the contracting parties) on a set of promises (or contractual terms) together with a set of constraints that govern their behavior and/or state in fulfilling those promises.

A service provider's policy may become a service provider/consumer contract when a service consumer agrees to the provider's policy. That agreement may be formal, or may be informal. If a consumer's policy and a providers policy are mutually exclusive, then some form of negotiation or mediation to resolve the mutual exclusion before the service consumer/provider interaction can occur.

Both policies and contracts imply a desire to see constraints respected and enforced. Policies are owned by individual (or aggregate) stakeholders, and contracts are owned by the parties to the contract; these stakeholders are responsible for ensuring that any constraints in the policy or contract are enforced – although, of course, the actual enforcement may be delegated to a different mechanism. A contract does not necessarily oblige the contracting parties to act (for example to use a service) but it does constraint how they act if and when action covered by the contract occurs (for example, when a service is invoked and used).

Two important types of constraint that are relevant to a SOA ecosystem are permission and Obligation.

Permission

> A permission is a constraint that identifies **actions** that an actor is (or is not) allowed to perform and/or the **states** the actor is (or is not) permitted to be in.

Note that permissions are distinct from ability and from authority. Authority refers to the legitimate nature of an action as performed by an actor on behalf of a social structure and ability refers to whether an actor has the capacity to perform the action, whereas permission does not always involve acting on behalf of anyone, nor does it imply or require the capacity to perform the action.

Obligation

> An obligation is a constraint that prescribes the actions that an actor must (or must not) perform and/or the states the actor must (or must not) be in.

An example of obligations is the case where the service consumer and provider have entered into an agreement to provide and consume a service such that the consumer is obligated to pay for the service and the provider is obligated to provide the service – based on the terms of the contract.

An obligation can also be a requirement to to *maintain* a given state. This may range from a requirement to maintain a minimum balance on an account to a requirement that a service provider ‘remember’ that a particular service consumer is logged in.

Both permissions and obligations can be identified ahead of time, but only Permissions can be validated a priori: before the intended action or before entering the constrained state. Obligations can only be validated a posteriori through some form of auditing or verification process.

3.1.6 Communication

Communication

> A communication is a process of reaching mutual understanding, in which participants not only exchange information as messages but also create and share meaning..

A communication involves one or more actors playing the role of **sender** and at least one other actor playing the role of **recipient**; all actors must perform their part in order for the communication to occur.

A given communication may involve any number of **recipients**. In some situations, the sender may not be aware of the recipient. However, without both a sender and a recipient there is no communication. A given communication does not necessarily involve interaction between the actors; it can be a simple one-way transmission requiring no further action by the recipient. However, interaction does, necessarily, involve communication.

A communication involves a message, which an actor receiving must be able to correctly interpret. The extent of that correct interpretation depends on the role of the actor and the purpose of the communication.

A communication is not effective unless the recipient can correctly interpret the message. However, interpretation can itself be characterized in terms of semantic engagement: the proper understanding of a message in a given context.

We can characterize the necessary modes of interpretation in terms of a shared understanding of a common vocabulary and of the purpose of the communication. More formally, we can say that a communication has a combination of message and purpose.

Interactions between service consumers and providers do not need to resemble human speech. Machine-machine communication is typically highly stylized in form, it may have particular forms and it may involve particular terms not found in everyday human communication.

3.1.7 Semantics and Semantic Engagement

A SOA ecosystem is a space in which actors need to share understanding[10] as well as sharing actions. Indeed, such shared understanding is a pre-requisite to a joint action being carried out as intended. It is vital to a trusted and effective ecosystem. Semantics are therefore pervasive throughout SOA ecosystems and important in communicative actions described above, as well as a driver for policies and other aspects of the ecosystem.

In order to arrive at shared understanding, an actor must effectively process and understand assertions in a manner appropriate to the particular context. An assertion, in general, is a measurable and explicit statement made by an actor. In a SOA ecosystem, in particular, assertions are concerned with the 'what' and the 'why' of the state of the ecosystem and its actors.

Understanding and interpreting those assertions allows other actors to know what may be expected of them in any particular joint action. An actor can potentially 'understand' an assertion in a number of ways, but it is specifically the process of arriving at a *shared* understanding that is important in the ecosystem. This process is semantic engagement by the actor with the SOA ecosystem. It can be instantaneous or progressively achieved. It is important that there is a level of engagement appropriate to the particular context.

Semantic Engagement

> Semantic engagement is the process by which an actor engages with a set of assertions based on that actor's interpretation and understanding of those assertions.

Different actors have differing capabilities and requirements for understanding assertions. This is true for both human and non-human actors. For example, a purchase order process does not require that a message forwarding agent 'understand' the purchase order, but a processing agent does need to 'understand' the purchase order in order to know what to with the order once received.

The impact of any assertion can only be fully understood in terms of specific social contexts; contexts that necessarily include the actors that are involved. For example, a policy statement that governs the actions relating to a particular resource may have a different impact or purpose for the participant that owns the resource than for the actor that is trying to access it: the former understands the purpose of the policy as a statement of enforcement; and the latter understands it as a statement of constraint.

3.2 Action in a SOA Ecosystem Model

Participants cannot always achieve desired results leveraging resources in their own ownership domain; thus generating a need for which they look for and leverage services provided by other participants, using resources beyond their ownership and control; They identify service providers with which they think they can interact to achieve their objective; They thus engage in joint action with those other actors (service providers) in order to bring about the desired outcome; the SOA ecosystem provides the environment to make this happen.

An action model is put forth a-priori by the service provider, and is effectively a promise by the service provider that the actions identified in the action model and invoked consistent with the process model will result in the described real world effect. Action model is basically a description of the actions that the service is willing to do on behalf of another. They should be associated with a real-world effect. The potential service consumer is interested in accessing or acquiring the real-world effect, and the action model identifies the actions that the service consumer will have to be a party to in order to access or generate the real-world effect.

[10] We use a mechanical, Turing test-based approach to understanding here: if an actor behaves as though it understands an utterance then we assume that it does understand it.

When the consumer "invokes" a service, a joint action is started as identified in the action model, consistent with the temporal sequence as defined by the process model, and where the consumer and the provider are the two parties of the joint action. Additionally, the consumer can be assured that the identified real-world effects will be accomplished through evidence provided via the service description.

Since the service provider does not know about all potential service consumers, the service provider may also describe what additional constraints are necessary in order for the service consumer to invoke particular actions, and thus participate in the joint action. These additional constraints, along with others that might not be listed, are preconditions for the joint action to occur and/or continue (as per the process model), and are referred to in the SOA RM as execution context. Execution context goes all the way from human beings involved in aligning policies, semantics, network connectivity and communication protocols, to the automated negotiation of security protocols and end-points as the individual actions proceed through the process model.

Also, it is important to note that both actions and RWE are 'fractal' in nature, in the sense that they can often be broken down into more and more granularity depending on how they are examined and what level of detail is important.

All of these things are important to getting to the core of participants' interest in a SOA ecosystem: the ability to leverage resources or capabilities to achieve a desired outcome, and in particular where those resources or capabilities do not belong to them or are beyond their direct control. i.e., that are outside of their ownership boundary.

In order to use such resources, participants must be able to identify their own needs in the form of requirements, identify and compose into a business solution those resources or capabilities that will meet their needs, and engage in joint action – the coordinated set of actions that participants pursue in order to achieve measurable results in furtherance of their goals.

In order to act in a way that is appropriate and consistent both to their own goals, objectives and policies, and those of others, participants must also communicate with each other.

A key aspect of joint action revolves around the trust that both parties must exhibit in order to participate in the joint action. The willingness to act and a mutual understanding of both the information exchanged and the expected results is the particular focus of Sections **Error! Reference source not found.**6 and 3.1.7.

3.2.1 Needs, Requirements and Capabilities

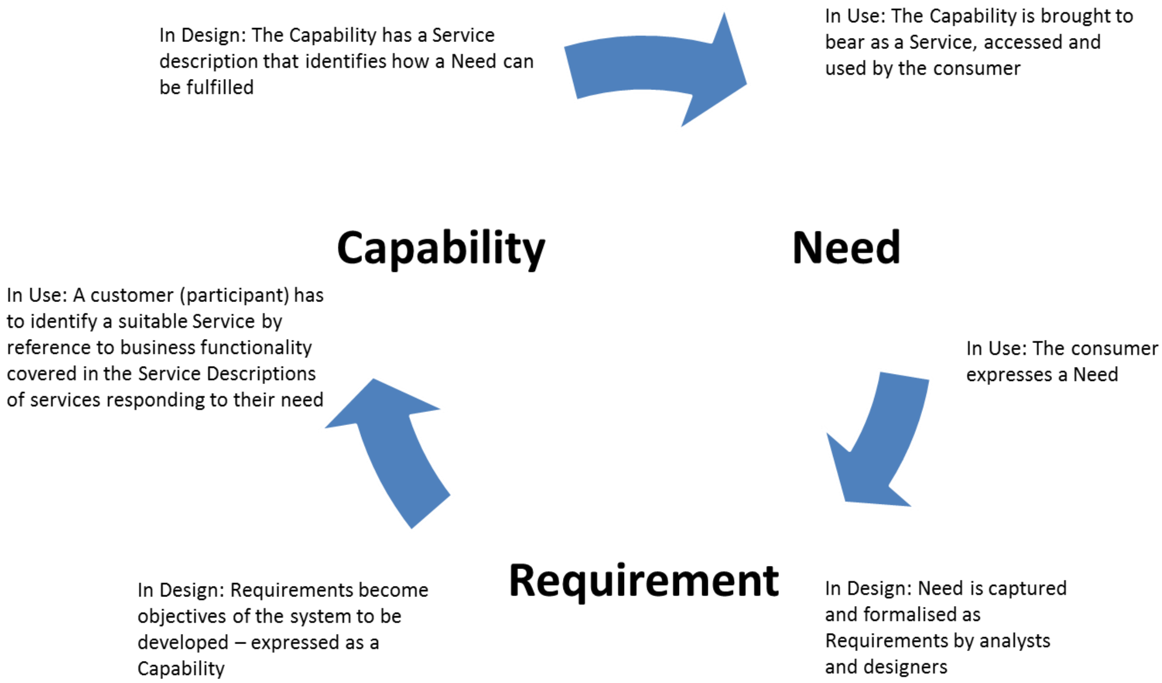
Participants in a SOA ecosystem often need other participants to *do* something, leveraging a capability that they do not themselves possess. For example, a customer requiring a book may call upon a service provider to deliver the book. Likewise, the service provider needs the customer to pay for it.

There is a reason that participants are engaged in this activity: different participants have different **needs** and have or apply different **capabilities** for satisfying them.These are core to the concept of a service. The SOA-RM defines a service as "the mechanism by which needs and capabilities are brought together". This idea of services being a mechanism "between" needs and capabilities was introduced in order to emphasize capability as the notional or existing business functionality that would address a well-defined need. Service is therefore the *implementation* of such business functionality *such that it is accessible* through a well-defined interface. A capability that is isolated, or by itself (i.e., not accessible to potential consumers) is emphatically not a service.

Business functionality

Business functionality is a defined set of business-aligned tasks that provide recognizable business value to ‘consumer’ stakeholders and possibly others in the SOA ecosystem.

Figure 10 Realtionship between Need, Requirement and Capability



The idea of a service in a SOA ecosystem combines business functionality with implementation, including the artifacts needed and made available as IT resources. From the perspective of software developers, a SOA service enables the use of capabilities in an IT context. For the consumer, the service (combining business functionality and implementation) generates intended real world effects. The consumer is not concerned with the underlying artifacts which make that delivery possible.

In a SOA context, the consumer (as a stakeholder) expresses a need (“I want to buy a book”) and looks to an appropriate service to fulfill that need and assesses issues such as the trustworthiness, intent and willingness of a particular provider. This ecosystem communication continues up to the point when the consumer is ready to act. The consumer (as an actor now) will then interact with a provider by invoking a service (for example, ordering the book using an online bookseller) and engaging in relevant actions (validating the purchase, submitting billing and delivery details) within the system with a view to achieving the desired Real World Effect (having the book delivered).

Need

A need is a general statement expressed by a stakeholder of the lack of something deemed necessary. It may be formalized as one or more **requirements** that must be fulfilled in order to achieve a stated goal.

Requirement

A requirement is a formal statement of a desired result (a real world effect) that, if achieved, will satisfy a need.

This requirement can then be used to create a capability that in turn can be brought to bear to satisfy that need. Both the requirement and the capability to fulfill it are expressed in terms of desired real world effect.

Capability

A capability is an ability to achieve a real world effect.

The Reference Model makes a distinction between a capability (as a potential to generate a real world effect) and the ability of bringing that capability to bear (via a realized service) as the realization of the real world effect.

3.2.2 Services Reflecting Business

The SOA paradigm often emphasizes the prescribed interface through which service interaction is accomplished. While this enables predictable integration in the sense of traditional software development, the prescribed interface alone does not guarantee that services will be composable into business solutions.

Business solution

> A **business solution** is a set of defined interactions that combine implemented or notional business functionality in order to address a set of business needs.

Composability

> **Composability** is the ability to combine individual services, each providing defined business functionality, so as to provide more complex business solutions.

Composability is important because many of the benefits of a SOA approach assume multiple uses for services, and multiple use requires that the service deliver a business function that is reusable in multiple business solutions.

To achieve composability, capabilities must be identified that serve as building blocks for business solutions. In a SOA ecosystem, these building blocks are captured as services representing well-defined business functions, operating under well-defined policies and other constraints, and generating well-defined real world effects. These service building blocks should be relatively stable so as not to force repeated changes in the compositions that utilize them, but should also embody SOA attributes that readily support creating compositions that can be varied to reflect changing circumstances.

The SOA paradigm emphasizes both composition of services and opacity of how a given service is implemented. With respect to opacity, the SOA-RM states that the service could carry out its described functionality through one or more automated and/or manual processes that in turn could invoke other available services.

Any composition can itself be made available as a service and the details of the business functionality, conditions of use, and effects are among the information documented in its service description.

For services to be useful as composable building blocks in the SOA ecosystem, the services should, whenever possible, deliver capability that is applicable to multiple needs. Simply providing a Web Service interface for an existing IT artifact does not, in general, create opportunities for sharing business functions. Furthermore, the use of tools to auto-generate service software interfaces will not guarantee services than can effectively be used within compositions if the underlying code represents programming constructs rather than business functions. In such cases, services that tightly reflect the software details will be as brittle to change as the underlying code and will not exhibit the undefined but intuitive characteristic of loose coupling.

3.2.3 Action, Communication and Joint Action

In general terms, entities act in order to achieve their goals. However, the form of action that is of most interest within a SOA ecosystem is that involving interaction across ownership boundaries (between more than one actor) – **joint action.**

3.2.3.1 Action and Actors

Action

> An action is the application of intent to cause an effect.

The aspect of action that distinguishes it from mere force or accident is that someone *intends* that the action achieves a desired objective or effect. This definition of action is very general. In the case of SOA, we are mostly concerned with actions that take place within a system and have specific effects on the

SOA ecosystem – what we call **Real World Effects**. The actual real world effect of an action, however, may go beyond the intended effect.

Objectives refer to real world effects that participants believe are achievable by a specific action or set of actions that deliver appropriate changes in shared state. In contrast, a goal is not expressed in terms of specific action but rather in terms of desired end state.

For example, someone may wish to have enough light to read a book. In order to satisfy that goal, the reader walks over to flip a light switch. The *objective* is to change the state of the light bulb, by turning on the lamp, whereas the *goal* is to be able to read. The *real world effect* is more light being available to enable the person to read.

While an effect is any measurable change resulting from an action, a SOA ecosystem is concerned more specifically with real world effects.

Real World Effect

> A real world effect is a measurable change to the shared state of pertinent entities, relevant to and experienced by specific stakeholders of an ecosystem.

This implies measurable change in the overall state of the SOA ecosystem. In practice, however, it is specific state changes of certain entities that are relevant to particular participants that constitute the real world effect as experienced by those participants.

3.2.3.2 Communication and Joint Actions

In this Reference Architecture Foundation, we are concerned with two levels of activity: as communication and as participants engaged in joint actions to use and offer services.

In order for multiple actors to participate in a joint action, they must each act according to their role within the joint action. This is achieved through communication and messaging.

Communication – the formulation, transmission, receipt and interpretation of messages – is the foundation of all joint actions within the SOA ecosystem, given the inherent separation – often across ownership boundaries – of actors in the system.

Communication between actors requires that they play the roles of ‘sender’ or ‘receiver’ of messages as appropriate to a particular action – although it is not necessarily required that they both be active simultaneously.

An actor sends a message in order to communicate with other actors. The communication itself is often not intended as part of the desired real world effect but rather includes messages that seek to establish, manage, monitor, report on, and guide the joint action throughout its execution.

Like communication, joint action usually involves different actors. However, joint action – resulting from the deliberate actions undertaken by different actors – *intentionally* impacts shared state within the system leading to real world effects.

Joint Action

> Joint action is the coordinated set of actions involving the efforts of two or more actors to achieve an effect.

Note that the effect of a joint action is *not* always equivalent to one or more effects of the individual actions of the participating actors, i.e., it may be more than the sum of the parts.

Different viewpoints lead to either communication or joint action as being considered most important. For example, from the viewpoint of ecosystem security, the integrity of the communications may be dominant; from the viewpoint of ecosystem governance, the integrity of the joint action may be dominant.

3.2.4 State, Shared State and Real-World Effect

State

> State is the condition of an entity at a particular time.

State is characterized by a set of facts that is true of the entity. In principle, the total state of an entity (or the world as a whole) is unbounded. In practice, we are concerned only with a subset of the State of an entity that is measurable and useful in a given context.

For example, the total state of a lightbulb includes the temperature of the filament of the bulb. It also includes a great deal of other state – the composition of the glass, the dirt that is on the bulb's surface and so on. However, an actor may be primarily interested in whether the bulb is 'on' or 'off' and not on the amount of dirt accumulated. That actor's characterization of the state of the bulb reduces to the fact: 'bulb is now on'.

In a SOA ecosystem, there is a distinction between the set of facts about an entity that only that entity can access – the so-called Private State – and the set of facts that may be accessible to other actors in the SOA-based system – the public or Shared State.

Private State

> The private state is that part of of an entity's state that is knowable by, and accessible to, only that entity.

Shared State

> Shared state is that part of an entity's state that is knowable by, and may be accessible to, other actors.

Note that shared state does not imply that the state *is* accessible to *all* actors. It simply refers to that subset of state that *may* be accessed by *other* actors. Generally this will be the case when actors need to participate in joint actions.

It is the aggregation of the shared states of pertinent entities that constitutes the desired effect of a joint action. Thus the change to this shared state is what is experienced in the wider ecosystem as a real world effect

3.3 Architectural Implications

3.3.1 Social structures

A SOA ecosystem's participants are organized into various forms of social structure. Not all social structures are hierarchical: a SOA ecosystem should be able to incorporate peer-to-peer forms of organization as well as hierarchic structures. In addition, it should be possible to identify and manage any constitutional agreements that define the social structures present in a SOA ecosystem.

- Different social structures have different rules of engagement
  - Techniques for expressing constitutions are important
- social structures have roles and members
  - Techniques for identifying, managing members of social structures
  - Techniques for describing roles and role adoption
- social structures may be complex
  - Child social structures' constitutions depend on their parent constitutions
- Social structures overlap and interact
  - A given actor may be member of multiple social structures
  - Social structures may be associated with different jurisdictions
  - Social structures may involved in disputes with one another
    - Requiring conflict resolution
  - Social structures inform and limit the "kinds" of governance that can be effectively deployed

3.3.2 Resource and Ownership

Communication about and between, visibility into, and leveraging of resources requires the unambiguous identification of those resources. Ensuring unambiguous identities implies

- Mechanism for assigning and guaranteeing uniqueness of globally unique identifiers

- Identifying the extent of the enterprise over which the identifier needs to be understandable and unique
- Mechanism and framework for ensuring the long-livedness of identifiers (i.e., they cannot just change arbitrarily)

3.3.3 Policies and Contracts

- Policies are constraints
  - It is necessary to be able to express required policies
  - It is necessary to be able to enforce the constraints
  - It is necessary to manage potentially large numbers of policies
- Policies have owners
  - The right to establish policies is an aspect of the social structure.
- Policies may not be consistent with one another
  - Policy conflict resolution techniques
- Agreements are constraints agreed to
  - Contracts often need to be enforced by mechanisms of the social structure

3.3.4 Communications as a Means of Mediating Action

Using message exchange for mediating action implies

- Ensuring correct identification of the structure of messages:
  - Identifying the syntax of the message;
  - Identifying the vocabularies used in the communication
  - Identifying the higher-level structure such as the illocutionary form of the communication
- A principal objective of communication is to mediate action
  - Messages convey actions and events
  - Receiving a message is an action, but is not the same action as the action conveyed by the message
  - Actions are associated with objectives of the actors involved
    - Explicit representation of objectives may facilitate automated processing of messages
  - An actor agreeing to adopt an objective becomes responsible for that objective

3.3.5 Semantics

Semantics is pervasive in a SOA ecosystem. There are many forms of utterance that are relevant to the ecosystem: apart from communicated content there are policy statements, goals, purposes, descriptions, and agreements which are all forms of utterance.

The operation of the SOA ecosystem is significantly enhanced if

- A careful distinction is made between public semantics and private semantics. In particular, it MUST be possible for actors to process content such as communications, descriptions and policies solely on the basis of the public semantics of those utterances.
- A well founded semantics ensures that any assertions that are essential to the operator of the ecosystem (such as policy statements, and descriptions) have carefully chosen written expressions and associated decision procedures.
- The role of vocabularies as a focal point for multiple actors to be able to understand each other is critical. While no two actors can fully share their interpretation of elements of vocabularies, ensuring that they do understand the public meaning of vocabularies' elements is essential.

3.3.6 Trust and Risk

In traditional systems, the balance between trust and risk is achieved by severely restricting interactions and by controlling the participants of a system.

It is important that actors are able to explicitly reason about both trust and risk in order to effectively participate in a SOA ecosystem. The more open and public the SOA ecosystem is, the more important it is for actors to be able to reason about their participation.

3.3.7 Needs, Requirements and Capabilities

In the process of capturing needs as requirements, and the subsequent requirements decomposition and allocation processes need to be informed by capabilities that already exist.

- Architecture needs to
  - Take into account existing capabilities available as services

3.3.8 The Importance of Action

Participants participate in a SOA ecosystem in order to get their needs met. This involves action; both individual actions and joint actions.

Any architectural realization of a SOA ecosystem should address:

- How actions are modeled:
  - Identifying the performer or agent of the action;
  - the target of the action; and the
  - verb of the action.

Any explicit models of joint action should take into account

- The choreography that defines the joint action.
- The potential for multiple joint actions to be layered on top of each other

4 *Realization of a SOA Ecosystem* view

Make everything as simple as possible but no simpler.
Albert Einstein

The *Realization of a SOA Ecosystem* view focuses on the infrastructure elements that are needed in order to support the discovery and interaction with services. The key questions asked are "What are services, what support is needed and how are they realized?"

The models in this view include the Service Description Model, the Service Visibility Model, the Interacting with Services Model, and the Policies and Contracts Model.

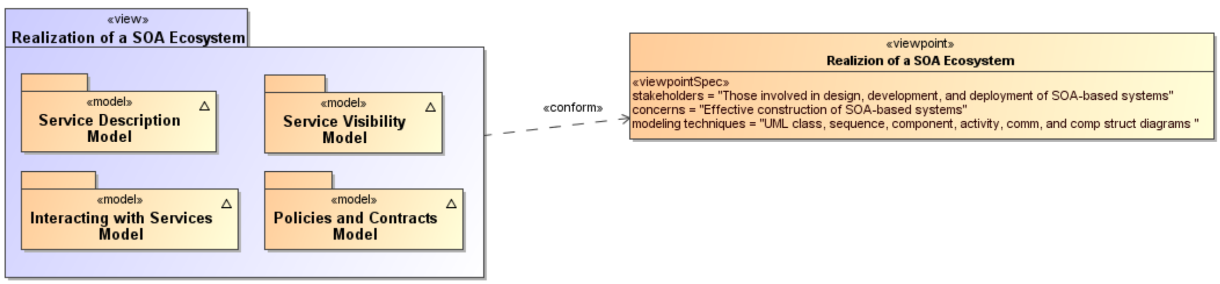


Figure 11 Model Elements Described in the Realization of a SOA Ecosystem *view*

The Service Description Model informs the participants of what services exist and the conditions under which these can be used. Some of those conditions follow from policies and agreements on policy that flow from the Policies and Contracts Model. The information in the service description as augmented by details of policy provides the basis for visibility as defined in the SOA Reference Model and captured in the Service Visibility Model. Finally, the process by which services as described are used under the defined conditions and agreements is described in the Interacting with Services Model.

4.1 Service Description Model

A service description is an artifact, usually document-based, that defines or references the information needed to use, deploy, manage and otherwise control a service. This includes not only the information and behavior models associated with a service to define the service interface but also includes information needed to decide whether the service is appropriate for the current needs of the service consumer. Thus, the service description will also include information such as service reachability, service functionality, and the policies and contracts associated with a service.

A service description artifact may be a single document or it may be an interlinked set of documents. For the purposes of this model, differences in representation are to be ignored, but the implications of a "web of documents" is discussed later in this section.

There are several points to note regarding the following discussion of service description:

- The Reference Model states that one of the hallmarks of SOA is the large amount of associated description. The model presented below focuses on the description of services but it is equally important to consider the descriptions of the consumer, other participants, and needed resources other than services.
- Descriptions are inherently incomplete but may be determined as *sufficient* when it is possible for the participants to access and use the described services based only on the descriptions provided. This means that, at one end of the spectrum, a description along the lines of "*That service on that machine*" may be sufficient for the intended audience. On the other extreme, a service description with a machine-process-able description of the semantics of its operations and real world effects may be required for services accessed via automated service discovery and planning systems.
- Descriptions come with context, i.e. a given description comprises information needed to adequately support the context. For example, a list of items can define a version of a service, but for many

contexts an indicated version number is sufficient without the detailed list. The current model focuses on the description needed by a service consumer to understand what the service does, under what conditions he service will do it, how well does the service do it, and what steps are needed by the consumer to initiate and complete a service interaction. Such information also enables the service provider to clearly specify what is being provided and the intended conditions of use.

- Descriptions change over time as, for example, the ingredients and nutrition information for food labeling continues to evolve. A requirement for transparency of transactions may require additional description for those associated contexts.
- Description always proceeds from a basis of what is considered "common knowledge". This may be social conventions that are commonly expected or possibly codified in law. It is impossible to describe everything and it can be expected that a mechanism as far reaching as SOA will also connect entities where there is inconsistent "common" knowledge.
- Descriptions will become the collection point of information related to a service or any other resource, but it is not necessarily the originating point or the motivation for generating this information. In particular, given a SOA service as the access to an underlying capability, the service may point to some of the capability's previously generated description, e.g. a service providing access to a data store may reference update records that indicate the freshness of the data.
- Descriptions of the provider and consumer are the essential building blocks for establishing the execution context of an interaction.

These points emphasize that there is no one "right" description for all contexts and for all time. Several descriptions for the same subject may exist at the same time, and this emphasizes the importance of the description referencing source material maintained by that material's owner rather than having multiple copies that become out of synch and inconsistent.

It may also prove useful for a description assembled for one context to cross-reference description assembled for another context as a way of referencing ancillary information without overburdening any single description. Rather than a single artifact, description can be thought of as a web of documents that enhance the total available description.

This Reference Architecture Foundation uses the term service description for consistency with the concept defined in the Reference Model. Some SOA literature treats the idea of a "service contract" as equivalent to service description. Inthe SOA-RAF, the term service description is preferred. Replacing service description with service contract implies just one side of the interaction is governing and misses the point that a single set of policies identified by a service description may lead to numerous contracts, i.e. service level agreements, leveraging the same description.

4.1.1 The Model for Service Description

Figure 12 shows Service Description as a subclass of the general Description class, where Description is a subclass of the resource class as defined in Section 3.1.5.1. In addition, each resource is assumed to have a description. The following section discusses the relationships among elements of general description and the subsequent sections focus on service description itself. Other descriptions, such as those of participants, are important to SOA but are not individually elaborated in this document.

4.1.1.1 Elements Common to General Description

The general Description class is composed of a number of elements that are expected to be common among all specialized descriptions supporting a service oriented architecture. A registry often contains a subset of the description instance, where the chosen subset is identified as that which facilitates mediated discovery. Additional information contained in a more complete description may be needed to initiate and continue interaction.

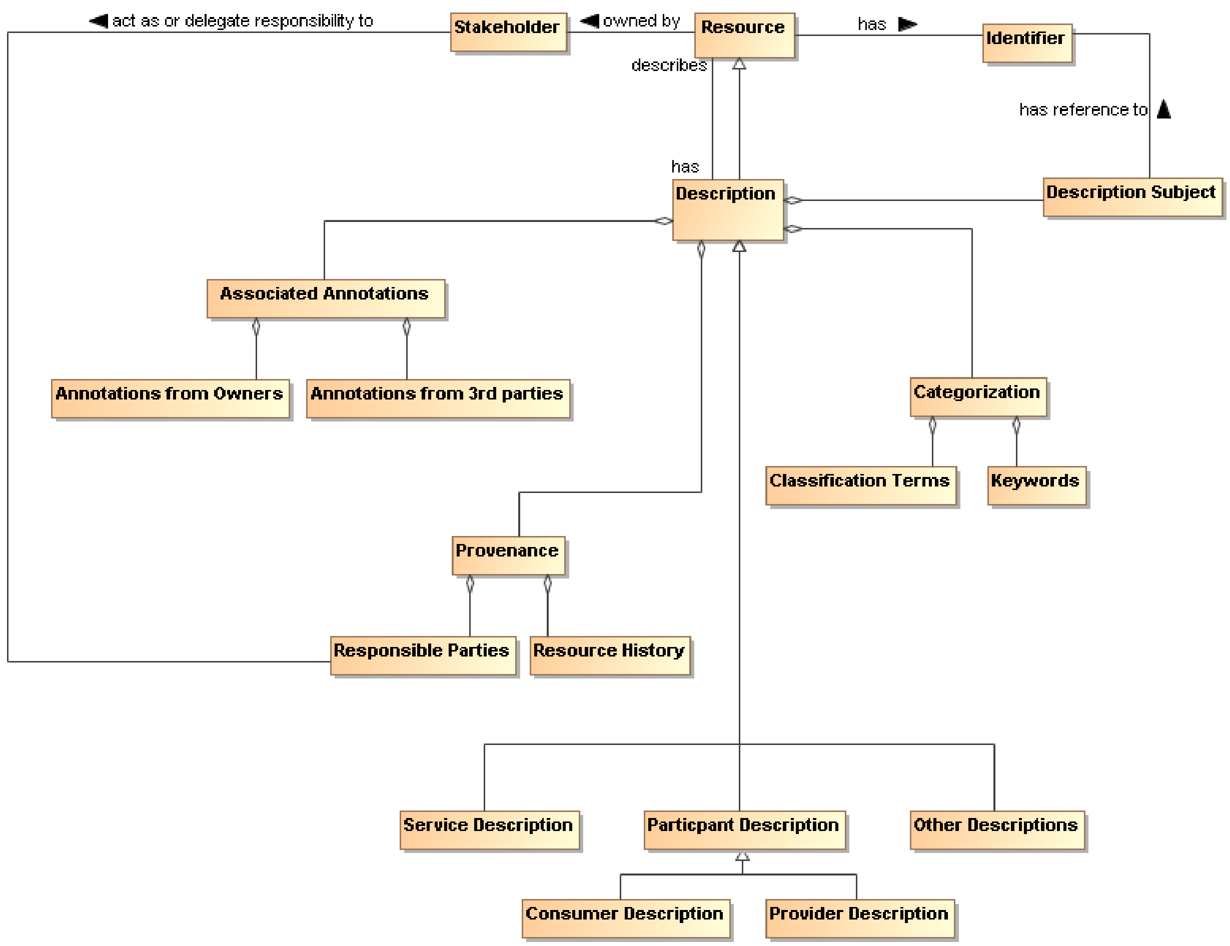


Figure 12 General Description

4.1.1.1.1 Description Subject

The subject of a description is a resource. The value assigned to the Description Subject class may be of any form that provides understanding of what constitutes the resource, but it is often in human-readable text. The Description Subject MUST also reference the Identifier of the resource it describes so it can unambiguously identify the subject of each description instance.

As a resource, Description also has an identifier with a unique value for each description instance. The description instance provides vital information needed to both establish visibility of the resource and to support its use in the execution context for the associated interaction. The identifier of the description instance allows the description itself to be referenced for discussion, access, or reuse of its content.

4.1.1.1.2 Provenance

While the resource Identifier provides the means to know which subject and subject description are being considered, Provenance as related to the Description class provides information that reflects on the quality or usability of the subject. Provenance specifically identifies the entity (human, defined role, organization, ...) that assumes responsibility for the resource being described and tracks historic information that establishes a context for understanding what the resource provides and how it has changed over time. Responsibilities may be directly assumed by the stakeholder who owns a resource or the Owner may designate Responsible Parties for the various aspects of maintaining the resource and provisioning it for use by others. There may be more than one entity identified under Responsible Parties; for example, one entity may be responsible for code maintenance while another is responsible for provisioning of the executable code. The historical aspects may also have multiple entries, such as when and how data was collected and when and how it was subsequently processed, and as with other elements of description, may provide links to other assets maintained by the resource owner.

4.1.1.1.3 Keywords and Classification Terms

A traditional element of description has been to associate the resource being described with predefined keywords or classification taxonomies that derive from referenceable formal definitions and vocabularies. This Reference Architecture Foundation does not prescribe which vocabularies or taxonomies may be referenced, nor does it limit the number of keywords or classifications that may be associated with the resource. It does, however, state that a normative definition SHOULD be referenced, whether that be a representation in a formal ontology language, a pointer to an online dictionary, or any other accessible source. See Section 4.1.1.2 for further discussion on associating semantics with assigned values.

4.1.1.1.4 Associated Annotations

The general description instance may also reference associated documentation that is in addition to that considered necessary in this model. For example, the owner of a service may have documentation on best practices for using the service. Alternately, a third party may certify a service based on their own criteria and certification process; this may be vital information to other prospective consumers if they were willing to accept the certification in lieu of having to perform another certification themselves. Note, while the examples of Associated Documentation presented here are related to services, the concept applies equally to description of other entities.

4.1.1.2 Assigning Values to Description Instances

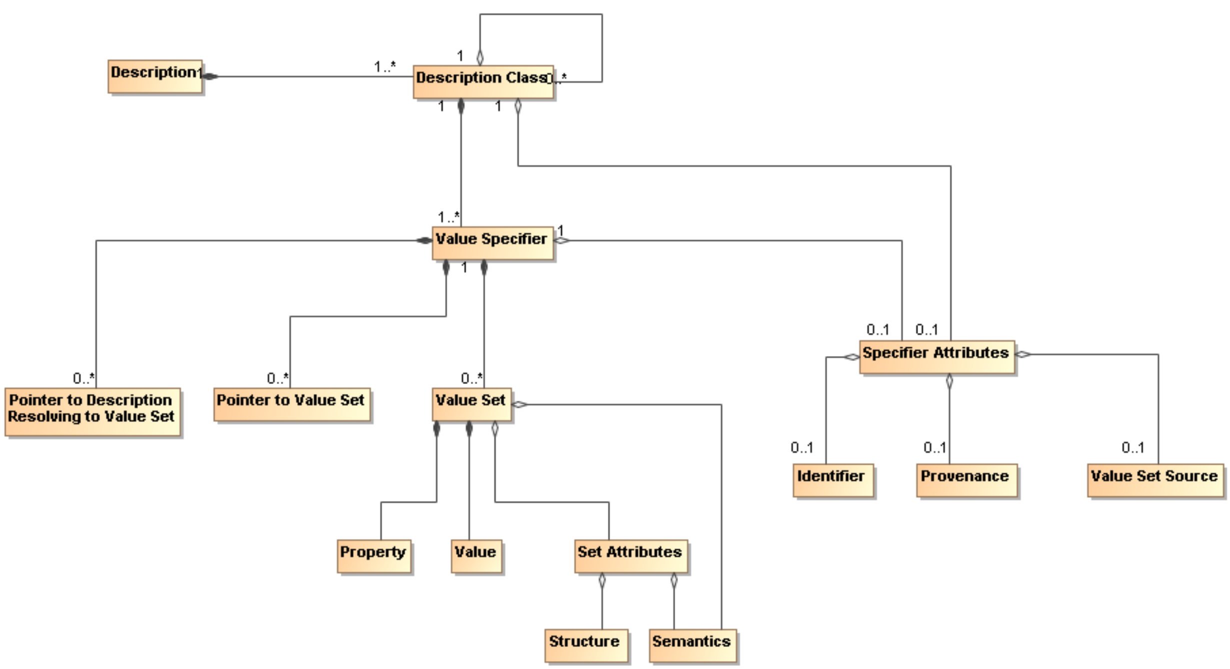


Figure 13 Representation of a Description

Figure 12 shows the template for a general description but individual description instances depend on the ability to associate meaningful values with the identified elements. Figure 13 shows a model for a collection of information that provides for value assignment and traceability for both the value meaning and the source of a value. The model is not meant to replace existing or future schema or other structures that have or will be defined for specific implementations, but it is meant as guidance for the information such structures need to capture to generate sufficient description. It is expected that tools will be developed to assist the user in populating description and auto-filling many of these fields, and in that context, this model provides guidance to the tool developers.

In Figure 13 each class has an associated value specifier or is made up of components that will eventually resolve to a value specifier. For example, Description has several components, one of which is Categorization, which would have an associated a value specifier.

A value specifier consists of

- a collection of value sets with associated property-value pairs, pointers to such value sets, or pointers to descriptions that eventually resolve to value sets that describe the component; and
- attributes that qualify the value specifier and the value sets it contains.

The qualifying attributes for the value specifier include

- an optional identifier that would allow the value set to be defined, accessed, and reused elsewhere;
- provenance information that identifies the party (individual, role, or organization) that has responsibility for assigning the value sets to any description component;
- an optional source of the value set, if appropriate and meaningful, e.g. if a particular data source is mandated.

If the value specifier is contained within a higher-level component, (such as Service Description containing Service Functionality), the component may inherit values from the attributes from its container.

Note, provenance as a qualifying attribute of a value specifier is different from provenance as part of an instance of Description. Provenance for a service identifies those who own and are responsible for the service, as described in Section 3. Provenance for a value specifier identifies who is responsible for choosing and assigning values to the value sets that comprise the value specifier. It is assumed that granularity at the value specifier level is sufficient and provenance is not required for each value set.

The value set also has attributes that define its structure and semantics.

- The semantics of the value set property should be associated with a semantic context conveying the meaning of the property within the execution context, where the semantic context could vary from a free text definition to a formal ontology.
- For numeric values, the structure would provide the numeric format of the value and the “semantics” would be conveyed by a dimensional unit with an identifier to an authoritative source defining the dimensional unit and preferred mechanisms for its conversion to other dimensional units of like type.
- For nonnumeric values, the structure would provide the data structure for the value representation and the semantics would be an associated semantic model.
- For pointers, architectural guidelines would define the preferred addressing scheme.

The value specifier may indicate a default semantic model for its component value sets and the individual value sets may provide an override.

The property-value pair construct is introduced for the value set to emphasize the need to identify unambiguously both what is being specified and what is a consistent associated value. The further qualifying of Structure and Semantics in the Set Attributes allows for flexibility in defining the form of the associated values.

4.1.1.3 Model Elements Specific to Service Description

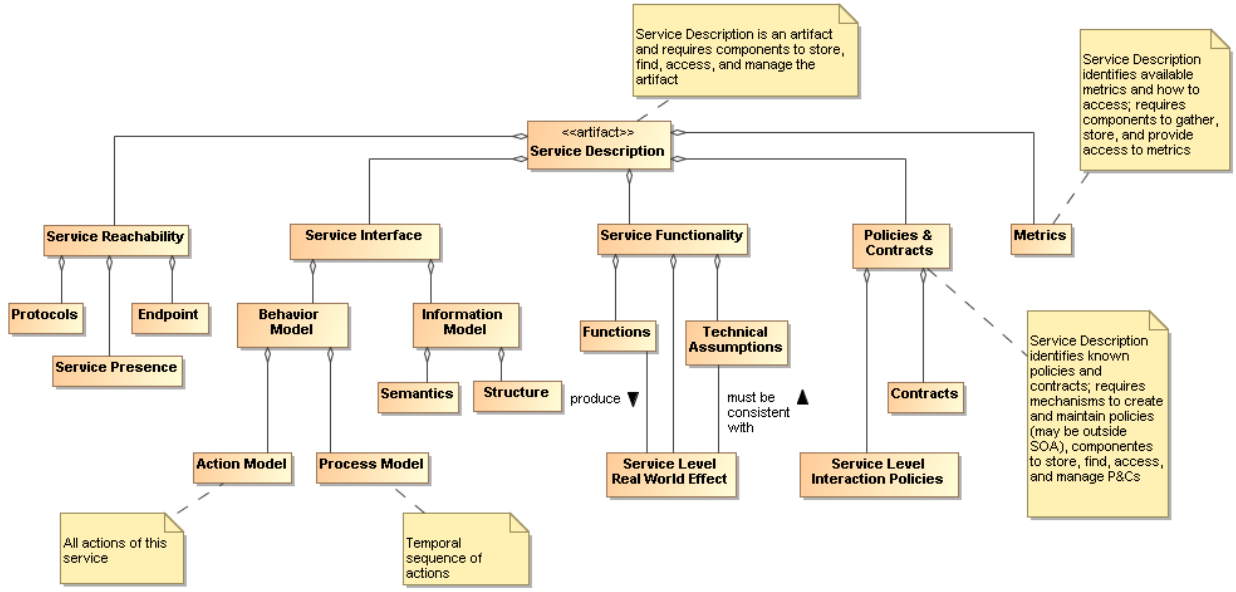


Figure 14 Service Description

The major elements for the Service Description subclass follow directly from the areas discussed in the Reference Model. Here, we discuss the detail shown in *Figure 14* and the purpose served by each element of service description.

Note, the intent in the subsections that follow is to describe how a particular element, such as the service interface, is reflected in the service description, not to elaborate on the details of that element.

4.1.1.3.1 Service Interface

As noted in the Reference Model, the service interface is the means for interacting with a service. For the SOA-RAF and as shown in Section 4.3 the service interface will support an exchange of messages, where

- the message conforms to a referenceable message exchange pattern (MEP),
- the message payload conforms to the structure and semantics of the indicated information model,
- the messages are used to denote events or actions against the service, where the actions are specified in the action model and any required sequencing of actions is specified in the process model.

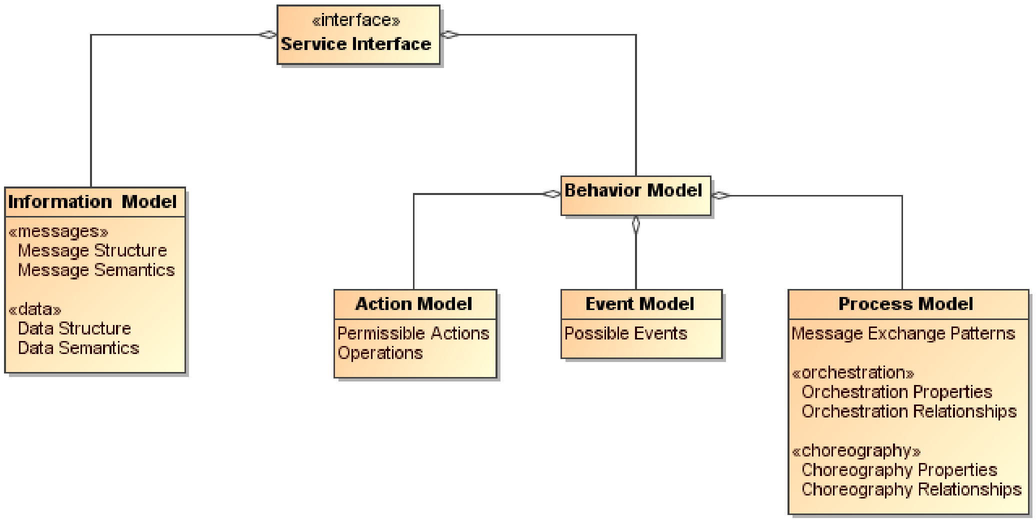


Figure 15 Service Interface

Note we distinguish the structure and semantics of the message from that of the underlying protocol that conveys the message. The message structure may include nested structures that are independently defined, such as an enclosing envelope structure and an enclosed data structure.

These aspects of messages are discussed in more detail in Section 4.3

4.1.1.3.2 Service Reachability

Service reachability, as modeled in Section 4.2.2.3 enables service participants to locate and interact with one another. To support service reachability, the service description should indicate the endpoints to which a service consumer can direct messages to invoke actions and the protocol to be used for message exchange using that endpoint.

As applied in general to an action, the endpoint is the conceptual location where one applies an action; with respect to service description, it is the actual address where a message is sent.

In addition, the service description should provide information on collected metrics for service presence; see Section 4.1.1.3.4 for the discussion of metrics as part of service description.

4.1.1.3.3 Service Functionality

While the service interface and service reachability are concerned with the mechanics of using a service, service functionality and performance metrics (discussed in Section 4.1.1.3.4) describe what can be expected when interacting with a service. Service Functionality, shown in *Figure 14* as part of the overall Service Description model and extended in *Figure 16*, is an unambiguous expression of service function(s) and the real world effects of invoking the function. The Functions represent business activities in some domain that produce the desired real world effects.

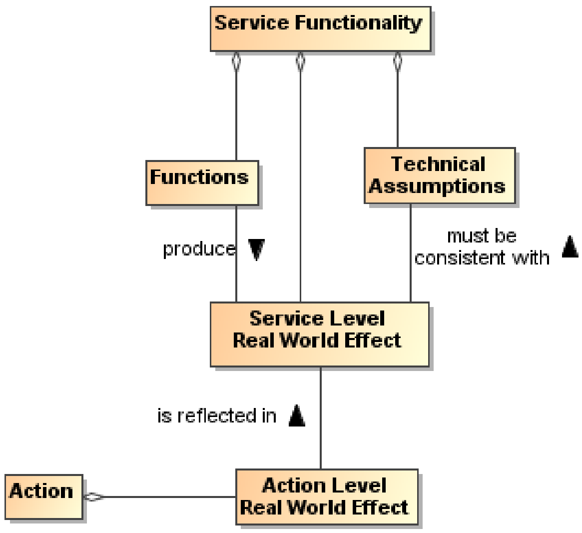


Figure 16 Service Functionality

The Service Functionality may also be constrained by Technical Assumptions that underlie the effects that can result. Technical assumptions are defined as domain specific restrictions and may express underlying physical limitations, such as flow speeds must be below sonic velocity or disk access that cannot be faster than the maximum for its host drive. Technical assumptions are related to the underlying capability accessed by the service. In any case, the real world effects must be consistent with the Technical Assumptions.

In *Figure 14* and *Figure 16*, we specifically refer to Service Level and Action Level real world effects.

Service Level Real World Effect

> A service level real world effect is a specific change in shared state or information returned as a result of interacting with a service.

Action Level Real World Effect

> An action level real world effect is a specific change in shared state or information returned as a result of performing a specific action against a service.

Service description describes the service as a whole while the component aspects should contribute to that whole. Thus, while individual Actions may contribute to the real world effects to be realized from interaction with the service, there would be a serious disconnect for Actions to contribute real world effects that could not consistently be reflected in the Service Level Real World Effects and thus the Service Functionality. The relationship to Action Level Real World Effects and the implications on defining the scope of a service are discussed in Section 4.1.2.1.

Elements of Service Functionality may be expressed as natural language text, reference to an existing taxonomy of functions, or reference to a more formal knowledge capture providing richer description and context.

4.1.1.3.4 Policies and Contracts, Metrics, and Compliance Records

Policies prescribe the conditions and constraints for interacting with a service and impact the willingness to continue visibility with the other participants. Whereas technical assumptions are statements of “physical” fact, policies are subjective assertions made by the service provider (sometimes as passed on from higher authorities).

The service description provides a central location for identifying what policies have been asserted by the service provider. The specific representation of the policy, e.g. in some formal policy language, is likely done outside of the service description and the service description would reference the normative definition of the policy.

Policies may also be asserted by other service participants, as illustrated by the model shown in Figure 17. Policies that are generally applicable to any interaction with the service are asserted by the service provider and included in the Policies and Contracts section of the service description. Conversely, policies that are asserted by specific consumers or consumer communities would be identified as part of a description's Annotations from 3rd parties (see Section 4.1.1.1.4) because these would be specific to those parties and not a general aspect of the service being described.

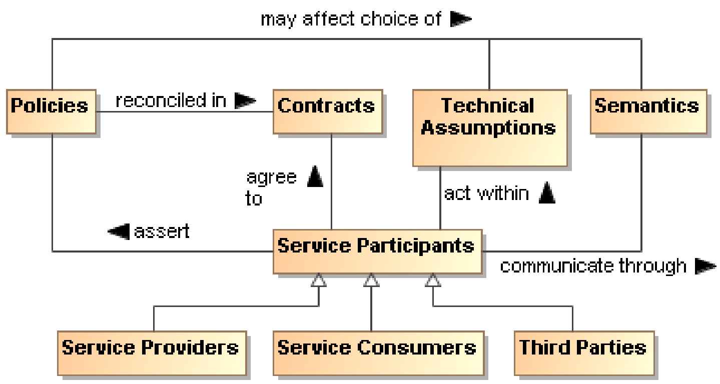


Figure 17 Model for Policies and Contracts as related to Service Participants

In *Figure 14* and Figure 18, we specifically refer to Service Level Interaction Policies. In a similar manner to that discussed for Service Level vs. Action Level Real World Effects in Section 4.1.1.3.3, individual Actions may have associated policies stating conditions for performing the action, but these must be reflected in and be consistent with the policies made visible at the service level and thus the description of the service as a whole. The relationship to Action Level Policies and the implications on defining the scope of a service are discussed in Section 4.1.2.1.

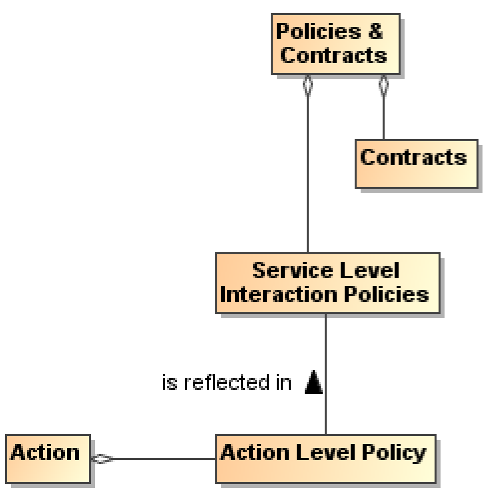


Figure 18 Action-Level and Service-Level Policies

As noted in Figure 17, the policies asserted may affect the allowable Technical Assumptions that can be embodied in services or their underlying capabilities and may affect the semantics that can be used. For example of the former, there may be a policy that specifies the surge capacity to be accommodated by a server, and a service that designs for a smaller capacity would not be appropriate to use. For the latter, a policy may require that only services using a community-sponsored vocabulary can be used.

Contracts are agreements among the service participants. The contract may reconcile inconsistent policies asserted by the participants or may specify details of the interaction. Service level agreements (SLAs) are one commonly used category of contracts.

References to contracts under which the service can be used may also be included in the service description. As with policies, the specific representation of the contract, e.g. in some formal contract language, is likely done outside of the service description and the service description would reference the normative definition of the contract. Policies and contracts are discussed further in Section 4.4.

The definition and later enforcement of policies and contracts are predicated on the existence of metrics; the relationships among the relevant concepts are shown in the model in Figure 19. Performance Metrics identify quantities that characterize the speed and quality of realizing the real world effects produced using the SOA service; in addition, policies and contracts may depend on nonperformance metrics, such as whether a license is in place to use the service. Some of these metrics reflect the underlying capability, e.g. a SOA service cannot respond in two seconds if the underlying capability is expected to take five seconds to do its processing; some metrics reflect the implementation of the SOA service, e.g. what level of caching is present to minimize data access requests across the network.

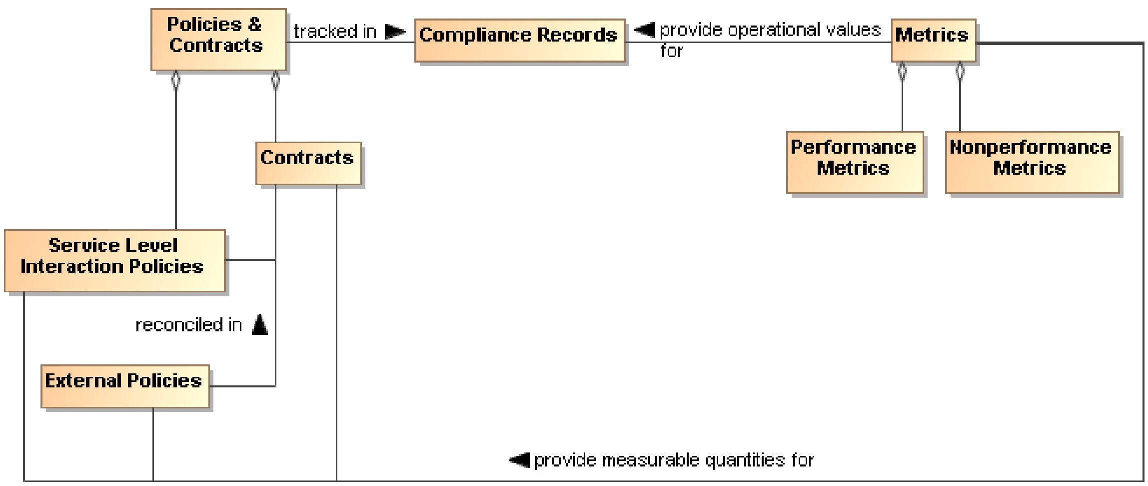


Figure 19 Policies and Contracts, Metrics, and Compliance Records

As with many quantities, the metrics associated with a service are not themselves defined by this Service Description because it is not known *a priori* which metrics are being collected or otherwise checked by the services, the SOA infrastructure, or other resources that participate in the SOA interactions. However, the service description SHOULD provide a placeholder (possibly through a link to an externally compiled list) for identifying which metrics are available and how these can be accessed.

The use of metrics to evaluate compliance is discussed in Section **Error! Reference source not found.**. he results of compliance evaluation SHOULD be maintained in compliance records and the means to access the compliance records SHOULD be included in the Policies and Contracts portion of the service description. For example, the description may be in the form of static information (e.g. over the first year of operation, this service had a 91% availability), a link to a dynamically generated metric (e.g. over the past 30 days, the service has had a 93.3% availability), or access to a dynamic means to check the service for current availability (e.g. a ping). The relationship between service presence and the presence of the individual actions that can be invoked is discussed under Reachability in Section 4.2.2.3.

Note, even when policies relate the perspective of a single participant, policy compliance can be measured and policies may be enforceable without contractual agreement with other participants. This should be reflected in the policy, contract, and compliance record information maintained in the service description.

4.1.2 Use Of Service Description

4.1.2.1 Service Description in support of Service Interaction

If we assume we have awareness, i.e. access to relevant descriptions, the service participants must still establish willingness and presence to ensure full visibility (See Section 4.2) and to interact with the service. Service description provides necessary information for many aspects of preparing for and carrying through with interaction. Recall the fundamental definition of service is a mechanism to access an underlying capability; the service description describes this mechanism and its use. It lays the groundwork for what can occur, whereas service interaction defines the specifics through which occurrences are realized.

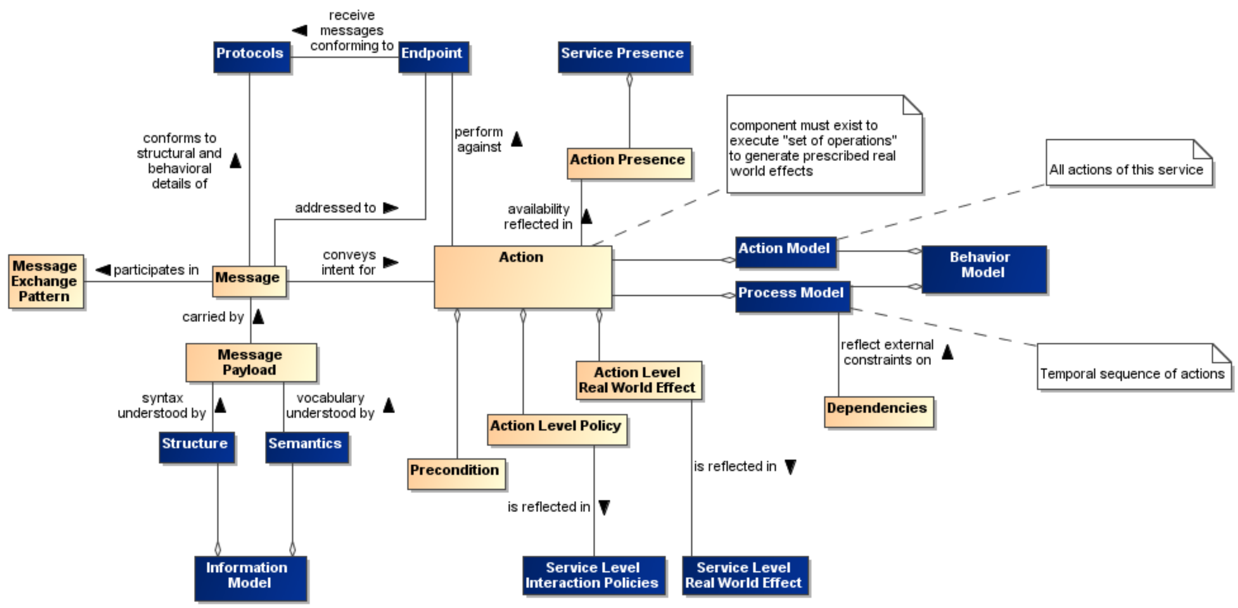


Figure 20 Relationship Between Action and Service Description Components

Figure 20 combines the models in the subsections of Section 4.1.1 to concisely relate action and the relevant components of Service Description. The purpose of Figure 20 is to demonstrate that the components of service description go beyond arbitrary documentation and form the critical set of information needed to define the what and how of action. In Figure 20, the leaf nodes from *Figure 14* are shown in blue.

action is invoked via a Message where the structure and behavioral details of the message conform to an identified Protocol and is directed to the address of the identified endpoint, and the message payload conforms to the service Information Model.

The availability of an action is reflected in the Action Presence and each Action Presence contributes to the overall Service Presence; this is discussed further in Section 4.2.2.3. Each action has its own endpoint and also its own protocols associated with the endpoint[11] and to what extent, e.g. current or average availability, there is presence for the action through that endpoint. The endpoint and service presence are also part of the service description.

An action may have preconditions where a Precondition is something that needs to be in place before an action can occur, e.g. confirmation of a precursor action. Whether preconditions are satisfied is evaluated when someone tries to perform the action and not before. Presence for an action means someone can initiate it and is independent of whether the preconditions are satisfied. However, the successful completion of the action may depend on whether its preconditions were satisfied.

Analogous to the relationship between actions and preconditions, the Process Model may imply Dependencies for succeeding steps in a process, e.g. that a previous step has successfully completed, or may be isolated to a given step. An example of the latter would be a dependency that the host server has scheduled maintenance and access attempts at these times would fail. Dependencies related to the process model do not affect the presence of a service although these may affect whether the business function successfully completes.

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[11] This is analogous to a WSDL 2.0 interface operation (WSDL 1.1 portType) having one or more defined bindings and the service identifies the endpoints (WSDL 1.1 ports) corresponding to the bindings.

The conditions under which an action can be invoked may depend on policies associated with the action. The Action Level Policies MUST be reflected in the Service Level Interaction Policies because such policies may be critical to determining whether the conditions for use of the service are consistent with the policies asserted by the service consumer. The service level interaction policies are included in the service description.

Similarly, the result of invoking an action is one or more real world effects, and the Action Level Real World Effects MUST be reflected in the Service Level Real World Effect included in the service description. The unambiguous expression of action level policies and real world effects as service counterparts is necessary to adequately understand what constitutes the service interaction.

An adequate service description MUST provide a consumer with information needed to determine if the service policies and the (business) functions and service-level real world effects are of interest and there is nothing in the technical assumptions that preclude use of the service.

Note at this level, the business functions are not concerned with the action or process models. These models are detailed separately.

The service description is not intended to be isolated documentation but rather an integral part of service use. Changes in service description SHOULD immediately be made known to consumers and potential consumers.

4.1.2.1.1 Description and Invoking Actions Against a Service

At this point, let us assume the descriptions were sufficient to establish willingness; see Section 4.2.2.2. Figure 20 indicates the service endpoint establishes where to actually carry out the interaction. This is where we start considering the action and process models.

The action model identifies the multiple actions a user can perform against a service and the user would perform these in the context of the process model as specified or referenced under the Service Interface portion of Service Description. For a given business function, there is a corresponding process model, where any process model may involve multiple actions. From the above discussion of model elements of description we may conclude (1) actions have reachability information, including endpoint and presence, (2) presence of service is some aggregation of presence of its actions, (3) action preconditions and service dependencies do not affect presence although these may affect successful completion.

Having established visibility, the interaction can proceed. Given a business function, the consumer knows what will be accomplished (the service functionality), the conditions under which interaction will proceed (service policies and contracts), and the process that must be followed (the process model). The remaining question is how does the description information for structure and semantics enable interaction.

We have established the importance of the process model in identifying relevant actions and their sequence. Interaction proceeds through messages and thus it is the syntax and semantics of the messages with which we are here concerned. A common approach is to define the structure and semantics that can appear as part of a message; then assemble the pieces into messages; and, associate messages with actions. Actions make use of structure and semantics as defined in the information model to describe its legal messages.

The process model identifies actions to be performed against a service and the sequence for performing the actions. For a given action, the Reachability portion of description indicates the protocol bindings that are available, the endpoint corresponding to a binding, and whether there is presence at that endpoint. The interaction with actions is through messages that conform to the structure and semantics defined in the information model and the message sequence conforming to the action's identified MEP. The result is some portion of the real world effect that must be assessed and/or processed (e.g. if an error exists, that part that covers the error processing would be invoked).

4.1.2.1.2 The Question of Multiple Business Functions

Action level effects and policies MUST be reflected at the service level for service description to support visibility.

It is assumed that a SOA service represents an identifiable business function to which policies can be applied and from which desired business effects can be obtained. While contemporary discussions of

SOA services and supporting standards do not constrain what actions or combinations of actions can or should be defined for a service, the SOA-RAF considers the implications of service description in defining the range of actions appropriate for an individual SOA service.

Consider the situation if a given SOA service is the container for multiple independent (but loosely related) business functions. These are not multiple effects from a single function but multiple functions with potentially different sets of effects for each function. A service can have multiple actions a user may perform against it, and this does not change with multiple business functions. As an individual business function corresponds to a process model, so multiple business functions imply multiple process models. The same action may be used in multiple process models but the aggregated service presence would be specific to each business function because the components being aggregated may be different between process models. In summary, for a service with multiple business functions, each function has (1) its own process model and dependencies, (2) its own aggregated presence, and (3) possibly its own list of policies and real world effects.

A common variation on this theme is for a single service to have multiple endpoints for different levels of quality of service (QoS). Different QoS imply separate statements of policy, separate endpoints, possibly separate dependencies, and so on. One could say the QoS variation does not require this because there can be a single QoS policy that encompasses the variations. and all other aspects of the service would be the same except for the endpoint used for each QoS. However, the different aspects of policy at the service level would need to be mapped to endpoints, and this introduces an undesirable level of coupling across the elements of description. In addition, it is obvious that description at the service level can become very complicated if the number of combinations is allowed to grow.

One could imagine a service description that is basically a container for action descriptions, where each action description is self contained; however, this would lead to duplication of description components across actions. If common description components are factored, this either is limited to components common across all actions or requires complicated tagging to capture the components that often but do not universally apply.

If a provider cannot describe a service as a whole but must describe every action, this leads to the situation where it may be extremely difficult to construct a clear and concise service description that can effectively support discovery and use without tedious logic to process the description and assemble the available permutations. In effect, if adequate description of an action begins to look like description of a service, it may be best to have it as a separate service.

Recall, more than one service can access the same underlying capability, and this is appropriate if a different real world effect is to be exposed. Along these lines, one can argue that different QoS are different services because getting a response in one minute rather than one hour is more than a QoS difference; it is a fundamental difference in the business function being provided.

As a best practice, a criteria for whether a service is appropriately scoped may be the ease or difficulty in creating an unambiguous service description. A consequence of having tightly-scoped services is there will be a greater reliance on combining services, i.e. more fundamental business functions, to create more advanced business functions. This is consistent with the principles of service oriented architecture and is the basic position of the Reference Architecture, although not an absolute requirement. Combining services increases the reliance on understanding and implementing the concepts of orchestration, choreography, and other approaches yet to be developed; these are discussed in more detail in section 4.4 Interacting with Services.

4.1.2.1.3 Service Description, Execution Context, and Service Interaction

The service description MUST provide sufficient information to support service visibility, including the willingness of service participants to interact. However, the corresponding descriptions for providers and consumers may both contain policies, technical assumptions, constraints on semantics, and other technical and procedural conditions that must be aligned to define the terms of willingness. The agreements which encapsulate the necessary alignment form the basis upon which interactions may proceed – in the Reference Model, this collection of agreements and the necessary environmental support establish the execution context.

To illustrate the concept of the execution context, consider a Web-based system for timecard entry. For an employee onsite at an employer facility, the execution context requires a computer connected to the local network and the employee must enter their network ID and password. Relevant policies include that the employee must maintain the most recent anti-virus software and virus definitions for any computer connected to the network.

For the same employee connecting from offsite, the execution context specifies the need for a computer with installed VPN software and a security token to negotiate the VPN connection. The execution context also includes proxy settings as needed to connect to the offsite network. The employee must still comply with the requirements for onsite computers and access, but the offsite execution context includes additional items before the employee can access the same underlying capability and realize the same real world effect s, i.e. the timecard entries.

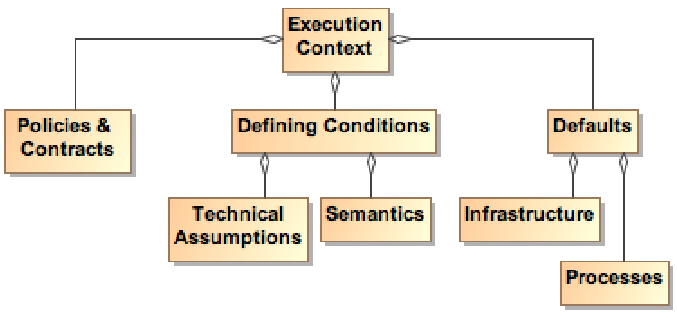


Figure 21 Execution Context

Figure 21 shows a few broad categories found in execution context. These are not meant to be comprehensive. Other items may need to be included to collect a sufficient description of the interaction conditions. Any other items not explicitly noted in the model but needed to set the environment SHOULD be included in the execution context.

While the execution context captures the conditions under which interaction can occur, it does not capture the specific service invocations that do occur in a specific interaction. A service interaction as modeled in Figure 20 introduces the concept of an Interaction Description which is composed of both the Execution Context and an Interaction Log. The execution context specifies the set of conditions under which the interaction occurs and the interaction log captures the sequence of service interactions that occur within the execution context. This sequence should follow the Process Model but can include details beyond those specified there. For example, the Process Model may specify an action that results in identifying a data source, and the identified source is used in a subsequent action. The Interaction Log would record the specific data source used.

The execution context can be thought of as the container in which the interaction occurs and the interaction log captures what happens inside the container. This combination is needed to support auditability and repeatability of the interactions.

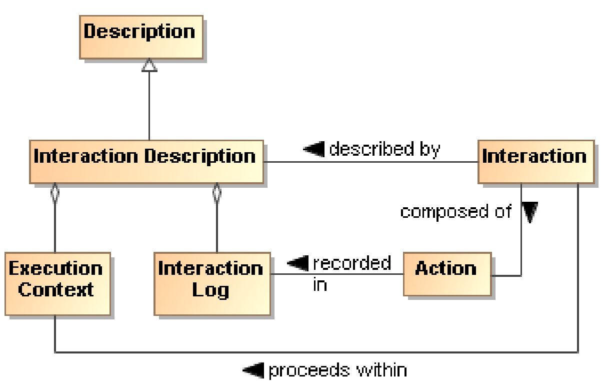


Figure 22 Interaction Description

SOA allows flexibility to accomplish repeatability or reusability. One benefit of this is that a service can be updated without disrupting the user experience of the service. So, Google can improve their ranking algorithm without notifying the user about the details of the update.

However, it may also be vital for the consumer to be able to recreate past results or to generate consistent results in the future, and information such as what conditions, which services, and which versions of those services are used is indispensible in retracing one's path. The interaction log is a critical part of the resulting real world effects because it defines how the effects were generated and possibly the meaning of observed effects. This increases in importance as dynamic composability becomes more feasible. In essence, a result has limited value if one does not know how it was generated.

The interaction log SHOULD be a detailed trace for a specific interaction, and its reuse is limited to duplicating that interaction. An execution context can act as a template for identical or similar interactions. Any given execution context MAY define the conditions of future interactions.

Such uses of execution context imply (1) a standardized format for capturing execution context and (2) a subclass of general description could be defined to support visibility of saved execution contexts. The specifics of the relevant formats and descriptions are beyond the scope of this document.

A service description is unlikely to track interaction descriptions or the constituent execution contexts or interaction logs that include mention of the service. However, as appropriate, linking to specific instances of either of these could be done through associated annotations.

4.1.3 Relationship to Other Description Models

While the representation shown in Figure 13 is derived from considerations related to service description, it is acknowledged that other metadata standards are relevant and should, as possible, be incorporated into this work. Two standards of particular relevance are the Dublin Core Metadata Initiative (DCMI) and ISO 11179, especially Part 5.

When the service description (or even the general description class) is considered as the DCMI "resource", Figure 13 aligns nicely with the DCMI resource model. While some differences exist, these are mostly in areas where DCMI goes into detail that is considered beyond the scope of the current Reference Architecture. For example, DCMI defines classes of "shared semantics" whereas this Reference Architecture Framework considers that an identification of relevant semantic models is sufficient. Likewise, the DCMI "description model" goes into the details of possible syntax encodings whereas for the Reference Architecture Framework it is sufficient to identify the relevant formats.

With respect to ISO 11179 Part 5, the metadata fields defined in that reference may be used without prejudice as the properties in Figure 13. Additionally, other defined metadata sets may be used by the service provider if the other sets are considered more appropriate, i.e. it is fundamental to this reference architecture to identify the need and the means to make vocabulary declarations explicit but it is beyond the scope to specify which vocabularies are to be used. In addition, the identification of domain of the properties and range of the values has not been included in the current Reference Architecture discussion, but the text of ISO 11179 Part 5 can be used consistently with the model prescribed in this document.

Description as defined here considers a wide range of applicability and support of the principles of service oriented architecture. Other metadata models can be used in concert with the model presented here because most of these focus on a finer level of detail that is outside the present scope, and so provide a level of implementation guidance that can be applied as appropriate.

4.1.4 Architectural Implications

The description of service description indicates numerous architectural implications on the SOA ecosystem:

- It changes over time and its contents will reflect changing needs and context. This requires the existence of:
    - mechanisms to support the storage, referencing, and access to normative definitions of one or more versioning schemes that may be applied to identify different aggregations of

descriptive information, where the different schemes may be versions of a versioning scheme itself;

  - configuration management mechanisms to capture the contents of the each aggregation and apply a unique identifier in a manner consistent with an identified versioning scheme;
  - one or more mechanisms to support the storage, referencing, and access to conversion relationships between versioning schemes, and the mechanisms to carry out such conversions.

- Description makes use of defined semantics, where the semantics may be used for categorization or providing other property and value information for description classes. This requires the existence of:
  - semantic models that provide normative descriptions of the utilized terms, where the models may range from a simple dictionary of terms to an ontology showing complex relationships and capable of supporting enhanced reasoning;
  - mechanisms to support the storage, referencing, and access to these semantic models;
  - configuration management mechanisms to capture the normative description of each semantic model and to apply a unique identifier in a manner consistent with an identified versioning scheme;
  - one or more mechanisms to support the storage, referencing, and access to conversion relationships between semantic models, and the mechanisms to carry out such conversions.
- Descriptions include reference to policies defining conditions of use and optionally contracts representing agreement on policies and other conditions. This requires the existence of (as also enumerated under governance):
  - descriptions to enable the policy modules to be visible, where the description includes a unique identifier for the policy and a sufficient, and preferably a machine processible, representation of the meaning of terms used to describe the policy, its functions, and its effects;
  - one or more discovery mechanisms that enable searching for policies that best meet the search criteria specified by the service participant; where the discovery mechanism has access to the individual policy descriptions, possibly through some repository mechanism;
  - accessible storage of policies and policy descriptions, so service participants can access, examine, and use the policies as defined.
- Descriptions include references to metrics which describe the operational characteristics of the subjects being described. This requires the existence of (as partially enumerated under governance):
  - the infrastructure monitoring and reporting information on SOA resources;
  - possible interface requirements to make accessible metrics information generated or most easily accessed by the service itself;
  - mechanisms to catalog and enable discovery of which metrics are available for a described resources and information on how these metrics can be accessed;
  - mechanisms to catalog and enable discovery of compliance records associated with policies and contracts that are based on these metrics.
- Descriptions of the interactions are important for enabling auditability and repeatability, thereby establishing a context for results and support for understanding observed change in performance or results. This requires the existence of:
  - one or more mechanisms to capture, describe, store, discover, and retrieve interaction logs, execution contexts, and the combined interaction descriptions;
  - one or more mechanisms for attaching to any results the means to identify and retrieve the interaction description under which the results were generated.
- Descriptions may capture very focused information subsets or can be an aggregate of numerous component descriptions. Service description is an example of an aggregate for which manual maintenance of the whole would not be feasible. This requires the existence of:
  - tools to facilitate identifying description elements that are to be aggregated to assemble the composite description;
  - tools to facilitate identifying the sources of information to associate with the description elements;
  - tools to collect the identified description elements and their associated sources into a standard, referenceable format that can support general access and understanding;

    - tools to automatically update the composite description as the component sources change, and to consistently apply versioning schemes to identify the new description contents and the type and significance of change that occurred.
- Descriptions provide up-to-date information on what a resource is, the conditions for interacting with the resource, and the results of such interactions. As such, the description is the source of vital information in establishing willingness to interact with a resource, reachability to make interaction possible, and compliance with relevant conditions of use. This requires the existence of:
    - one or more discovery mechanisms that enable searching for described resources that best meet the criteria specified by a service participant, where the discovery mechanism has access to individual descriptions, possibly through some repository mechanism;
    - tools to appropriately track users of the descriptions and notify them when a new version of the description is available.

4.2 Service Visibility Model

One of the key requirements for participants interacting with each other in the context of a SOA is achieving visibility: before services can interoperate, the participants have to be visible to each other using whatever means are appropriate. The Reference Model analyzes visibility in terms of awareness, willingness, and reachability. In this section, we explore how visibility may be achieved.

4.2.1 Visibility to Business

The relationship of visibility to the SOA ecosystem encompasses both human social structures and automated IT mechanisms. Figure 23 depicts a business setting that is a basis for visibility as related to the social structure Model in the *Participation in a SOA Ecosystem* view (see Section **Error! Reference ource not found.**). Service consumers and service providers may have direct awareness or mediated awareness where mediated awareness is achieved through some third party. A consumer's willingness to use a service is reflected by the consumer's presumption of satisfying goals and needs based on the description of the service. Service providers offer capabilities that have real world effects that result in a change in state of the consumer. Reachability of the service by the consumer leads to interactions that change the state of the consumer. The consumer can measure the change of state to determine if the claims made by description and the real world effects of consuming the service meet the consumer's needs.

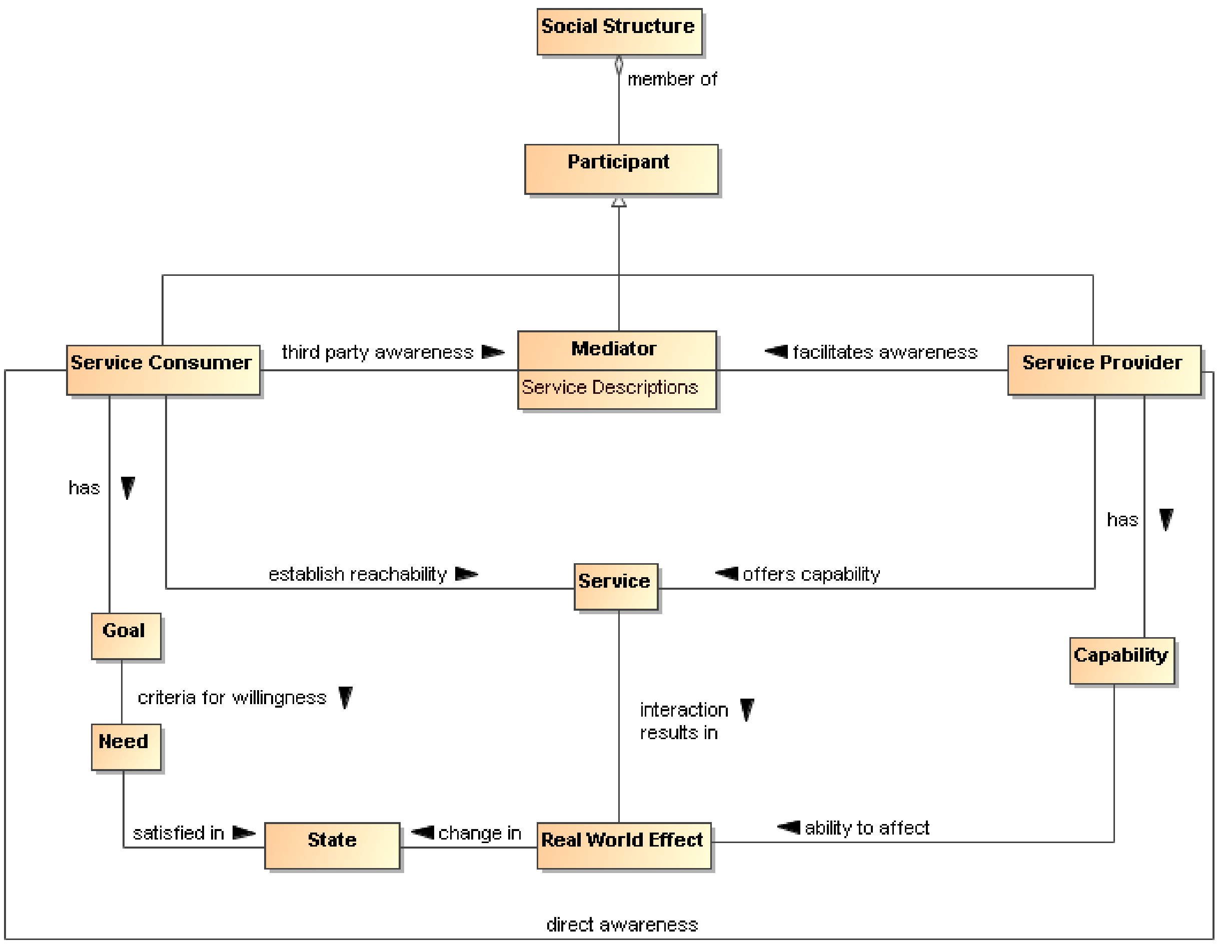


Figure 23 Visibility to Business

Visibility and interoperability in a SOA ecosystem requires more than location and interface information. A meta-model for this broader view of visibility is depicted in Section 4.1. In addition to providing improved awareness of service capabilities through description of information such as reachability, behavior models, information models, functionality, and metrics, the service description may contain policies valuable for determination of willingness to interact.

A mediator of service descriptions may provide event notifications to both consumers and providers about information relating to service descriptions. One example of this capability is a publish/subscribe model where the mediator allows consumers to subscribe to service description version changes made by the provider. Likewise, the mediator may provide notifications to the provider of consumers that have subscribed to service description updates.

Another important business capability in a SOA environment is the ability to narrow visibility to trusted members within a social structure. Mediators for awareness may provide policy based access to service descriptions allowing for the dynamic formation of awareness between trusted members.

4.2.2 Visibility

Attaining visibility is described in terms of steps that lead to visibility. While there can be many contexts for visibility within a single social structure, the same general steps can be applied to each of the contexts to accomplish visibility.

Attaining SOA visibility requires

- service description creation and maintenance,
- processes and mechanisms for achieving awareness of and accessing descriptions,

- processes and mechanisms for establishing willingness of participants,
- processes and mechanisms to determine reachability.

Visibility may occur in stages, i.e. a participant can become aware enough to look or ask for further description, and with this description, the participant can decide on willingness, possibly requiring additional description. For example, if a potential consumer has a need for a tree cutting (business) service, the consumer can use a web search engine to find web sites of providers. The web search engine (a mediator) gives the consumer links to relevant web pages and the consumer can access those descriptions. For those prospective providers that satisfy the consumer's criteria, the consumer's willingness to interact increases. The consumer may contact several tree services to get detailed cost information (or arrange for an estimate) and may ask for references (further description). The consumer is likely to establish full visibility and proceed with interaction with the tree service who mutually establishes visibility.

4.2.2.1 Awareness

A service participant is aware of another participant if it has access to a description of that participant with sufficient completeness to establish the other requirements of visibility.

Awareness is inherently a function of a participant; awareness can be established without any action on the part of the target participant other than the target providing appropriate descriptions. Awareness is often discussed in terms of consumer awareness of providers but the concepts are equally valid for provider awareness of consumers.

Awareness can be decomposed into the creation of descriptions, making them available, and discovering the descriptions. Discovery can be initiated or it can be by notification. Initiated discovery for business may require formalization of the required capabilities and resources to achieve business goals.

Achieving awareness in a SOA can range from word of mouth to formal service descriptions in a standards-based registry-repository.   Some other examples of achieving awareness in a SOA are the use of a web page containing description information, email notifications of descriptions, and document based descriptions.

A mediator as discussed for awareness is a third party participant that provides awareness to one or more consumers of one or more services. Direct awareness is awareness between a consumer and provider without the use of a third party.

Direct awareness may be the result of having previously established an execution context, or direct awareness may include determining the presence of services and then querying the service directly for description. As an example, a priori visibility of some sensor device may provide the means for interaction or a query for standardized sensor device metadata may be broadcast to multiple locations. If acknowledged, the service interface for the device may directly provide description to a consumer so the consumer can determine willingness to interact.

The same medium for awareness may be direct in one context and may be mediated in another context. For example, a service provider may maintain a web site with links to the provider's descriptions of services giving the consumers direct awareness to the provider's services. Alternatively, a community may maintain a mediated web site with links to various provider descriptions of services for any number of consumers. More than one mediator may be involved, as different mediators may specialize in different mediation functions.

Descriptions may be formal or informal. Section 4.1, provides a comprehensive model for service description that can be applied to formal registry/repositories used to mediate visibility. Using consistent description taxonomies and standards based mediated awareness helps provide more effective awareness.

4.2.2.1.1 Mediated Awareness

Mediated awareness promotes loose coupling by keeping the consumers and services from explicitly referring to each other and the descriptions. Mediation lets interaction vary independently. Rather than all potential service consumers being informed on a continual basis about all services, there is a known or agreed upon facility or location that houses the service description.

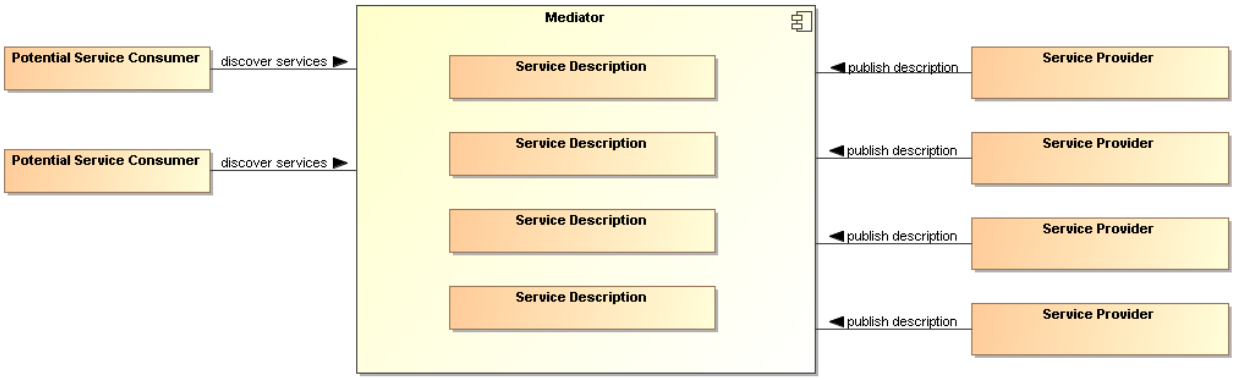


Figure 24 Mediated Service Awareness

In Figure 24, the potential service consumers perform queries or are notified in order to locate those services that satisfy their needs. As an example, the telephone book is a mediated registry where individuals perform manual searches to locate services (i.e. the yellow pages). The telephone book is also a mediated registry for solicitors to find and notify potential customers (i.e. the white pages).

In mediated service awareness for large and dynamic numbers of service consumers and service providers, the benefits typically far outweigh the management issues associated with it. Some of the benefits of mediated service awareness are

- Potential service consumers have a known location for searching thereby eliminating needless and random searches
- Typically a consortium of interested parties (or a sufficiently large corporation) signs up to host the mediation facility
- Standardized tools and methods can be developed and promulgated to promote interoperability and ease of use.

However, mediated awareness can have some risks associated with it:

- A single point of failure. If the central mediation service fails then a large number of service providers and consumers are potentially adversely affected.
- A single point of control. If the central mediation service is owned by, or controlled by, someone other than the service consumers and/or providers then the latter may be put at a competitive disadvantage based on policies of the discovery provider.

A common mechanism for mediated awareness is a registry-repository. The registry stores links or pointers to service description artifacts. The repository in this example is the storage location for the service description artifacts. Service descriptions can be pushed (publish/subscribe for example) or pulled from the register-repository mediator.

The registry is like a card catalog at the library and a repository is like the shelves for the books. Standardized metadata describing repository content can be stored as registry objects in a registry and any type of content can be stored as repository items in a repository. The registry may be constructed such that description items stored within the mediation facility repository has intrinsic links in the registry while description items stored outside the mediation facility have extrinsic links in the registry.

When independent but like SOA IT mechanisms interoperate with one another, the IT mechanisms may be referred to as federated.

4.2.2.1.2 Awareness in Complex Social Structures

Awareness applies to one or more communities within one or more social structures where a community consists of at least one description provider and one description consumer. These communities may be part of the same social structure or be part of different ones.

In Figure 25, awareness can be within a single community, multiple communities, or all communities in the social structure. The social structure can encourage or restrict awareness through its policies, and these policies can affect participant willingness. The information about policies should be incorporated in the relevant descriptions. The social structure also governs the conditions for establishing contracts, the results of which will be reflected in the execution context if interaction is to proceed.

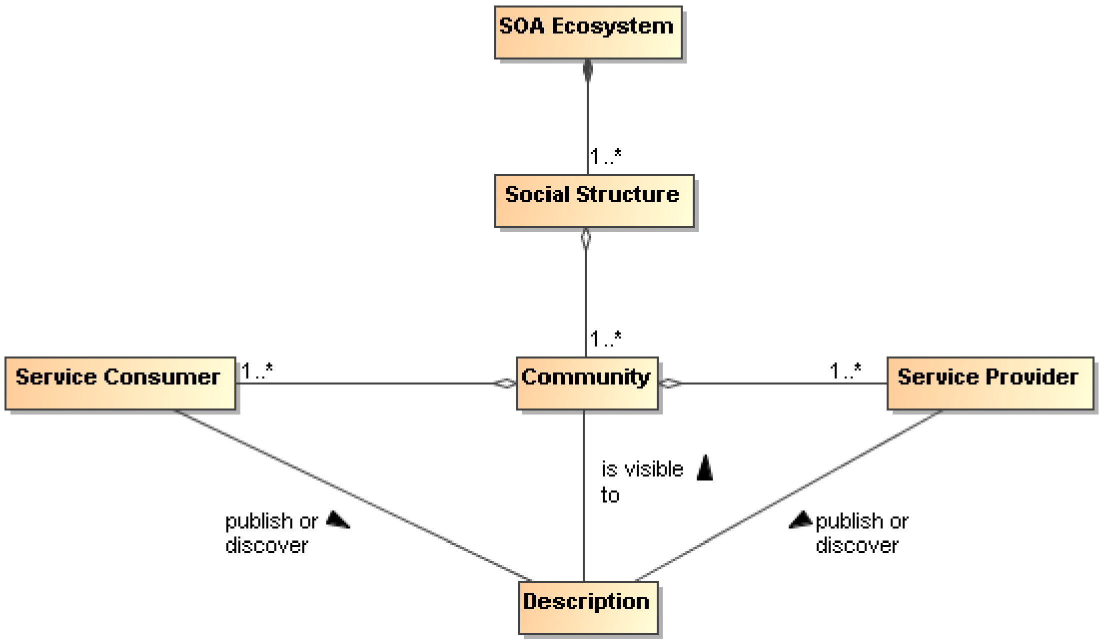


Figure 25 Awareness in a SOA Ecosystem

IT policy/contract mechanisms can be used by visibility mechanisms to provide awareness between communities. The IT mechanisms for awareness may incorporate trust mechanisms to assure awareness between trusted communities. For example, government organizations may want to limit awareness of an organization’s services to specific communities of interest.

Another common business model for awareness is maximizing awareness to communities within the social structure, the traditional market place business model. A centralized mediator often arises as a provider for this global visibility, a gatekeeper of visibility so to speak. For example, Google is a centralized mediator for accessing information on the web. As another example, television networks have centralized entities providing a level of awareness to communities that otherwise could not be achieved without going through the television network.

However, mediators have motivations, and they may be selective in which information they choose to make available to potential consumers. For example, in a secure environment, the mediator may enforce security policies and make information selectively available depending on the security clearance of the consumers.

4.2.2.2 Willingness

Having achieved awareness, participants use descriptions to help determine their willingness to interact with another participant. Both awareness and willingness are determined prior to consumer/provider interaction.

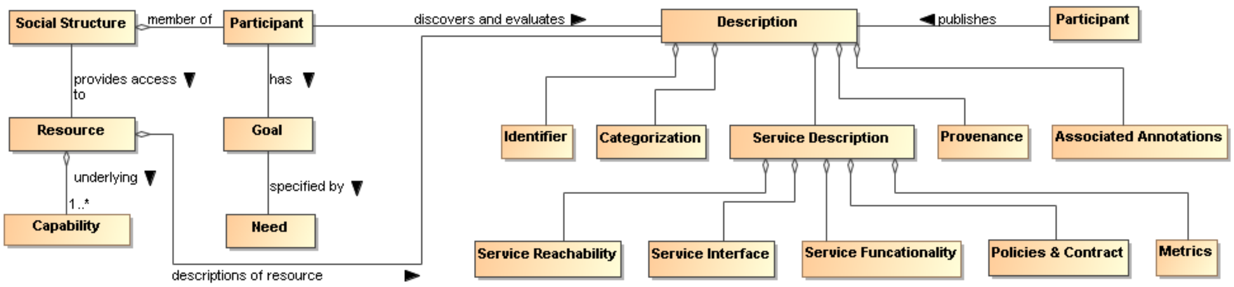


Figure 26 Business, Description and Willingness

Figure 26 relates elements of the *Participation in a SOA Ecosystem* view, and elements from the Service Description Model to willingness. By having a willingness to interact within a particular social structure, the social structure provides the participant access to capabilities based on conditions the social structure finds appropriate for its context. The participant can use these capabilities to satisfy goals and objectives as specified by the participant's needs.

In Figure 26, information used to determine willingness is defined by Description. Information referenced by Description may come from many sources. For example, a mediator for descriptions may provide 3rd party annotations for reputation. Another source for reputation may be a participant's own history of interactions with another participant.

A participant inspects functionality for potential satisfaction of needs. Identity is associated with any participant, however, identity may or may not be verified. If available, participant reputation may be a deciding factor for willingness to interact. Policies and contracts referenced by the description may be particularly important to determine the agreements and commitments required for business interactions. Provenance may be used for verification of authenticity of a resource.

Mechanisms that aid in determining willingness make use of the artifacts referenced by descriptions of services. Mechanisms for establishing willingness could be as simple as rendering service description information for human consumption to automated evaluation of functionality, policies, and contracts by a rules engine. The rules engine for determining willingness could operate as a policy decision procedure as defined in Section 4.4.

4.2.2.3 Reachability

Reachability involves knowing the endpoint, protocol, and presence of a service. At a minimum, reachability requires information about the location of the service and the protocol describing the means of communication.

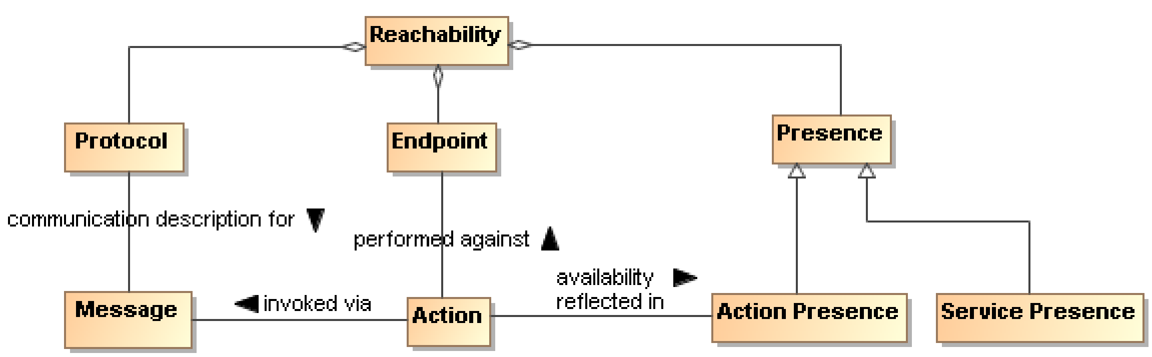


Figure 27 Service Reachability

Endpoint

An endpoint is a reference-able entity, processor or resource against which an action can be performed.

Protocol

A protocol is a structured means by which service interaction is regulated.

Presence

Presence is the measurement of reachability of a service at a particular point in time.

A protocol defines a structured method of communication with a service. Presence is determined by interaction through a communication protocol. Presence may not be known in many cases until the act of interaction begins. To overcome this problem, IT mechanisms may make use of presence protocols to provide the current up/down status of a service.

Service reachability enables service participants to locate and interact with one another. Each action may have its own endpoint and also its own protocols associated with the endpoint and whether there is presence for the action through that endpoint. Presence of a service is an aggregation of the presence of the service's actions, and the service level may aggregate to some degraded or restricted presence if some action presence is not confirmed. For example, if error processing actions are not available, the service can still provide required functionality if no error processing is needed. This implies reachability relates to each action as well as applying to the service/business as a whole.

4.2.3 Architectural Implications

Visibility in a SOA ecosystem has the following architectural implications on mechanisms providing support for awareness, willingness, and reachability:

- Mechanisms providing support for awareness have the following minimum capabilities:
    - creation of Description, preferably conforming to a standard Description format and structure;
    - publishing of Description directly to a consumer or through a third party mediator;
    - discovery of Description, preferably conforming to a standard for Description discovery;
    - notification of Description updates or notification of the addition of new and relevant Descriptions;
    - classification of Description elements according to standardized classification schemes.
- In a SOA ecosystem with complex social structures, awareness may be provided for specific communities of interest. The architectural mechanisms for providing awareness to communities of interest require support for:
    - policies that allow dynamic formation of communities of interest;
    - trust that awareness can be provided for and only for specific communities of interest, the bases of which is typically built on keying and encryption technology.
- The architectural mechanisms for determining willingness to interact require support for:
    - verification of identity and credentials of the provider and/or consumer;
    - access to and understanding of description;
    - inspection of functionality and capabilities;
    - inspection of policies and/or contracts.
- The architectural mechanisms for establishing reachability require support for:
    - the location or address of an endpoint;
    - verification and use of a service interface by means of a communication protocol;
    - determination of presence with an endpoint which may only be determined at the point of interaction but may be further aided by the use of a presence protocol for which the endpoints actively participate.

4.3 Interacting with Services Model

Interaction is the activity involved in using a service to access capability in order to achieve a particular desired real world effect, where real world effect is the actual *result* of using a service. An interaction can be characterized by a sequence of actions. Consequently, interacting with a service, i.e. performing actions against the service—usually mediated by a series of message exchanges—involves actions performed by the service. Different modes of interaction are possible such as modifying the shared state of a resource. Note that a participant (or delegate acting on behalf of the participant) can be the sender of a message, the receiver of a message, or both.

4.3.1 Interaction Dependencies

Recall from the Reference Model that service visibility is the capacity for those with needs and those with capabilities to be able to interact with each other, and that the service interface is the means by which the underlying capabilities of a service are accessed. Ideally, the details of the underlying service implementation are abstracted away by the service interface. [Service] interaction therefore has a direct dependency on the visibility of the service as well as its implementation-neutral interface (see Figure 28). Service visibility is composed of awareness, willingness, and reachability and service interface is composed of the information and behavior models. Service visibility is modeled in Section 4.2 while service interface is modeled in Section 4.1.

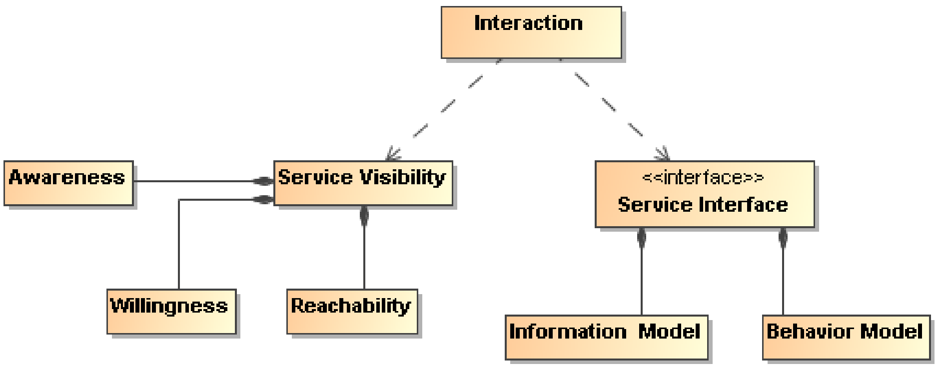


Figure 28 Interaction dependencies.

4.3.2 Actions and Events

For purposes of the SOA-RAF, the authors have committed to the use of message exchange between service participants to denote actions performed against and by the service, and to denote events that report on real world effects that are caused by the service actions. A visual model of the relationship between these concepts is shown in Figure 29.

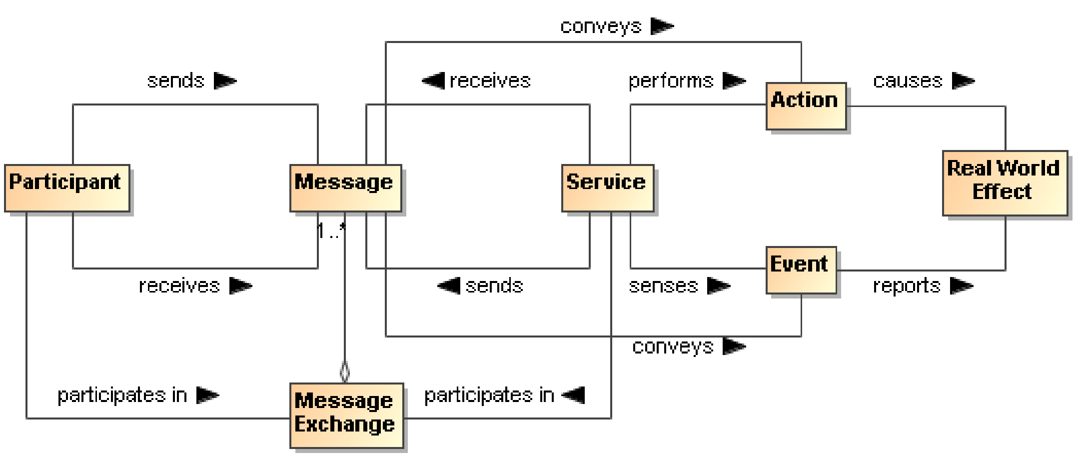


Figure 29 A "message" conveys either an action or an event.

A *message* conveys either an action or an event. In other words, both actions and events, realized by the SOA services, are denoted by the messages. The Reference Model states that the action model characterizes the “permissible set of actions that may be invoked against a service.” We extend that notion here to include events as part of the event model and that messages denote either actions or notification of events.

In Section **Error! Reference source not found.**, we saw that participants interact with each other in rder to perform actions. An action is not itself the same thing as the result of performing the action. When an action is performed against a service, the real world effect that results is reported in the form of notification of events.

4.3.3 Message Exchange

Message exchange is the means by which service participants (or their delegates) interact with each other. There are two primary modes of interaction: joint actions that cause real world effects, and notification of events that report real world effects. [12]

A message exchange is used to affect an action when the messages contain the appropriately formatted content that should be interpreted as joint action and the delegates involved interpret the message appropriately.

A message exchange is also used to communicate event notifications. An event is an occurrence that is of interest to some participant; in our case when some real world effect has occurred. Just as action messages have formatting requirements, so do event notification messages. In this way, the Information Model of a service must specify the syntax (structure), and semantics (meaning) of the action messages and event notification messages as part of a service interface. It must also specify the syntax and semantics of any data that is carried as part of a payload of the action or event notification message. The Information Model is described in greater detail in the Service Description Model (see Section 4.1).

In addition to the Information Model that describes the syntax and semantics of the messages and data payloads, exception conditions and error handling in the event of faults (e.g., network outages, improper message formats, etc.) must be specified or referenced as part of the Service Description.

When a message is interpreted as an action, the correct interpretation typically requires the receiver to perform a set of operations. These *operations* represent the sequence of actions (often private) a service must perform in order to validly participate in a given joint action.

Similarly, the correct consequence of realizing a real world effect may be to initiate the reporting of that real world effect via an event notification.

Message Exchange

The means by which joint action and event notifications are coordinated by service participants (or delegates).

Operations

The sequence of actions a service must perform in order to validly participate in a given joint action.

4.3.3.1 Message Exchange Patterns (MEPs)

The SOA-RAF commits to the use of message exchange to denote actions against the services, and to denote notification of events that report on real world effects that arise from those actions.

Based on these assumptions, the basic temporal aspect of service interaction can be characterized by two fundamental message exchange patterns (MEPs):

- Request/response to represent how actions cause a real world effect
- Event notification to represent how events report a real world effect

This is by no means a complete list of all possible MEPs used for inter- or intra-enterprise messaging but it does represent those that are most commonly used in exchange of information and reporting changes in state both within organizations and across organizational boundaries, a hallmark of a SOA.

Recall from the Reference Model that the Process Model characterizes “the temporal relationships between and temporal properties of actions and events associated with interacting with the service.” Thus, MEPs are a key element of the Process Model. The meta-level aspects of the Process Model (just as with the Action Model) are provided as part of the Service Description Model (see Section 4.1).

[12] The notion of “joint” in joint action implies that you have to have a speaker *and* a listener in order to interact.

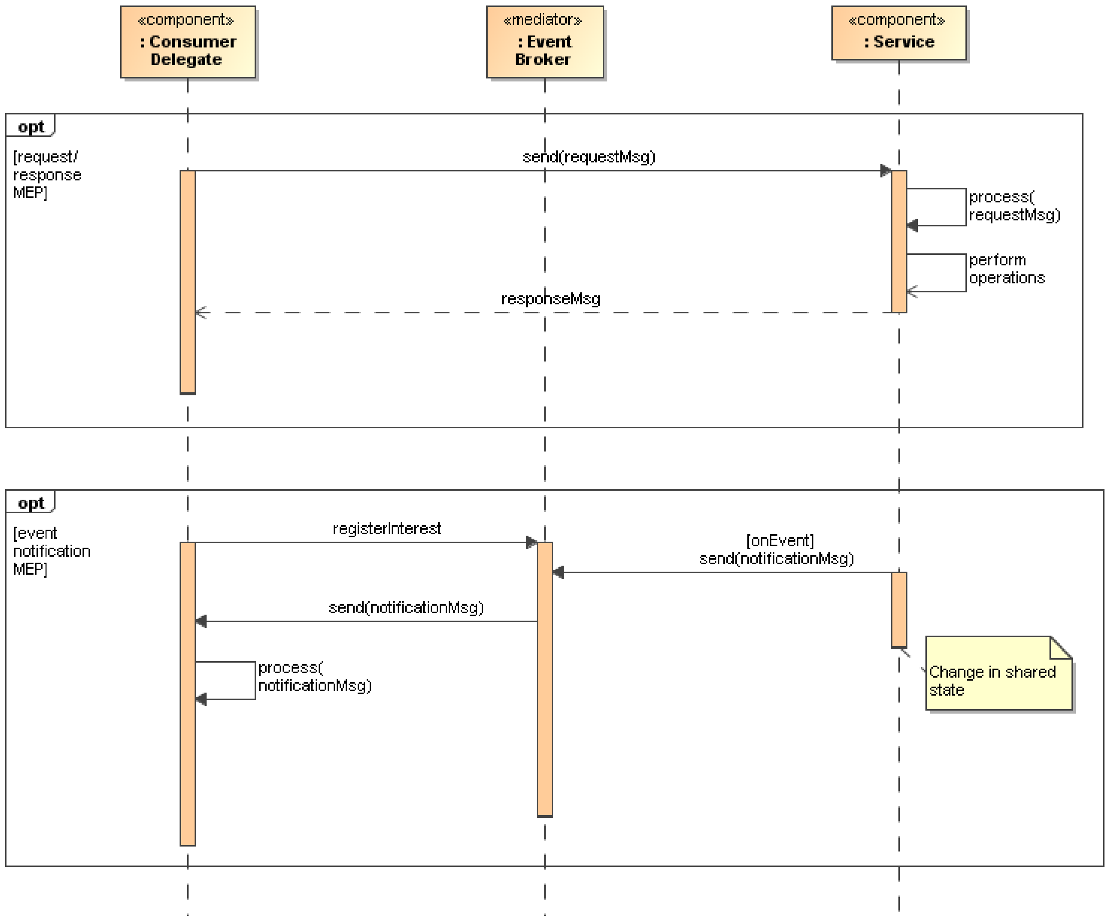


Figure 30 Fundamental SOA message exchange patterns (MEPs)

In the UML sequence diagram shown in Figure 30 it is assumed that the service participants (consumer and provider) have delegated message handling to hardware or software delegates acting on their behalf. In the case of the service consumer, this is represented by the *Consumer Delegate* component. In the case of the service provider, the delegate is represented by the *Service* component. The message interchange model illustrated represents a logical view of the MEPs and not a physical view. In other words, specific hosts, network protocols, and underlying messaging system are not shown as these tend to be implementation specific. Although such implementation-specific elements are considered outside the scope of this document, they are important considerations in modeling the SOA execution context. Recall from the Reference Model that the *execution context* of a service interaction is “the set of infrastructure elements, process entities, policy assertions and agreements that are identified as part of an instantiated service interaction, and thus forms a path between those with needs and those with capabilities.”

4.3.3.2 Request/Response MEP

In a request/response MEP, the Consumer Delegate component sends a request message to the Service component. The Service component then processes the request message. Based on the content of the message, the Service component performs the service operations. Following the completion of these operations, a response message is returned to the Consumer Delegate component. The response could be that a step in a process is complete, the initiation of a follow-on operation, or the return of requested information.[13]

Although the sequence diagram shows a *synchronous* interaction (because the sender of the request message, i.e., Consumer Delegate, is blocked from continued processing until a response is returned from the Service) other variations of request/response are valid, including *asynchronous* (non-blocking) interaction through use of queues, channels, or other messaging techniques.

What is important to convey here is that the request/response MEP represents action, which causes a real world effect, irrespective of the underlying messaging techniques and messaging infrastructure used to implement the request/response MEP.

4.3.3.3 Event Notification MEP

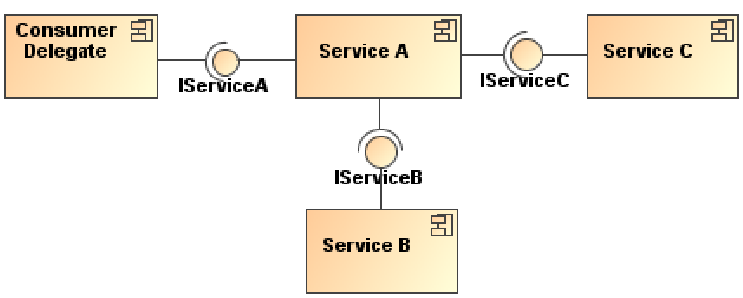
An event is made visible to interested consumers by means of an event notification message exchange that reports a real world effect; specifically, a change in shared state between service participants. The basic event notification MEP takes the form of a one-way message sent by a notifier component (in this case, the Service component) and received by components with an interest in the event (here, the Consumer Delegate component).

Often the sending component may not be fully aware of all the components that receive the notification; particularly in so-called publish/subscribe ("pub/sub") situations. In event notification message exchanges, it is rare to have a tightly-coupled link between the sending and the receiving component(s) for a number of practical reasons. One of the most common is the potential for network outages or communication interrupts that can result in loss of notification of events. Therefore, a third-party mediator component is often used to decouple the sending and receiving components .

Although this is typically an implementation issue, because this type of third-party decoupling is so common in event-driven systems, it is warranted for use in modeling this type of message exchange in the SOA-RAF. This third-party intermediary is shown in Figure 30 as an Event Broker mediator. As with the request/response MEP, no distinction is made between synchronous versus asynchronous communication, although asynchronous message exchange is illustrated in the UML sequence diagram depicted in Figure 30 .

4.3.4 Composition of Services

Composition of services is the act of aggregating or "composing" a single service from one or more other services. A simple model of service composition is illustrated in Figure 31.



[13] There are cases when a response is not always desired and this would be an example of a "one-way" MEP. Similarly, while not shown here, there are cases when some type of "callback" MEP is required in which the consumer agent is actually exposed as a service itself and is able to process incoming messages from another service.

Figure 31 Simple model of service composition.

Here, Service A is a service that has an exposed interface IServiceA, which is available to the Consumer Delegate and relies on two other services in its implementation. The Consumer Delegate does not know that Services B and C are used by Service A, or whether they are used in serial or parallel, or if their operations succeed or fail. The Consumer Delegate only cares about the success or failure of Service A. The exposed interfaces of Services B and C (IService B and IServiceC) are not necessarily hidden from the Consumer Delegate; only the fact that these services are used as part of the composition of Service A. In this example, there is no practical reason the Consumer Delegate could not interact with Service B or Service C in some other interaction scenario.

It is possible for a service composition to be opaque from one perspective and transparent from another. For example, a service may appear to be a single service from the Consumer's Delegate's perspective, but is transparently composed of one or more services from a service management perspective. A Service Management Service needs to be able to have visibility into the composition in order to properly manage the dependencies between the services used in constructing the composite service—including managing the service's lifecycle. The subject of services as management entities is described and modeled in the *Ownership in a SOA Ecosystem* View of the SOA-RAF and is not further elaborated in this section. The point to be made here is that there can be different levels of opaqueness or transparency when it comes to visibility of service composition.

Services can be composed in a variety of ways including direct service-to-service interaction by using programming techniques, or they can be aggregated by means of a scripting approach that leverages a service composition scripting language. Such scripting approaches are further elaborated in the following sub-sections on service-oriented business processes and collaborations.

4.3.4.1 Service-Oriented Business Processes

The concepts of business processes and collaborations in the context of transactions and exchanges across organizational boundaries are described and modeled as part of the *Participation in a SOA Ecosystem* view of this reference architecture (see Section **Error! Reference source not found.**). Here, e focus on the belief that the principle of composition of services can be applied to business processes and collaborations. Of course, business processes and collaborations traditionally represent complex, multi-step business functions that may involve multiple participants, including internal users, external customers, and trading partners. Therefore, such complexities cannot simply be ignored when transforming traditional business processes and collaborations to their service-oriented variants.

Business Processes

> Business processes are a set of one or more linked activities that are performed to achieve a certain business outcome.

Service orientation as applied to business processes (i.e., "service-oriented business processes") means that the aggregation or composition of all of the abstracted activities, flows, and rules that govern a business process can themselves be abstracted as a service **[BLOOMBERG/SCHMELZER]**.

When business processes are abstracted in this manner and accessed through SOA services, all of the concepts used to describe and model composition of services that were articulated in Section 4.3.4 apply. There are some important differences from a composite service that represents an abstraction of a business process from a composite service that represents a single-step business interaction. As stated earlier, business processes have temporal properties and can range from short-lived processes that execute on the order of minutes or hours to long-lived processes that can execute for weeks, months, or even years. Further, these processes may involve many participants. These are important considerations for the consumer of a service-oriented business process and these temporal properties must be articulated as part of the meta-level aspects of the service-oriented business process in its Service Description, along with the meta-level aspects of any sub-processes that may be of use or need to be visible to the service consumer.

In addition, a workflow activity represents a unit of work that some entity acting in a described role (i.e., role player) is asked to perform. Activities can be broken down into steps with each step representing a task for the role player to perform. A technique that is used to compose service-oriented business processes that are hierarchical (top-down) and self-contained in nature is known as *orchestration.*

Orchestration

> A technique used to compose service-oriented business processes that are executed and coordinated by an actor acting as "conductor."

An orchestration is typically implemented using a scripting approach to compose service-oriented business processes. This typically involves use of a standards-based orchestration scripting language. In terms of automation, an orchestration can be mechanized using a business process orchestration engine, which is a hardware or software component (delegate) responsible for acting in the role of central conductor/coordinator responsible for executing the flows that comprise the orchestration.

A simple generic example of such an orchestration is illustrated in Figure 32.

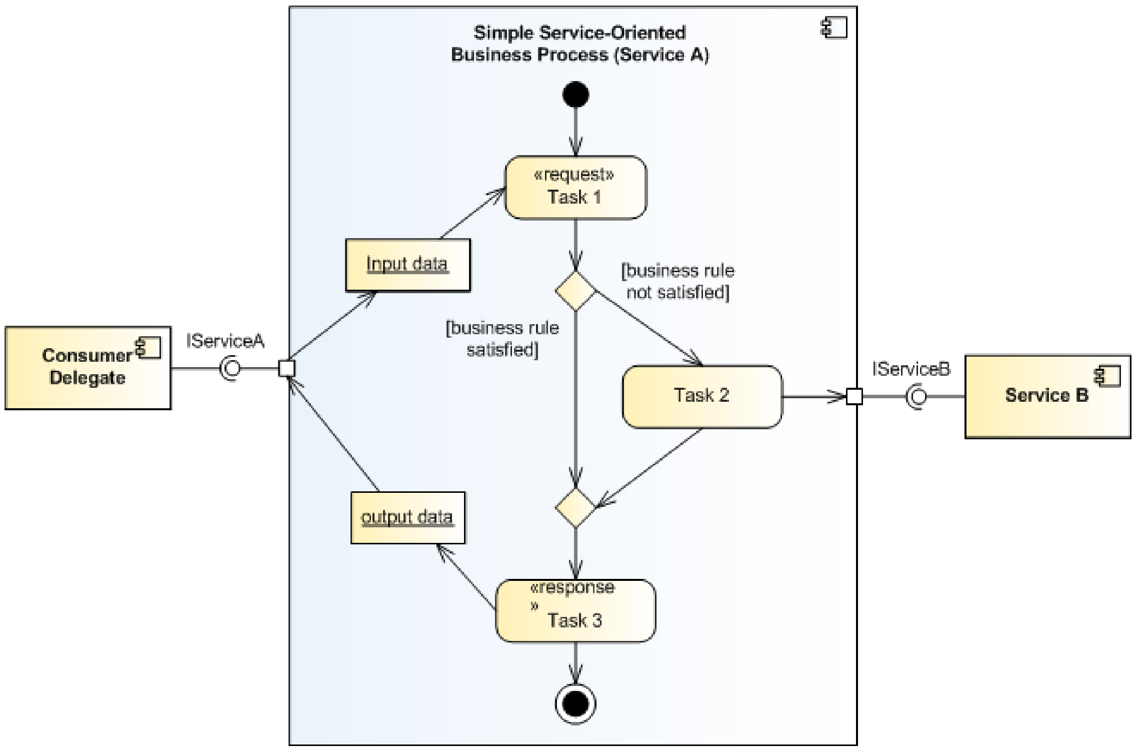


Figure 32 Abstract example of orchestration of service-oriented business process.

Here, we use a UML activity diagram to model the simple service-oriented business process as it allows us to capture the major elements of business processes such as the set of related tasks to be performed, linking between tasks in a logical flow, data that is passed between tasks, and any relevant business rules that govern the transitions between tasks. A task is a unit of work that an individual, system, or organization performs and can be accomplished in one or more steps or subtasks. While subtasks can be readily modeled, they are not illustrated in the orchestration model In Figure 32..

This particular example is based on a request/response MEP and captures how one particular task (Task 2) actually utilizes an externally-provided service, Service B. The entire service-oriented business process is exposed as Service A that is accessible via its externally visible interface, IServiceA.

Although not explicitly shown in the orchestration model above, it is assumed that there exists a software or hardware component, i.e., orchestration engine that executes the process flow. Recall that a central concept to orchestration is that process flow is coordinated and executed by a single conductor delegate; hence the name "orchestration."

4.3.4.2 Service-Oriented Business Collaborations

Business collaborations typically represent the interaction involved in executing business transactions, where a business transaction is defined in the *Participation in a SOA Ecosystem* view as "a joint action engaged in by two or more participants in which resources are exchanged" (see Section **Error! Reference source not found.**).

It is important to note that business collaborations represent “peer”-style interactions; in other words, peers in a business collaboration act as equals. This means that unlike the orchestration of business processes, there is no single or central entity that coordinates or “conducts” a business collaboration. These peer styles of interactions typically occur between trading partners that span organizational boundaries.

Business collaborations can also be service-enabled. For purposes of this Reference Architecture Foundation, we refer to these as “service-oriented business collaborations.” Service-oriented business collaborations do not necessarily imply exposing the entire peer-style business collaboration as a service itself but rather the collaboration uses service-based interchanges.

The technique that is used to compose service-oriented business collaborations in which multiple parties collaborate in a peer-style as part of some larger business transaction by exchanging messages with trading partners and external organizations (e.g., suppliers) is known as *choreography* **[NEWCOMER/LOMOW]**.

Choreography

> A technique used to characterize service-oriented business collaborations based on ordered message exchanges between peer entities in order to achieve a common business goal.

Choreography differs from orchestration primarily in that each party in a business collaboration describes its part in the service interaction. Note that choreography as we have defined it here should not be confused with the term *process choreography*, which is defined in the *Participation in a SOA Ecosystem* view as “the description of the possible interactions that may take place between two or more participants to fulfill an objective.” This is an example of domain-specific nomenclature that often leads to confusion and why we are making note of it here.

A simple generic example of a choreography is illustrated in Figure 33

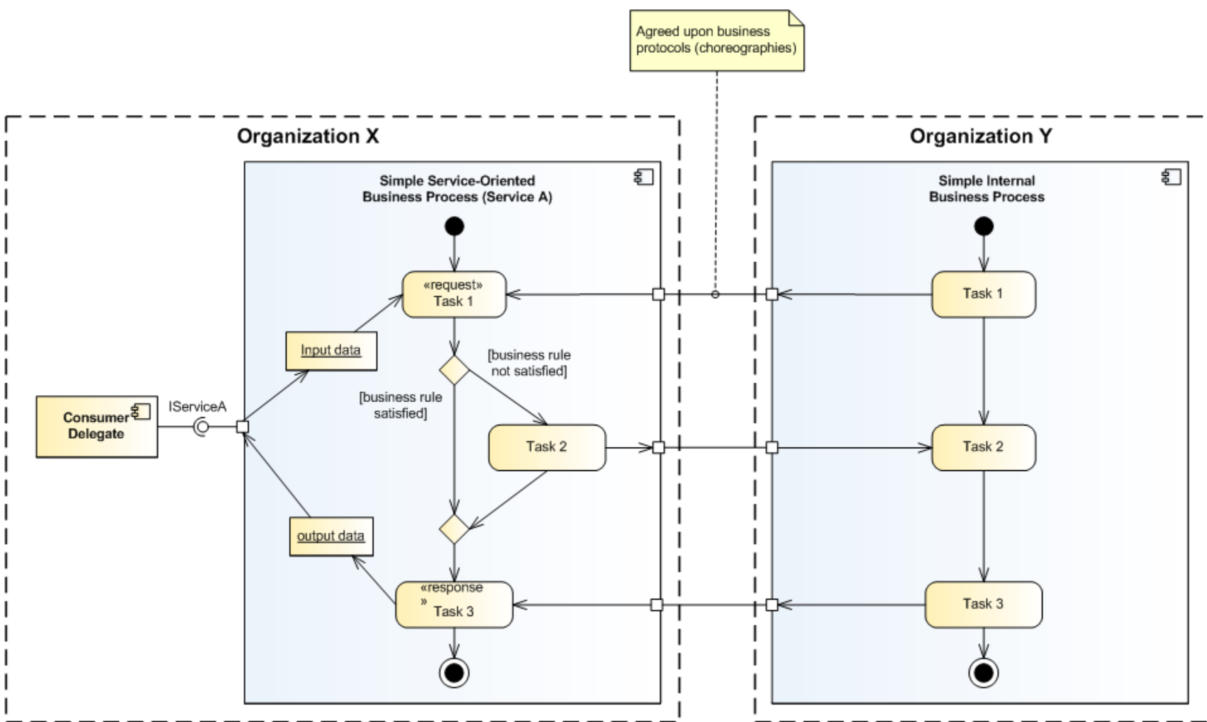


Figure 33 Abstract example of choreography of service-oriented business collaboration.

This example, which is a variant of the orchestration example illustrated earlier in Figure 32 adds trust boundaries between two organizations; namely, Organization X and Organization Y. It is assumed that these two organizations are peer entities that have an interest in a business collaboration, for example, Organization X and Organization Y could be trading partners. Organization X retains the service-oriented business process Service A, which is exposed to internal consumers via its provided service interface, IServiceA. Organization Y also has a business process that is involved in the business collaboration;

however, for this example, it is an internal business process that is not exposed to potential consumers either within or outside its organizational boundary.

The scripting language that is used for the choreography needs to define how and when to pass control from one trading partner to another, i.e., Organization X and Organization Y. Defining the business protocols used in the business collaboration involves precisely specifying the visible message exchange behavior of each of the parties involved in the protocol, without revealing internal implementation details **[NEWCOMER/LOMOW]**.

In a peer-style business collaboration, a choreography scripting language must be capable of describing the coordination of those service-oriented processes that cross organizational boundaries.

4.3.5 Architectural Implications of Interacting with Services

Interacting with Services has the following architectural implications on mechanisms that facilitate service interaction:

- A well-defined service Information Model that:
    - describes the syntax and semantics of the messages used to denote actions and events;
    - describes the syntax and semantics of the data payload(s) contained within messages;
    - documents exception conditions in the event of faults due to network outages, improper message/data formats, etc.;
    - is both human readable and machine processable;
    - is referenceable from the Service Description artifact.
- A well-defined service Behavior Model that:
    - characterizes the knowledge of the actions invokes against the service and events that report real world effects as a result of those actions;
    - characterizes the temporal relationships and temporal properties of actions and events associated in a service interaction;
    - describe activities involved in a workflow activity that represents a unit of work;
    - describes the role (s) that a role player performs in a service-oriented business process or service-oriented business collaboration;
    - is both human readable and machine processable;
    - is referenceable from the Service Description artifact.
- Service composition mechanisms to support orchestration of service-oriented business processes and choreography of service-oriented business collaborations such as:
    - Declarative and programmatic compositional languages;
    - Orchestration and/or choreography engines that support multi-step processes as part of a short-lived or long-lived business transaction;
    - Orchestration and/or choreography engines that support compensating transactions in the presences of exception and fault conditions.
- Infrastructure services that provides mechanisms to support service interaction, including but not limited to:
    - mediation services such as message and event brokers, providers, and/or buses that provide message translation/transformation, gateway capability, message persistence, reliable message delivery, and/or intelligent routing semantics;
    - binding services that support translation and transformation of multiple application-level protocols to standard network transport protocols;
    - auditing and logging services that provide a data store and mechanism to record information related to service interaction activity such as message traffic patterns, security violations, and service contract and policy violations
    - security services that abstract techniques such as public key cryptography, secure networks, virus protection, etc., which provide protection against common security threats in a SOA ecosystem;
    - monitoring services such as hardware and software mechanisms that both monitor the performance of systems that host services and network traffic during service interaction, and are capable of generating regular monitoring reports.
- A layered and tiered service component architecture that supports multiple message exchange patterns (MEPs) in order to:

- promote the industry best practice of separation of concerns that facilitates flexibility in the presence of changing business requirements;
- promote the industry best practice of separation of roles in a service development lifecycle such that subject matter experts and teams are structured along areas of expertise;
- support numerous standard interaction patterns, peer-to-peer interaction patterns, enterprise integration patterns, and business-to-business integration patterns.

4.4 Policies and Contracts Model

A common phenomenon of many machines and systems is that the scope of potential behavior is much broader than is actually needed for a particular circumstance. This is especially true of a system as powerful as a SOA ecosystem. As a result, the behavior and performance of the system tend to be under-constrained by the implementation; instead, the actual behavior is expressed by means of policies of some form. Policies define the choices that stakeholders make; these choices are used to guide the actual behavior of the system to the desired behavior and performance.

As noted in Section 3.1.5 a policy is a constraint of some form that is promulgated by a stakeholder who has the responsibility of ensuring that the constraint is enforced. In contrast, contracts are **agreements** between participants. However, like policies, it is a necessary part of contracts that they are enforceable.

While responsibility for enforcement may differ, both contracts and policies share a common characteristic – there is a **constraint** that must be enforced. In both cases the mechanisms needed to enforce policy constraints are likely to be identical; in this model we focus on the issues involved in representing policies and contracts and on some of the principles behind their enforcement.

4.4.1 Policy and Contract Representation

A **policy constraint** is a specific kind of constraint: the ontology of policies and contracts includes the core concepts of permission, obligation, owner, subject. In addition, it may be necessary to be able combine policy constraints and to be able to resolve policy conflicts.

4.4.1.1 Policy Framework

Policy Framework

A policy framework is a language in which policy constraints may be expressed.

A policy framework combines a syntax for expressing policy constraints together with a decision procedure for determining if a policy constraint is satisfied.

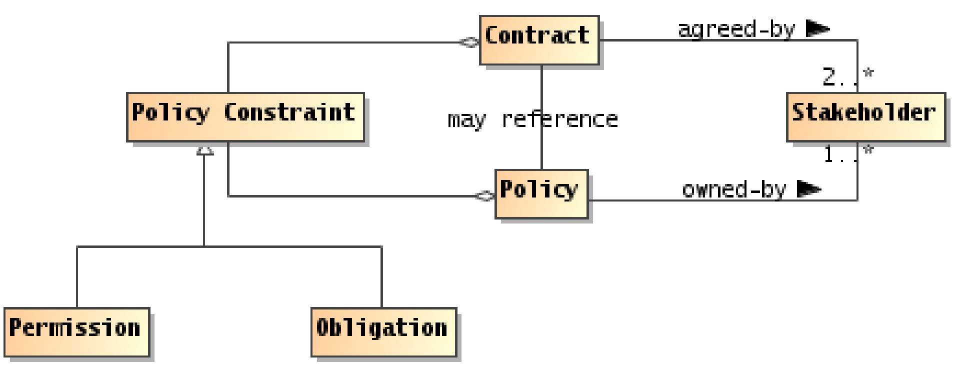


Figure 34 Policies and Contracts

We can characterize (caricature) a policy framework in terms of a logical framework and an ontology of policies. The policy ontology details specific kinds of policy constraints that can be expressed; and the logical framework is a 'glue' that allows us to express combinations of policies.

Logical Framework

> A logical framework is a linguistic framework consisting of a syntax – a way of writing expressions – and a semantics – a way of interpreting the expressions.

Policy Ontology

> A policy ontology is a formalization of a set of concepts that are relevant to forming policy expressions.

For example, a policy ontology that allows to identify simple constraints – such as the existence of a property, or that a value of a property should be compared to a fixed value – is often enough to express many basic constraints.

Included in many policy ontologies are the basic signals of permissions and obligations. Some policy frameworks are sufficiently constrained that there is not possibility of representing an obligation; in which case there is often no need to 'call out' the distinction between permissions and obligations.

The logical framework is also a strong determiner of the expressivity of the policy framework. The richer the logical framework, the richer the set of policy constraints that can be expressed. However, there is a strong inverse correlation between expressivity and ease and efficiency of implementation.

In the discussion that follows we assume the following basic policy ontology:

Policy Owner

> A policy owner is a stakeholder that asserts and enforces the policy.

Policy Subject

> A policy subject is an actor who is subject to the constraints of a policy or contract.

Policy Constraint

> A policy constraint is a measurable proposition that characterizes the constraint that the policy is about.

Policy Object

> A policy object is an identifiable state, action or resource that is potentially constrained by the policy.

4.4.2 Policy and Contract Enforcement

The enforcement of policy constraints has to address two core problems: how to enforce the atomic policy constraints, and how to enforce combinations of policy constraints. In addition, it is necessary to address the resolution of policy conflicts.

4.4.2.1 Enforcing Simple Policy Constraints

The two primary kinds of policy constraint – permission and obligation – naturally lead to different styles of enforcement. A permission constraint must typically be enforced *prior* to the policy subject invoking the **policy object**. On the hand, an obligation constraint must typically be enforced post-facto through some form of auditing process and remedial action.

For example, if a communications policy required that all communication be encrypted, this is enforceable at the point of communication: any attempt to communicate a message that is not encrypted can be blocked.

Similarly, an obligation to pay for services rendered is enforced by ensuring that payment arrives within a reasonable period of time. Invoices are monitored for prompt (or lack of) payment.

The key concepts in enforcing both forms of policy constraint are the policy decision and the policy enforcement.

Policy Decision

> A policy decision is a determination as to whether a given policy constraint is satisfied or not.

A policy decision is effectively a measurement of some state – typically a portion of the SOA ecosystem's **shared state**. This implies a certain *timeliness* in the measuring: a measurement that is too early or is too late does not actually help in determining if the policy constraint is satisfied appropriately.

Policy Enforcement

> A policy enforcement is the use of a mechanism to limit the behavior and/or state of policy subjects to comply with a policy decision.

A policy enforcement implies the use of some mechanism to ensure compliance with a policy decision. The range of mechanisms is completely dependent on the kinds of atomic policy constraints that the policy framework may support. As noted above, the two primary styles of constraint – permission and **obligation** –lead to different styles of enforcement.

4.4.2.2 Enforcing Policy Combinations

Enforcing policy combinations is primarily an elaboration of enforcing simple policy constraints. The process of policy decisions is enhanced to allow a measurement to involve combinations of policy constraints and the process of policy enforcement may need to be enhanced to coordinate the enforcement of multiple policy constraints simultaneously.

4.4.2.3 Conflict Resolution

Whenever it is possible that more than one policy constraint applies in a given situation, there is the potential that the policies themselves are not mutually consistent. For example, a policy that requires communication to be encrypted and a policy that requires an administrator to read every communication conflict with each other – the two policies cannot both be satisfied.

In general, with sufficiently rich policy frameworks, it is not possible to always resolve policy conflicts automatically. However, a reasonable approach is to augment the policy decision process with simple policy conflict resolution rules; with the potential for *escalating* a policy conflict to human adjudication.

Policy Conflict

> A policy conflict exists between two or more policies in a policy decision process if it is not possible to satisfy all the policies that apply.

Policy Conflict Resolution

> A policy conflict resolution rule is a way of determining which policy should prevail in a policy conflict.

The inevitable consequence of policy conflicts is that it is not possible to guarantee that all policies are satisfied at all times. This, in turn, implies a certain *flexibility* in the application of policy constraints: they will not always be honored.

4.4.3 Architectural Implications

The key choices that must be made in a system of policies center around the policy framework and policy enforcement mechanisms

- There SHOULD be a standard policy framework that is adopted across the SOA ecosystem:
  - This framework MUST permit the expression of simple policy constraints
  - The framework MAY allow (to a varying extent) the combination of policy constraints, including
    - Both positive and negative constraints
    - Conjunctions and disjunctions of constraints
    - The quantification of constraints
  - The framework MUST at least allow the policy subject and the policy object to be identified as well as the policy constraint.
  - The framework MAY allow further structuring of policies into modules, inheritance between policies and so on.
- There SHOULD be mechanisms that facilitate the application of policies:

- There SHOULD be mechanisms that allow policy decisions to be made, consistent with the policy frameworks and with the state of the SOA ecosystem.
- There SHOULD be mechanisms to enforce policy decisions
    - There SHOULD be mechanisms to support the measurement of whether certain policy constraints are satisfied or not, or to what degree they are satisfied.
    - Such enforcement mechanisms MAY include support for both permission-style constraints and obligation-style constraints.
    - Enforcement mechanisms MAY support the simultaneous enforcement of multiple policy constraints across multiple points in the SOA ecosystem.
- There SHOULD be mechanisms to resolve policy conflicts
    - This MAY involve escalating policy conflicts to human adjudication.
- There SHOULD be mechanisms that support the management and promulgation of policies.

5 *Ownership in a SOA Ecosystem* View

Governments are instituted among Men,
deriving their just power from the consent of the governed
American Declaration of Independence

The *Owning Service Oriented Architectures* View focuses on the issues, requirements and responsibilities involved in owning a SOA-based system.

Owning a SOA-based system raises significantly different challenges to owning other complex systems -- such as Enterprise suites -- because there are strong limits on the control and authority of any one party when a system spans multiple ownership domains.

Even when a SOA-based system is deployed internally within an organization, there are multiple internal stakeholders involved and there may not be a simple hierarchy of control and management. Thus, an early consideration of how multiple boundaries affect SOA-based systems provides a firm foundation for dealing with them in whatever form they are found rather than debating whether the boundaries should exist.

This view focuses on the Governance of SOA-based systems, on the security challenges involved in running a SOA-based system and the management challenges.

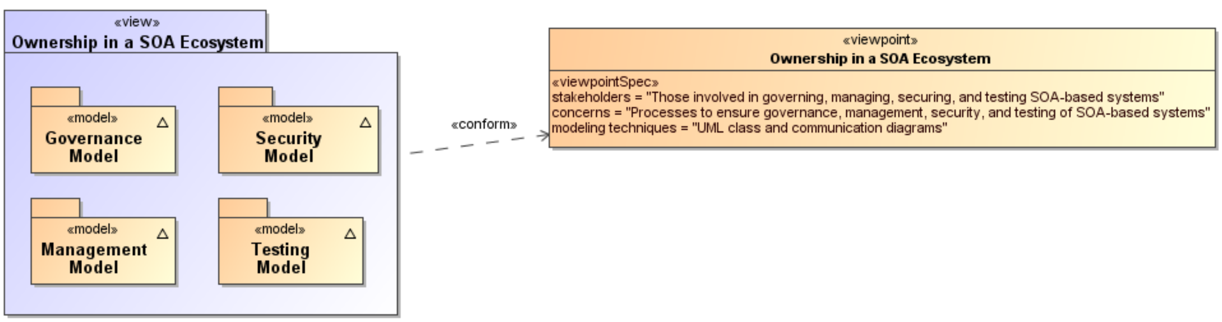


Figure 35 Model Elements Described in the Ownership in a SOA Ecosystem *View*

The following subsections present models of these functions.

5.1 Governance Model

The Reference Model defines Service Oriented Architecture as an architectural paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains **[SOA-RM]**. Consequently, it is important that organizations that plan to engage in service interactions adopt governance policies and procedures sufficient to ensure that there is standardization across both internal and external organizational boundaries to promote the effective creation and use of SOA-based services.

5.1.1 Understanding Governance

5.1.1.1 Terminology

Governance is about making decisions that are aligned with the overall organizational strategy and culture of the enterprise. **[Gartner]** It specifies the decision rights and accountability framework to encourage desirable behaviors **[Weill/Ross-MIT Sloan School]** towards realizing the strategy and defines incentives (positive or negative) towards that end. It is less about overt control and strict adherence to rules, and more about guidance and effective and equitable usage of resources to ensure sustainability of an organization's strategic objectives. **[TOGAF v8.1]**

To accomplish this, governance requires organizational structure and processes and must identify who has authority to define and carry out its mandates. It must address the following questions: 1) what decisions must be made to ensure effective management and use?, 2) who should make these decisions?, and 3) how will these decisions be made and monitored? , and (4) how will these decisions be communicated? The intent is to achieve goals, add value, and reduce risk.

Within a single ownership domain such as an enterprise, generally there is a hierarchy of governance structures. Some of the more common enterprise governance structures include corporate governance, technology governance, IT governance, and architecture governance **[TOGAF v8.1]**. These governance structures can exist at multiple levels (global, regional, and local) within the overall enterprise.

It is often asserted that SOA governance is a specialization of IT governance as there is a natural hierarchy of these types of governance structures; however, the focus of SOA governance is less on decisions to ensure effective management and use of IT as it is to ensure effective management and use of SOA-based systems. Certainly, SOA governance must still answer the basic questions also associated with IT governance, i.e., who should make the decisions, and how these decisions will be made and monitored.

5.1.1.2 Relationship to Management

There is often confusion centered on the relationship between governance and management. As described earlier, governance is concerned with decision making. Management, on the other hand, is concerned with execution. Put another way, governance describes the world as leadership wants it to be; management executes activities that intends to make the leadership's desired world a reality. Where governance determines who has the authority and responsibility for making decisions and the establishment of guidelines for how those decisions should be made, management is the actual process of making, implementing, and measuring the impact of those decisions **[Loeb]**. Consequently, governance and management work in concert to ensure a well-balanced and functioning organization as well as an ecosystem of inter-related organizations. In the sections that follow, we elaborate further on the relationship between governance and management in terms of setting and enforcing service policies, contracts, and standards as well as addressing issues surrounding regulatory compliance.

5.1.1.3 Why is SOA Governance Important?

One of the hallmarks of SOA that distinguishes it from other architectural paradigms for distributed computing is the ability to provide a uniform means to offer, discover, interact with and use capabilities (as well the ability to compose new capabilities from existing ones) all in an environment that transcends domains of ownership. Consequently, ownership, and issues surrounding it, such as obtaining acceptable terms and conditions (T&Cs) in a contract, is one of the primary topics for SOA governance. Generally, IT governance does not include T&Cs, for example, as a condition of use as its primary concern.

Just as other architectural paradigms, technologies, and approaches to IT are subject to change and evolution, so too is SOA. Setting policies that allow change management and evolution, establishing strategies for change, resolving disputes that arise, and ensuring that SOA-based systems continue to fulfill the goals of the business are all reasons why governance is important to SOA.

5.1.1.4 Governance Stakeholders and Concerns

As noted in Section **Error! Reference source not found.** the participants in a service interaction include he service provider, the service consumer, and other interested or unintentional third parties. Depending on the circumstances, it may also include the owners of the underlying capabilities that the SOA services access. Governance must establish the policies and rules under which duties and responsibilities are defined and the expectations of participants are grounded. The expectations include transparency in aspects where transparency is mandated, trust in the impartial and consistent application of governance, and assurance of reliable and robust behavior throughout the SOA ecosystem.

5.1.2 A Generic Model for Governance

Governance

> Governance is the prescribing of conditions and constraints consistent with satisfying common goals and the structures and processes needed to define and respond to actions taken towards realizing those goals.

The following is a generic model of governance represented by segmented models that begin with motivation and proceed through measuring compliance. It is not all-encompassing but a focused subset that captures the aspects necessary to describe governance for SOA. It does not imply that practical application of governance is a single, isolated instance of these models; in reality, there may be hierarchical and parallel chains of governance that deal with different aspects or focus on different goals. This is discussed further in section 5.1.2.5. The defined models are simultaneously applicable to each of the overlapping instances.

A given enterprise may already have portions of these models in place. To a large extent, the models shown here are not specific to SOA; discussions on direct applicability begin in section 5.1.3.

5.1.2.1 Motivating Governance

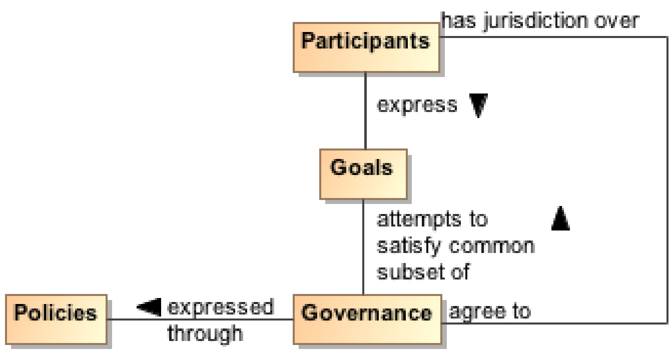


Figure 36 Motivating governance model

An organizational domain such as an enterprise is made up of participants who may be individuals or groups of individuals forming smaller organizational units within the enterprise. The overall business strategy should be consistent with the Goals of the participants; otherwise, the business strategy would not provide value to the participants and governance towards those ends becomes difficult if not impossible. This is not to say that an instance of governance simultaneously satisfies all the goals of all the participants; rather, the goals of any governance instance must sufficiently satisfy a useful subset of each participant's goals so as to provide value and ensure the cooperation of all the participants.

A policy is the formal characterization of the conditions and constraints that governance deems as necessary to realize the goals which it is attempting to satisfy. Policy may identify required conditions or actions or may prescribe limitations or other constraints on permitted conditions or actions. For example, a policy may prescribe that safeguards must be in place to prevent unauthorized access to sensitive material. It may also prohibit use of computers for activities unrelated to the specified work assignment. Policy is made operational through the promulgating and implementing of Rules and Regulations (as defined in section 5.1.2.3).

As noted in section 4.4.2, policy may be asserted by any participant or on behalf of the participant by its organization. Part of the purpose of governance is to arbitrate among diverse goals of participants and diverse policies articulated to realize those goals. The intent is to form a consistent whole that allows governance to minimize ambiguity about its purpose. While resolving all ambiguity would be an ideal, it is unlikely that all inconsistencies will be identified and resolved before governance becomes operational.

For governance to have effective jurisdiction over participants, there must be some degree of agreement by all participants that they will abide by the governance mandates. A minimal degree of agreement often presages participants who “slow-roll” if not actively reject complying with Policies that express the specifics of governance.

5.1.2.2 Setting Up Governance

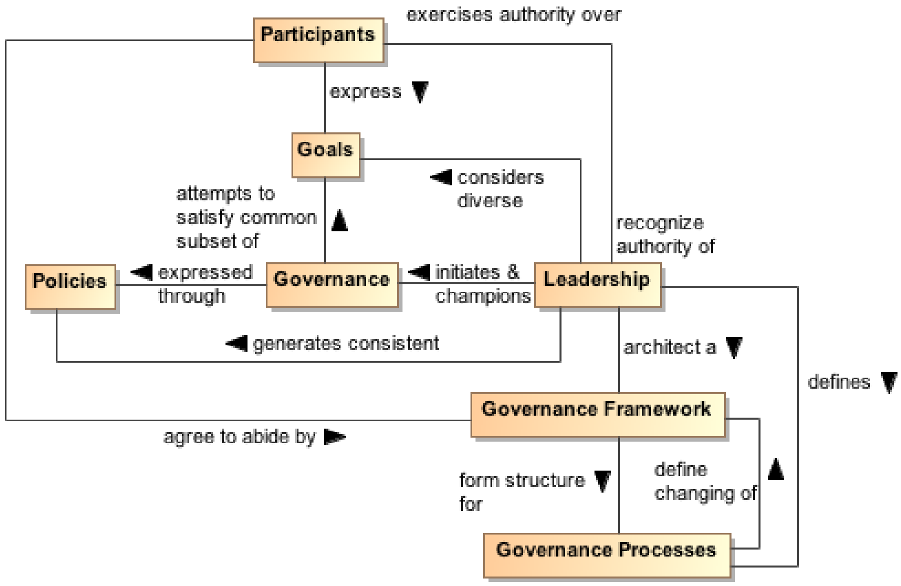


Figure 37 Setting up governance model

Leadership

> Leadership is the entity who has the responsibility and authority to generate consistent policies through which the goals of governance can be expressed and to define and champion the structures and processes through which governance is realized.

Governance Framework

> The Governance Framework is a set of organizational structures that enable governance to be consistently defined, clarified, and as needed, modified to respond to changes in its domain of concern.

Governance Processes

> Governance Processes are the defined set of activities that are performed within the Governance Framework to enable the consistent definition, application, and as needed, modification of Rules that organize and regulate the activities of participants for the fulfillment of expressed policies. (See section 5.1.2.3 for elaboration on the relationship of Governance Processes and Rules.)

As noted earlier, governance requires an appropriate organizational structure and identification of who has authority to make governance decisions. In Figure 37, the entity with governance authority is designated the Leadership. This is someone, possibly one or more of the participants, that participants recognize as having authority for a given purpose or over a given set of issues or concerns.

The Leadership is responsible for prescribing or delegating a working group to prescribe the Governance Framework that forms the structure for Governance Processes which define how governance is to be carried out. This does not itself define the specifics of how governance is to be applied, but it does provide an unambiguous set of procedures that should ensure consistent actions which participants agree are fair and account for sufficient input on the subjects to which governance is applied.

The participants may be part of the working group that codifies the Governance Framework and Processes. When complete, the participants must acknowledge and agree to abide by the products generated through application of this structure.

The Governance Framework and Processes are often documented in the charter of a body created or designated to oversee governance. This is discussed further in the next section. Note that the Governance Processes should also include those necessary to modify the Governance Framework itself.

An important function of Leadership is not only to initiate but also be the consistent champion of governance. Those responsible for carrying out governance mandates must have Leadership who makes it clear to participants that expressed Policies are seen as a means to realizing established goals and that compliance with governance is required.

5.1.2.3 Carrying Out Governance

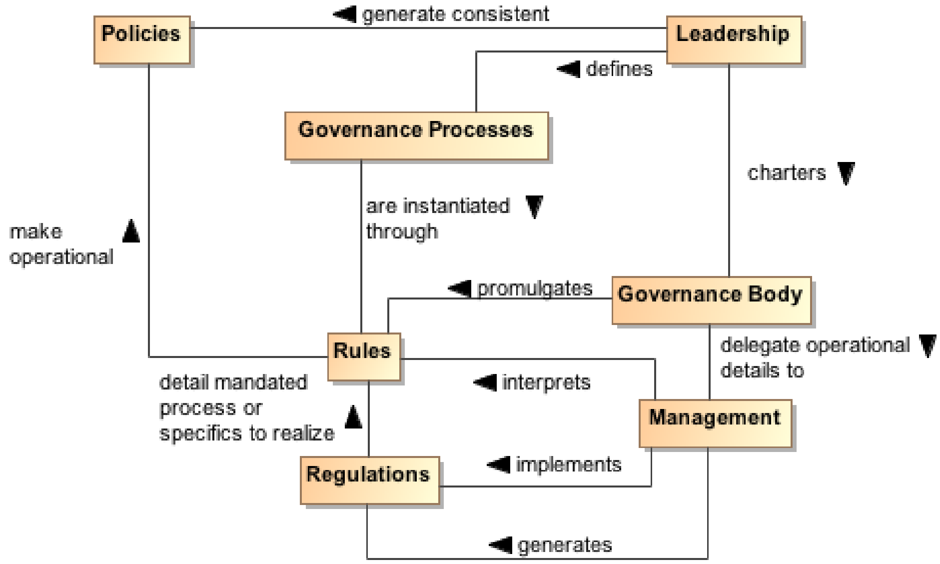


Figure 38 Carrying out governance model

Rule

A Rule is a prescribed guide for carrying out activities and processes leading to desired results, e.g. the operational realization of policies.

Regulation

A Regulation is a mandated process or the specific details that derive from the interpretation of Rules and lead to measureable quantities against which compliance can be measured.

To carry out governance, Leadership charters a Governance Body to promulgate the Rules needed to make the Policies operational. The Governance Body acts in line with Governance Processes for its rule-making process and other functions. Whereas Governance is the setting of Policies and defining the Rules that provide an operational context for Policies, the operational details of governance may be delegated by the Governance Body to Management. Management generates Regulations that specify details for Rules and other procedures to implement both Rules and Regulations. For example, Leadership could set a Policy that all authorized parties should have access to data, the Governance Body would promulgate a Rule that PKI certificates are required to establish identity of authorized parties, and Management can specify a Regulation of who it deems to be a recognized PKI issuing body. In summary, Policy is a predicate to be satisfied and Rules prescribe the activities by which that satisfying occurs. A number of rules may be required to satisfy a given policy; the carrying out of a rule may contribute to several policies being realized.

Whereas the Governance Framework and Processes are fundamental for having participants acknowledge and commit to compliance with governance, the Rules and Regulations provide operational constraints which may require resource commitments or other levies on the participants. It is important for participants to consider the framework and processes to be fair, unambiguous, and capable of being carried out in a consistent manner and to have an opportunity to formally accept or ratify this situation. Rules and Regulations, however, do not require individual acceptance by any given participant although some level of community comment may be part of the Governance Processes. Having agreed to governance, the participants are bound to comply or be subject to prescribed mechanisms for enforcement.

5.1.2.4 Ensuring Governance Compliance

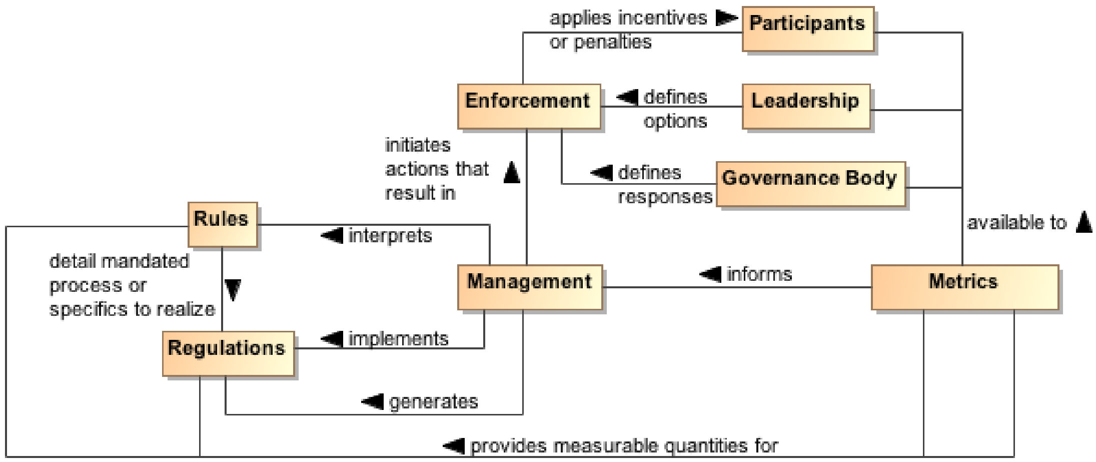


Figure 39 Ensuring governance compliance model

Setting Rules and Regulations does not ensure effective governance unless compliance can be measured and Rules and Regulations can be enforced. Metrics are those conditions and quantities that can be measured to characterize actions and results. Rules and Regulations MUST be based on collected Metrics or there is no means for Management to assess compliance. The Metrics are available to the participants, the Leadership, and the Governance Body so what is measured and the results of measurement are clear to everyone.

The Leadership in its relationship with participants has certain options that can be used for Enforcement. A common option may be to effect future funding. The Governance Body defines specific enforcement responses, such as what degree of compliance is necessary for full funding to be restored. It is up to Management to identify compliance shortfalls and to initiate the Enforcement process.

Note, enforcement does not strictly need to be negative consequences. Management can use Metrics to identify exemplars of compliance and Leadership can provide options for rewarding the participants. The Governance Body defines awards or other incentives.

5.1.2.5 Considerations for Multiple Governance Chains

As noted in section 5.1.2, instances of the governance model often occur as a tiered arrangement, with governance at some level delegating specific authority and responsibility to accomplish a focused portion of the original level's mandate. For example, a corporation may encompass several lines of business and each line of business governs its own affairs in a manner that is consistent with and contributes to the goals of the parent organization. Within the line of business, an IT group may be given the mandate to provide and maintain IT resources, giving rise to IT governance.

In addition to tiered governance, there may be multiple governance chains working in parallel. For example, a company making widgets has policies intended to ensure they make high quality widgets and make an impressive profit for their shareholders. On the other hand, Sarbanes-Oxley is a parallel governance chain in the United States that specifies how the management must handle its accounting and information that needs to be given to its shareholders. The parallel chains may just be additive or may be in conflict and require some harmonization.

Being distributed and representing different ownership domains, a SOA participant falls under the jurisdiction of multiple governance domains simultaneously and may individually need to resolve consequent conflicts. The governance domains may specify precedence for governance conformance or it may fall to the discretion of the participant to decide on the course of actions they believe appropriate.

5.1.3 Governance Applied to SOA

5.1.3.1 Where SOA Governance is Different

SOA governance is often discussed in terms of IT governance, but rather than a parent-child relationship, Figure 40 shows the two as siblings of the general governance described in section 5.1.2. There are obvious dependencies and a need for coordination between the two, but the idea of aligning IT with business already demonstrates that resource providers and resource consumers must be working towards common goals if they are to be productive and efficient. While SOA governance is shown to be active in the area of infrastructure, it is a specialized concern for having a dependable platform to support service interaction; a range of traditional IT issues is therefore out of scope of this document. A SOA governance plan for an enterprise will not of itself resolve shortcomings with the enterprise's IT governance.

Governance in the context of SOA is that organization of services: that promotes their visibility; that facilitates interaction among service participants; and that directs that the results of service interactions are those real world effects as described within the service description and constrained by policies and contracts as assembled in the execution context.

SOA governance must specifically account for control across different ownership domains, i.e. all the participants may not be under the jurisdiction of a single governance authority. However, for governance to be effective, the participants must agree to recognize the authority of the Governance Body and must operate within the Governance Framework and through the Governance Processes so defined.

SOA governance must account for interactions across ownership boundaries, which may also imply across enterprise governance boundaries. For such situations, governance emphasizes the need for agreement that some Governance Framework and Governance Processes have jurisdiction, and the governance defined must satisfy the Goals of the participants for cooperation to continue. A standards development organization such as OASIS is an example of voluntary agreement to governance over a limited domain to satisfy common goals.

The specifics discussed in the figures in the previous sections are equally applicable to governance across ownership boundaries as it is within a single boundary. There is a charter agreed to when participants become members of the organization, and this charter sets up the structures and processes that will be followed. Leadership may be shared by the leadership of the overall organization and the leadership of individual groups themselves chartered per the Governance Processes. There are Rules/Regulations specific to individual efforts for which participants agree to local goals, and Enforcement can be loss of voting rights or under extreme circumstances, expulsion from the group.

Thus, the major difference for SOA governance is an appreciation for the cooperative nature of the enterprise and its reliance on furthering common goals if productive participation is to continue.

5.1.3.2 What Must be Governed

An expected benefit of employing SOA principles is the ability to quickly bring resources to bear to deal with unexpected and evolving situations. This requires a great deal of confidence in the underlying capabilities that can be accessed and in the services that enable the access. It also requires considerable flexibility in the ways these resources can be employed. Thus, SOA governance requires establishing confidence and trust while instituting a solid framework that enables flexibility, indicating a combination of strict control over a limited set of foundational aspects but minimum constraints beyond those bounds.

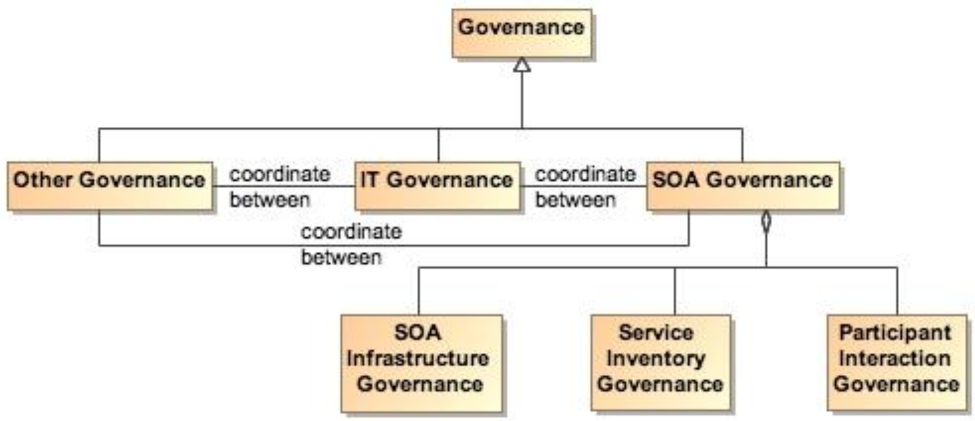


Figure 40 Relationship among types of governance

SOA governance applies to three aspects of service definition and use:

- SOA infrastructure – the “plumbing” that provides utility functions that enable and support the use of the service
- Service inventory – the requirements on a service to permit it to be accessed within the infrastructure
- Participant interaction – the consistent expectations with which all participants are expected to comply

5.1.3.2.1 Governance of SOA Infrastructure

The SOA infrastructure is likely composed of several families of SOA services that provide access to fundamental computing business services. These include, among many others, services such as messaging, security, storage, discovery, and mediation. The provisioning of an infrastructure on which these services may be accessed and the general realm of those contributing as utility functions of the infrastructure are a traditional IT governance concern. In contrast, the focus of SOA governance is how the existence and use of the services enables the SOA ecosystem.

By characterizing the environment as containing families of SOA services, the assumption is that there may be multiple approaches to providing the business services or variations in the actual business services provided. For example, discovery could be based on text search, on metadata search, on approximate matches when exact matches are not available, and numerous other variations. The underlying implementation of search algorithms are not the purview of SOA governance, but the access to the resulting service infrastructure enabling discovery must be stable, reliable, and extremely robust to all operating conditions. Such access enables other specialized SOA services to use the infrastructure in dependable and predictable ways, and is where governance is important.

5.1.3.2.2 Governance of the Service Inventory

Given an infrastructure in which other SOA services can operate, a key governance issue is which SOA services to allow in the ecosystem. The major concern SHOULD be a definition of well-behaved services, where the required behavior will likely inherit their characteristics from experiences with distributed computing but also evolve with SOA experience. A major requirement for ensuring well-behaved services is collecting sufficient metrics to know how the service affects the SOA infrastructure and whether it complies with established infrastructure policies.

Another common concern of service approval is whether there is a possibility of duplication of function by multiple services. Some governance models talk to a tightly controlled environment where a primary concern is to avoid any service duplication. Other governance models talk to a market of services where the consumers have wide choices. For the latter, it is anticipated that the better services will emerge from market consensus and the availability of alternatives will drive innovation.

Some combination of control and openness will emerge, possibly with a different appropriate balance for different categories of use. For SOA governance, the issue is less which services are approved but rather ensuring that sufficient description is available to support informed decisions for appropriate use. Thus, SOA governance SHOULD concentrate on identifying the required attributes to adequately describe a service, the required target values of the attributes, and the standards for defining the meaning of the attributes and their target values. Governance may also specify the processes by which the attribute values are measured and the corresponding certification that some realized attribute set may imply.

For example, unlimited access for using a service may require a degree of life cycle maturity that has demonstrated sufficient testing over a certain size community. Alternately, the policy may specify that a service in an earlier phase of its life cycle may be made available to a smaller, more technically sophisticated group in order to collect the metrics that would eventually allow the service to advance its life cycle status.

This aspect of governance is tightly connected to description because, given a well-behaved set of services, it is the responsibility of the consumer (or policies promulgated by the consumer's organization) to decide whether a service is sufficient for that consumer's intended use. The goal is to avoid global governance specifying criteria that are too restrictive or too lax for the local needs of which global governance has little insight.

Such an approach to specifying governance allows independent domains to describe services in local terms while still having the services available for informed use across domains. In addition, changes to the attribute sets within a domain can be similarly described, thus supporting the use of newly described resources with the existing ones without having to update the description of all the legacy content.

5.1.3.2.3 Governance of Participant Interaction

Finally, given a reliable services infrastructure and a predictable set of services, the third aspect of governance is prescribing what is required during a service interaction.

Governance would specify adherence to service interface and service reachability parameters and would require that the result of an interaction MUST correspond to the real world effects as contained in the service description. Governance would ensure preconditions for service use are satisfied, in particular those related to security aspects such as user authentication, authorization, and non-repudiation. If conflicts arise, governance would specify resolution processes to ensure appropriate agreements, policies, and conditions are met.

It would also rely on sufficient monitoring by the SOA infrastructure to ensure services remain well-behaved during interactions, e.g. do not use excessive resources or exhibit other prohibited behavior. Governance would also require that policy agreements as documented in the execution context for the interaction are observed and that the results and any after effects are consistent with the agreed policies. Governance will focus on more contractual and legal aspects rather than the precursor descriptive aspects. SOA governance may prescribe the processes by which SOA-specific policies are allowed to change, but there are probably more business-specific policies that will be governed by processes outside SOA governance.

5.1.3.3 Overarching Governance Concerns

There are numerous governance related concerns whose effects span the three areas just discussed. One is the area of standards, how these are mandated, and how the mandates may change. The Web Services standards stack is an example of relevant standards where a significant number are still under development. In addition, while there are notional scenarios that guide what standards are being developed, the fact that many of these standards do not yet exist precludes operational testing of their adequacy or effectiveness as a necessary and sufficient set.

That said, standards are critical to creating a SOA ecosystem where SOA services can be introduced, used singularly, and combined with other services to deliver complex business functionality. As with other aspects of SOA governance, the Governance Body should identify the minimum set felt to be needed and rigorously enforce that that set be used where appropriate. The Governance Body must take care to expand and evolve the mandated standards in a predictable manner and with sufficient technical guidance that new services are able to coexist as much as possible with the old, and changes to standards do not cause major disruptions.

Another area that may see increasing activity as SOA expands is additional regulation by governments and associated legal institutions. New laws are may deal with transactions which are service based, possibly including taxes on the transactions. Disclosures laws may mandate certain elements of description so both the consumer and provider act in a predictable environment and are protected from ambiguity in intent or action. Such laws are spawn rules and regulations that will influence the metrics collected for evaluation of compliance.

5.1.3.4 Considerations for SOA Governance

The Reference Architecture definition of a loosely coupled system is one in which the constraints on the interactions between components is minimal: sufficient to permit interoperation without additional constraints that may be an artifact of implementation technology. While governance experience for standalone systems provides useful guides, we must be careful not to apply constraints that would preclude the flexibility, agility, and adaptability we expect to realize from a SOA ecosystem.

One of the strengths of SOA is it can make effective use of diversity rather than requiring monolithic solutions. Heterogeneous organizations can interact without requiring each conforms to uniform tools, representation, and processes. However, with this diversity comes the need to adequately define those elements necessary for consistent interaction among systems and participants, such as which communication protocol, what level of security, which vocabulary for payload content of messages. The solution is not always to lock down these choices but to standardize alternatives and standardize the representations through which an unambiguous identification of the alternative chosen can be conveyed. For example, the URI standard specifies the URI string, including what protocol is being used, what is the target of the message, and how may parameters be attached. It does not limit the available protocols, the semantics of the target address, or the parameters that can be transferred. Thus, as with our definition of loose coupling, it provides absolute constraints but minimizes which constraints it imposes.

There is not a one-size-fits-all governance but a need to understand the types of things governance is called upon to do in the context of the goals of SOA. Some communities may initially desire and require very stringent governance policies and procedures while other see need for very little. Over time, best practices will evolve, resulting in some consensus on a sensible minimum and, except in extreme cases where it is demonstrated to be necessary, a loosening of strict governance toward the best practice mean.

A question of how much governance may center on how much time governance activities require versus how quickly is the system being governed expected to respond to changing conditions. For large single systems that take years to develop, the governance process could move slowly without having a serious negative impact. For example, if something takes two years to develop and the steps involved in governance take two months to navigate, then the governance can go along in parallel and may not have a significant impact on system response to changes. Situations where it takes as long to navigate governance requirements as it does to develop a response are examples where governance may need to be reevaluated as to whether it facilitates or inhibits the desired results. Thus, the speed at which services are expected to appear and evolve needs to be considered when deciding the processes for control. The added weight of governance should be appropriate for overall goals of the application domain and the service environment.

Governance, as with other aspects of any SOA implementation, should start small and be conceptualized in a way that keeps it flexible, scalable, and realistic. A set of useful guidelines would include:

- Do not hardwire things that will inevitably change. For example, develop a system that uses the representation of policies rather than code the policies into the implementations.
- Avoid setting up processes that demo well for three services without considering how they may work for 300. Similarly, consider whether the display of status and activity for a small number of services will also be effective for an operator in a crisis situation looking at dozens of services, each with numerous, sometimes overlapping and sometimes differing activities.
- Maintain consistency and realism. A service solution responding to a natural disaster cannot be expected to complete a 6-week review cycle but be effective in a matter of hours.

5.1.4 Architectural Implications of SOA Governance

The description of SOA governance indicates numerous architectural requirements on the SOA ecosystem:

- Governance is expressed through policies and assumes multiple use of focused policy modules that can be employed across many common circumstances. This requires the existence of:
    - descriptions to enable the policy modules to be visible, where the description includes a unique identifier for the policy and a sufficient, and preferably a machine process-able, representation of the meaning of terms used to describe the policy, its functions, and its effects;
    - one or more discovery mechanisms that enable searching for policies that best meet the search criteria specified by the service participant; where the discovery mechanism will have access to the individual policy descriptions, possibly through some repository mechanism;
    - accessible storage of policies and policy descriptions, so service participants can access, examine, and use the policies as defined.
- Governance requires that the participants understand the intent of governance, the structures created to define and implement governance, and the processes to be followed to make governance operational. This requires the existence of:
    - an information collection site, such as a Web page or portal, where governance information is stored and from which the information is always available for access;
    - a mechanism to inform participants of significant governance events, such as changes in policies, rules, or regulations;
    - accessible storage of the specifics of Governance Processes;
    - SOA services to access automated implementations of the Governance Processes
- Governance policies are made operational through rules and regulations. This requires the existence of:
    - descriptions to enable the rules and regulations to be visible, where the description includes a unique identifier and a sufficient, and preferably a machine process-able, representation of the meaning of terms used to describe the rules and regulations;
    - one or more discovery mechanisms that enable searching for rules and regulations that may apply to situations corresponding to the search criteria specified by the service participant; where the discovery mechanism will have access to the individual descriptions of rules and regulations, possibly through some repository mechanism;
    - accessible storage of rules and regulations and their respective descriptions, so service participants can understand and prepare for compliance, as defined.
    - SOA services to access automated implementations of the Governance Processes.
- Governance implies management to define and enforce rules and regulations. Management is discussed more specifically in section **Error! Reference source not found.**, but in a parallel to overnance, management requires the existence of:
    - an information collection site, such as a Web page or portal, where management information is stored and from which the information is always available for access;
    - a mechanism to inform participants of significant management events, such as changes in rules or regulations;
    - accessible storage of the specifics of processes followed by management.
- Governance relies on metrics to define and measure compliance. This requires the existence of:
    - the infrastructure monitoring and reporting information on SOA resources;
    - possible interface requirements to make accessible metrics information generated or most easily accessed by the service itself.

5.2 Security Model

Security is one aspect of confidence – the confidence in the integrity, reliability, and confidentiality of the system. In particular, security focuses on those aspects of assurance that involve the accidental or malign intent of other people to damage or compromise trust in the system and on the availability of SOA-based systems to perform desired capability.

Security

> Security concerns the set of mechanisms for ensuring and enhancing trust and confidence in the SOA ecosystem.

Providing for security for Service Oriented Architecture is somewhat different than for other contexts; although many of the same principles apply equally to SOA and to other systems. The fact that SOA embraces crossing ownership boundaries makes the issues involved with moving data more visible.

As well as securing the movement of data within and across ownership boundaries, security often revolves around resources: the need to guard certain resources against inappropriate access – whether reading, writing or otherwise manipulating those resources.

Any comprehensive security solution must take into account the people that are using, maintaining and managing the SOA. Furthermore, the relationships between them must also be incorporated: any security assertions that may be associated with particular interactions originate in the people that are behind the interaction.

We analyze security in terms of the social structures that define the legitimate permissions, obligations and roles of people in relation to the system, and mechanisms that must be put into place to realize a secure system. The former are typically captured in a series of security policy statements; the latter in terms of security *guards* that ensure that policies are enforced.

How and when to apply these derived security policy mechanisms is directly associated with the assessment of the *threat model* and a *security response model*. The threat model identifies the kinds of threats that directly impact the message and/or application of constraints, and the response model is the proposed mitigation to those threats. Properly implemented, the result can be an acceptable level of risk to the safety and integrity of the system.

5.2.1 Secure Interaction Concepts

We can characterize secure interactions in terms of key security concepts **[ISO/IEC 27002]**: confidentiality, integrity, authentication, authorization, non-repudiation, and availability. The concepts for secure interactions are well defined in other standards and publications. The security concepts here are not defined but rather related to the SOA ecosystem perspective of the SOA-RAF.

5.2.1.1 Confidentiality

Confidentiality concerns the protection of privacy of participants in their interactions. Confidentiality refers to the assurance that unauthorized entities are not able to read messages or parts of messages that are transmitted.

Note that confidentiality has degrees: in a completely confidential exchange, third parties would not even be aware that a confidential exchange has occurred. In a partially confidential exchange, the identities of the participants may be known but the content of the exchange obscured.

5.2.1.2 Integrity

Integrity concerns the protection of information that is exchanged – either from unauthorized writing or inadvertent corruption. Integrity refers to the assurance that information that has been exchanged has not been altered.

Integrity is different from confidentiality in that messages that are sent from one participant to another may be obscured to a third party, but the third party may still be able to introduce his own content into the exchange without the knowledge of the participants.

Figure 41 applies confidentiality and integrity to communicative action.

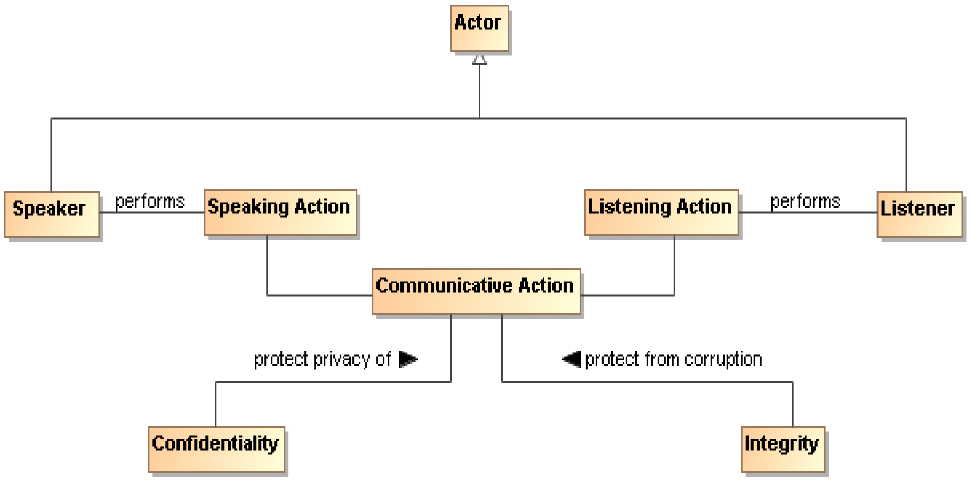


Figure 41 Confidentiality and Integrity

A communicative action is a joint action involved in the exchange of messages. Section 5.2.4 describes common computing techniques for providing confidentiality and integrity during message exchanges.

5.2.1.3 Authentication

Authentication concerns the identity of the participants in an exchange. Authentication refers to the means by which one participant can be assured of the identity of other participants.

Figure 42 applies authentication to the identity of participants.

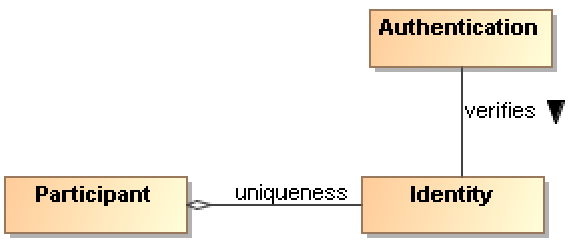


Figure 42 Authentication

5.2.1.4 Authorization

Authorization concerns the legitimacy of the interaction. Authorization refers to the means by which a stakeholder may be assured that the information and actions that are exchanged are either explicitly or implicitly approved.

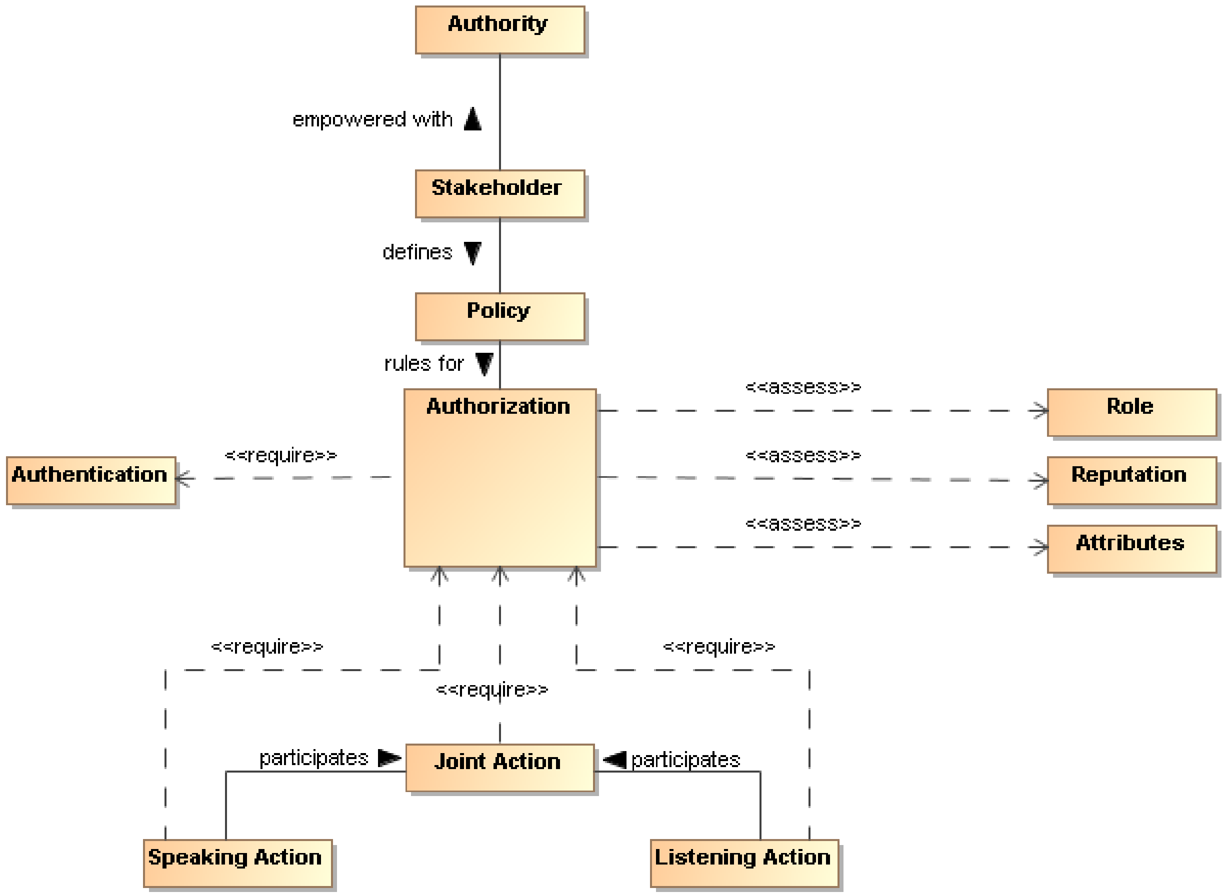


Figure 43 Authorization

The roles and attributes which provide a participant's credentials are expanded to include reputation. Reputation often helps determine willingness to interact, for example, reviews of a service provider will influence the decision to interact with the service provider. The roles, reputation, and attributes are represented as assertions measured by authorization decision points.

The role of policy for security is to permit stakeholders to express their choices. In Figure 43, a policy is a written constraint and the role, reputation, and attribute assertions are evaluated according to the constraints in the authorization policy. A combination of security mechanisms and their control via explicit policies can form the basis of an authorization solution.

5.2.1.5 Non-repudiation

Non-repudiation concerns the accountability of participants. To foster trust in the performance of a system used to conduct shared activities it is important that the participants are not able to later deny their actions: to repudiate them. Non-repudiation refers to the means by which a participant may not, at a later time, successfully deny having participated in the interaction or having performed the actions as reported by other participants.

5.2.1.6 Availability

Availability concerns the ability of systems to use and offer the services for which they were designed. One of the threats against availability is the so-called denial of service attack in which attackers attempt to prevent legitimate access to the system.

We differentiate here between general availability – which includes aspects such as systems reliability – and availability as a security concept where we need to respond to active threats to the system.

5.2.2 Where SOA Security is Different

The core security concepts are fundamental to all social interactions. The evolution of sharing information using a SOA requires the flexibility to dynamically secure computing interactions in a computing ecosystem where the owning social groups, roles, and authority are constantly changing as described in section 5.1.3.1.

SOA policy-based security can be more adaptive for a computing ecosystem than previous computing technologies allow for, and typically involves a greater degree of distributed mechanisms.

Standards for security, as is the case with all aspects of SOA, play a large role in flexible security on a global scale. SOA security may also involve greater auditing and reporting to adhere to regulatory compliance established by governance structures.

5.2.3 Security Threats

There are a number of ways in which an attacker may attempt to compromise the security of a system. The two primary sources of attack are third parties attempting to subvert interactions between legitimate participants and an entity that is participating but attempting to subvert its partner(s). The latter is particularly important in a SOA where there may be multiple ownership boundaries and trust boundaries.

The threat model lists some common threats that relate to the core security concepts listed in Section 5.2.1. Each technology choice in the realization of a SOA can potentially have many threats to consider.

Message alteration

If an attacker is able to modify the content (or even the order) of messages that are exchanged without the legitimate participants being aware of it then the attacker has successfully compromised the security of the system. In effect, the participants may unwittingly serve the needs of the attacker rather than their own.

An attacker may not need to completely replace a message with his own to achieve his objective: replacing the identity of the beneficiary of a transaction may be enough.

Message interception

If an attacker is able to intercept and understand messages exchanged between participants, then the attacker may be able to gain advantage. This is probably the most commonly understood security threat.

Man in the middle

In a man-in-the-middle attack, the legitimate participants believe that they are interacting with each other; but are in fact interacting with the attacker. The attacker attempts to convince each participant that he is their correspondent; whereas in fact he is not.

In a successful man-in-the-middle attack, legitimate participants do not have anaccurate understanding of the state of the other participants. The attacker can use this to subvert the intentions of the participants.

Spoofing

In a spoofing attack, the attacker convinces a participant that he is really someone else – someone that the participant would normally trust.

Denial of service attack

In a denial of service (DoS) attack, the attacker attempts to prevent legitimate users from making use of the service. A DoS attack is easy to mount and can cause considerable harm: by preventing legitimate interactions, or by slowing them down enough, the attacker may be able to simultaneously prevent legitimate access to a service and to attack the service by another means.

A variation of the DoS attack is the Distributed Denial of Service attack. In a DDoS attack the attacker uses multiple agents to the attack the target. In some circumstances this can be extremely difficult to counteract effectively.

One of the features of a DoS attack is that it does not require valid interactions to be effective: responding to invalid messages also takes resources and that may be sufficient to cripple the target.

Replay attack

In a replay attack, the attacker captures the message traffic during a legitimate interaction and then replays part of it to the target. The target is persuaded that a similar transaction to the previous one is being repeated and it responds as though it were a legitimate interaction.

A replay attack may not require that the attacker understand any of the individual communications; the attacker may have different objectives (for example attempting to predict how the target would react to a particular request).

False repudiation

In false repudiation, a user completes a normal transaction and then later attempts to deny that the transaction occurred. For example, a customer may use a service to buy a book using a credit card; then, when the book is delivered, refuse to pay the credit card bill claiming that *someone else* must have ordered the book.

5.2.4 Security Responses

Security goals are never absolute: it is not possible to guarantee 100% confidentiality, non-repudiation, etc. However, a well designed and implemented security response model can ensure acceptable levels of security risk. For example, using a well-designed cipher to encrypt messages may make the cost of breaking communications so great and so lengthy that the information obtained is valueless.

Performing threat assessments, devising mitigation strategies, and determining acceptable levels of risk are the foundation for an effective process to mitigating threats in a cost-effective way.[14] The choice in hardware and software to realize a SOA will be the basis for threat assessments and mitigation strategies. The stakeholders of a specific SOA implementation should determine acceptable levels of risk based on threat assessments and the cost of mitigating those threats.

5.2.4.1 Privacy Enforcement

The most efficient mechanism to assure confidentiality is the encryption of information. Encryption is particularly important when messages must cross trust boundaries; especially over the Internet. Note that encryption need not be limited to the content of messages: it is possible to obscure even the existence of messages themselves through encryption and ‘white noise’ generation in the communications channel.

The specifics of encryption are beyond the scope of this architecture. However, we are concerned about how the connection between privacy-related policies and their enforcement is made.

A policy enforcement point for enforcing privacy may take the form of an automatic function to encrypt messages as they leave a trust boundary; or perhaps simply ensuring that such messages are suitably encrypted.

Any policies relating to the level of encryption being used would then apply to these centralized messaging functions.

5.2.4.2 Integrity Protection

To protect against message tampering or inadvertent message alteration, and to allow the receiver of a message to authenticate the sender, messages may be accompanied by a digital signature. Digital

[14] In practice, there are perceptions of security from all participants regardless of ownership boundaries. Satisfying security policy often requires asserting sensitive information about the message initiator. The perceptions of this participant about information privacy may be more important than actual security enforcement within the SOA for this stakeholder.

signatures provide a means to detect if signed data has been altered. This protection can also extend to authentication and non-repudiation of a sender.

A common way a digital signature is generated is with the use of a private key that is associated with a public key and a digital certificate. The private key of some entity in the system is used to create a digital signature for some set of data. Other entities in the system can check the integrity of the signed data set via signature verification algorithms. Any changes to the data that was signed will cause signature verification to fail, which indicates that integrity of the data set has been compromised.

A party verifying a digital signature must have access to the public key that corresponds to the private key used to generate the signature. A digital certificate contains the public key of the owner, and is itself protected by a digital signature created using the private key of the issuing Certificate Authority (CA).

5.2.4.3 Message Replay Protection

To protect against replay attacks, messages may contain information that can be used to detect replayed messages. The simplest requirement to prevent replay attacks is that each message that is ever sent is unique. For example, a message may contain a message ID, a timestamp, and the intended destination.

By storing message IDs, and comparing each new message with the store, it becomes possible to verify whether a given message has been received before (and therefore should be discarded).

The timestamp may be included in the message to help check for message freshness. Messages that arrive after their message ID could have been cleared (after receiving the same message some time previously) may also have been replayed. A common means for representing timestamps is a useful part of an interoperable replay detection mechanism.

The destination information is used to determine if the message was misdirected or replayed. If the replayed message is sent to a different endpoint than the destination of the original message, the replay could go undetected if the message does not contain information about the intended destination.

In the case of messages that are replies to prior messages, it is also possible to include seed information in the prior messages that is randomly and uniquely generated for each message that is sent out. A replay attack can then be detected if the reply does not embed the random number that corresponds to the original message.

5.2.4.4 Auditing and Logging

False repudiation involves a participant denying that it authorized a previous interaction. An effective strategy for responding to such a denial is to maintain careful and complete logs of interactions which can be used for auditing purposes. The more detailed and comprehensive an audit trail is, the less likely it is that a false repudiation would be successful.

The countermeasures assume that the non-repudiation tactic (e.g. digital signatures) is not undermined itself. For example, if private key is stolen and used by an adversary, even extensive logging cannot assist in rejecting a false repudiation.

Unlike many of the security responses discussed here, it is likely that the scope for automation in rejecting a repudiation attempt is limited to careful logging.

5.2.4.5 Graduated engagement

The key to managing and responding to DoS attacks is to be careful in the use of resources when responding to interaction. Put simply, a system has a choice to respond to a communication or to ignore it. In order to avoid vulnerability to DoS attacks a service provider should be careful not to commit resources beyond those implied by the current state of interactions; this permits a graduation in commitment by the service provider that mirrors any commitment on the part of service consumers and attackers alike.

5.2.5 Architectural Implications of SOA Security

Providing SOA security in an ecosystem of governed services has the following implications on the policy support and the distributed nature of mechanisms used to assure SOA security:

- Security expressed through policies have the same architectural implications as described in Section 4.4.3 for policies and contracts architectural implications.
- Security policies require mechanisms to support security description administration, storage, and distribution.
- Service descriptions supporting security policies should:
    - have a meta-structure sufficiently rich to support security policies;
    - be able to reference one or more security policy artifacts;
    - have a framework for resolving conflicts between security policies.
- The mechanisms that make-up the execution context in secure SOA-based systems should:
    - provide protection of the confidentiality and integrity of message exchanges;
    - be distributed so as to provide centralized or decentralized policy-based identification, authentication, and authorization;
    - ensure service availability to consumers;
    - be able to scale to support security for a growing ecosystem of services;
    - be able to support security between different communication technologies;
- Common security services include:
    - services that abstract encryption techniques;
    - services for auditing and logging interactions and security violations;
    - services for identification;
    - services for authentication;
    - services for authorization;
    - services for intrusion detection and prevention;
    - services for availability including support for quality of service specifications and metrics.

5.3 Management Model

Management

Management is a process of controlling resources in accordance with the policies and principles defined by Governance.

There are three separate but linked domains of interest within the management of SOA:

1. the management and support of the resources that are involved in any complex structures – of which SOA-based solutions are excellent examples;
2. the promulgation and enforcement of the policies and service contracts agreed to by the stakeholders in SOA ecosystem;
3. the management of the relationships of the participants in SOA-based solutions – both to each other and to the services that they use and offer.

There are many artifacts related to management. Historically, systems management capabilities have been organized by the “FCAPS” functions (based on ITU-T Rec. M.3400 (02/2000), "TMN Management Functions"):

- fault management,
- configuration management,
- account management,
- performance and security management.

The primary task of the functional groups is to concentrate on maintaining systems in a trusted, active, and accessible state.

In the context of the SOA ecosystem, we see many possible resources that may require management such as services, service descriptions, service contracts, policies, roles, relationships, security, people and systems that implement services and infrastructure elements. In addition, given the ecosystem nature, it is also potentially necessary to manage the business relationships between participants.

Successful operation of a SOA ecosystem requires trust between the stakeholders and the ecosystem elements. In contrast, regular systems in technology are not necessarily operated or used in an environment requiring trust before the stakeholders make use of the system. Indeed, many of these systems exist in hierarchical management structures, within which use may be mandated by legal requirement, executive decision, or good business practice in furthering the business' strategy. Pre-condition of trust in the SOA ecosystem roots in both principles of service orientation and distributed authoritative ownership of independent services. Even for hierarchical management structures applied to a SOA ecosystem, the service use should have contractual basis rather than being mandated.

The trust may be established through agreements/contracts, policies, or implicitly through observation of repeated interactions with others. Explicit trust is usually accompanied by formalized documents suitable for the management activities. Implicit trust adds fragility to the management of a SOA ecosystem because failure to maintain consistent and predictable interactions will undermine the trust between participants and within the ecosystem as a whole.

Management in a SOA ecosystem is thus concerned with management taking actions that will establish the condition of trust that must be present before engaging in service interactions. These concerns should largely be handled within the governance of the ecosystem. The policies, agreements, and practices defined through the governance provide the boundaries within which management operates and for which management must provide enforcement and feedback. However, governance alone cannot anticipate all circumstances and must offer sufficient guidance in areas where anticipation is unclear or for which agreement between all stakeholders cannot be reached. Management in these cases must be flexible and adaptable to handle unanticipated conditions without unnecessarily breaking trust relationships.

Service management is the process – manual, automated, or a combination – of proactively monitoring and controlling the behavior of a service or a set of services. Service management operates under constraints attributed to the business and social context. Particularly, special policies may be used for governing cross-boundary relationships. Managing solutions that may be used across ownership boundaries based on such policies raises issues that are not typically present when managing a service within a single ownership domain. For example, care is required in managing a service when the owner of the service, the provider of the service, the host of the service and mediators to the service may all belong to different stakeholders.

Cross-boundary service management takes place in, at least, the following situations:

- using combinations of services that belong to different ownership realms
- using of services that mediate between ownership realms
- sharing monitoring and reporting means and results.

These situations are particularly important in ecosystems that are highly decentralized, in which the participants interact as peers as well as in the "master-servant" mode.

The management model shown in Figure 46 conveys how the SOA framework applies to managing services. Services management operates via service metadata, such as service lifecycles and attributes associated with service use, that are typically collected in or accessed through the service description.

[*this Figure to be re-drawn in common style*]

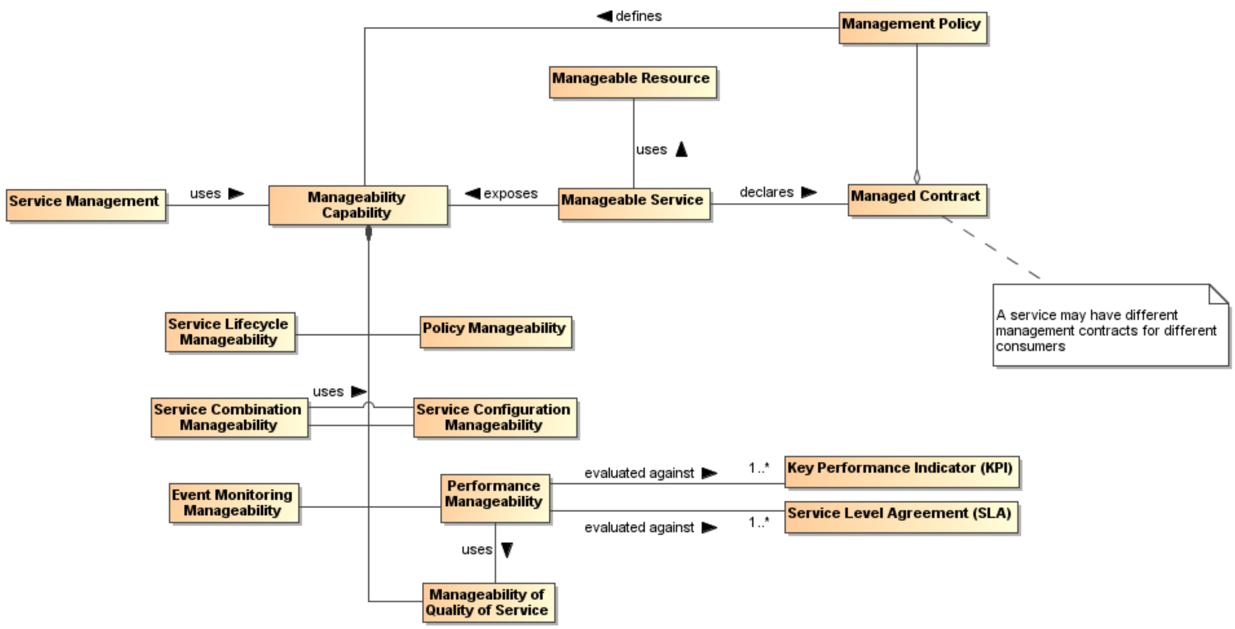


Figure 46 Manageability capabilities in SOA ecosystem

The service metadata of interest is that set of service properties that is manageable. These manageability properties are generally identifiable for any service consumed or supplied within the ecosystem. The necessary existence of these properties within the SOA ecosystem motivates the following definitions:

> **Manageability** of a resource is the capability that allows it to be controlled, monitored, and reported on with respect to some property. Note that manageability is not necessarily a part of the managed entities themselves and are generally considered to be external to the managed entities.

Each resource may be managed through a number of aspects of management, and the resources may be grouped to categories based on similarity of managed aspects. For example, the managed aspect relating to configuration manageability is referred to as “Configuration Manageability” for the collection of services. Resources not managed under a particular capability are resources, for which those manageability aspects have no clear meaning or use. As an example, all resources within a SOA ecosystem have a lifecycle that is meaningful within the ecosystem. Thus, all resources are manageable under Lifecycle Manageability. In contrast, not all resources report or handle events. Thus, Event Manageability is only concerned with those resources for which events are meaningful.

> **Life-cycle Manageability** of a service typically refers to how the service is created, how it is destroyed and how service versions must be managed. This manageability is the feature of the SOA ecosystem because the service cannot manage its own life cycle.

> Another important consideration is that services may have resource requirements that must be established at various points in the services’ life cycles. However actual providers of these resources maybe not known at the time of the service creation and, thus, have to be managed at the service run-time.

> **Combination Manageability** of a service addresses management of service characteristics that allow for creating and changing of combinations in which the service participates or that the service combines by itself. Known models of such combinations are aggregations and compositions. Examples of patterns of combinations are choreography and orchestration. Combination Manageability drives implementation of the Service Composability Principle of service orientation.

Service combination manageability resonates with the methodology of process management. Combination Manageability may be applied at different phases of the service creation and execution and, in some cases, can utilize Configuration Manageability.

Service combinations contribute the most in delivering business values to the stakeholders and managing service combinations is the one of the top-level tasks and features of the SOA ecosystem.

Configuration Manageability of a service allows managing the identity of and the interactions among internal elements of the service. Also, Configuration Manageability correlates with the management of service versions and configuration of the deployment of new services into the ecosystem. Configuration Management differs from the Combination Manageability in the scope and scale of manageability, and addresses lower level concerns than the architectural combination of services.

Event Monitoring Manageability allows managing the categories of events of interest related to services and reporting recognized events to the interested stakeholders. Such events may be the ones that trigger service invocations as well as execution of particular functionality provided by the service.

This is one of the key lower-level manageability aspects that the service provider and associated stakeholders are primarily interested. Monitored events may be internal or external to the SOA ecosystem. For example, a disaster in the oil producing industry, which is outside of the SOA ecosystem of the Insurer, can trigger the service’s functionality that is responsible for immediate or constant monitoring of the oil prices in the oil trading exchanges and, respectively, modify the premium paid by the insured oil companies.

Performance Manageability of a service allows controlling the service results, shared and sharable real world effects against the business goals and objectives of the service. This manageability assumes monitoring of the business performance as well as the management of this monitoring itself. Performance Manageability includes business and technical performance manageability means through performance criteria set, such as business key performance indicators (KPI) and service-level agreements (SLA).

The performance business- and technical-level characteristics of the service should be known from the service contract. The service provider and consumer must be able to monitor and measure these characteristics or be informed about the results measured by a third party.

Performance Manageability is the instrument for providing compliance of the service with its service contracts. Performance Manageability utilizes Manageability of Quality of Service.

Manageability of Quality of Service deals with management of service non-functional characteristics that may be of significant value to the service consumers and other stakeholders in the SOA ecosystem. Classic examples of this include bandwidth offerings associated with a service.

Manageability of quality of service assumes that the properties associated with service qualities are monitored during the service execution. Results of monitoring may be challenged against SLA and even KPI, which results in the continuous validation of how the service contract is preserved by the service provider.

Policy Manageability allows additions, changes and replacements of the policies associated with a resource in the SOA ecosystem. The ability to manage those policies (such as promulgating policies, retiring policies and ensuring that policy decision points and enforcement points are current) enables the ecosystem to apply policies and *evaluate* the results.

Capability to manage, i.e. use particular manageability, requires policies from governance to be translated into the details of rules and regulations and then corresponding measurement and feedback on the specifics.

In the following sub-sections, we describe how the elements of the SOA ecosystem may be managed with integrity.

5.3.1. Management Means and Relationships

A minimal set of management for the SOA ecosystem is shown on Figure 47 and elaborated in the following sections.

5.3.1.1. Management Policy

The management of resources within the SOA may be governed by management policies. In a deployed SOA-based solution, it may well be that different aspects of the management of a given service are managed by different management services. For example, the life-cycle management of services often involves managing service versions. Managing quality of service is often very specific to the service itself; for example, quality of service attributes for a video streaming service are quite different to those for a banking system.

There are additional concepts of management that also apply to IT management:

5.3.1.2. Network Management

Network management deals with the maintenance and administration of large scale physical networks such as computer networks and telecommunication networks. Specifics of the networks may affect service interactions from performance and operational perspectives.

Network and related system management executes a set of functions required for controlling, planning, deploying, coordinating, and monitoring the distributed services in the SOA ecosystem. However, while recognizing their importance, the specifics of systems management or network management are out of scope for this Reference Architecture Foundation.

[*this Figure to be re-drawn in common style*]

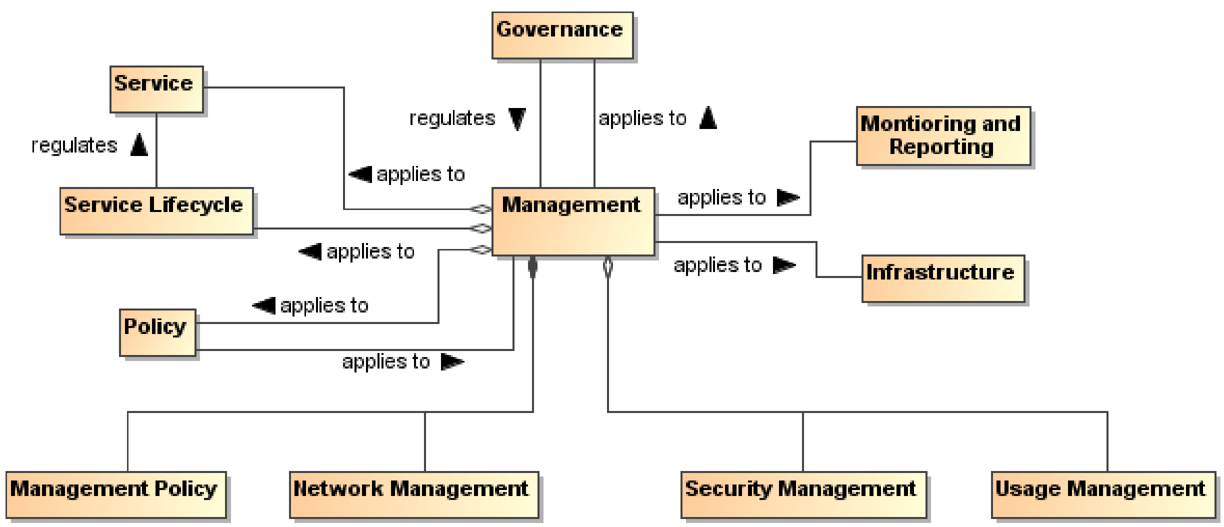


Figure 47 Management Means and Relationships in SOA ecosystem

5.3.1.3. Security Management

Management of the security related to resources includes identification of roles, permissions, access rights, and policy attributes defining security boundaries and events that may trigger a security response.

Security management within a SOA ecosystem is essential to maintaining the trust relationships between participants residing in different ownership domains. Security management must consider not just the internal properties related to interactions between participants but ecosystem properties that preserve the integrity of the ecosystem from external threats.

5.3.1.4. Usage Management

Usage Management applies to management of the use of resources. Usage management includes access properties, demand properties, and financial properties. Access properties include how the resource is accessed, who is using the resource, and the state of the resource after use. Demand properties are concerned with controlling or shaping demand for resources to optimize the overall operation of the ecosystem. Financial properties are those associated with assigning costs to the use of resources and distributing those cost assignments to the participants in an equitable manner.

5.3.2. Management and Governance

The primary role of governance in the context of a SOA ecosystem is to foster an atmosphere of predictability, trust, and efficiency, and it accomplishes this by allowing the stakeholders to negotiate and set the key policies that govern the running of the SOA-based solution. Recall that in an ecosystems perspective, the goal of governance is less to have complete fine-grained control but more to enable the individual participants to work together.

Policies for a SOA ecosystem will tend to focus on the rules of engagement between participants; for example, what kind of interactions are permissible, how will disputes be resolved, and so on. While governance may primarily focus on setting policies, management will focus on the realization and enforcement of policies. Effective management in the SOA ecosystem requires an ability for governance to understand the consequences of its policies, guidelines, and principles, and to adjust those as needed when inconsistencies or ambiguity become evident from the operation of the management functions. This understanding and adjustment must be facilitated by the results of management and so the mechanisms for providing feedback from management into governance must exist.

Governance operates via specialized activities and, thus, should be managed itself. Management to operationalize governance utilizes management policies that are included in the Governance Framework and Processes, and driven by the enterprise business model, business objectives and strategies. Where corporate management policies exist, these are usually guided and directed by the corporate executives. In peer relationships, the governing policies are set by either an external entity and accepted by the peers or by the peers themselves. This creates the appropriate authoritative level for the policies used for the management of the Governance Framework and Processes. Management to operationalize governance controls the life-cycle of the governing policies, including procedures and processes, for modifying the Governance Framework and Processes.

5.3.3. Management and Contracts

5.3.3.1 Management for Contracts and Policies

As we noted above, management can often be viewed as the application of contracts and individual policies to ensure the smooth running of the SOA ecosystem. Policies play an important role as the guiding constraints for management, as well as artifacts that need to be managed themselves. Service contracts also serve as both guiding constraints and artifacts that need to be managed. Policies and service contracts specify the service characteristics that have to be monitored, analysed and managed.

5.3.3.2 Contracts

As described in sections “Participation in a SOA Ecosystem view” and “Realization of a SOA Ecosystem view”, there are several types of contractual information in the SOA ecosystem. From the management perspective, three basic types of the contractual information relate to:

- · relationship between service provider and consumer;
- · communication with the service;
- · control of the quality of the service execution.

When a consumer prepares to interact with a service, the consumer and the service provider must come to agreement on service features and characteristics that will be provided by the service and available to the consumer; this agreement is known as a service contract.

Service Contract

> An implicit or an explicit and documented agreement between the service consumer and service provider about the use of the service based on
>
> - the commitment by a service provider to provide service functionality and results consistent with identified real world effects and
> - the commitment by a service consumer to interact with the service per specific means and per specified policies,

where both consumer and provider actions are in the manner described in the service description.

The service description provides the basis for the service contract and, in some situations, may be used as an implicit default service contract. In addition, the service description may set mandatory aspects of a service contract, e.g. for security services, or may specify acceptable alternatives. As an example of alternatives, the service description may identify which versions of a vocabulary will be recognized, and the specifics of the contract are satisfied when the consumer uses one of the alternatives. Another alternative could have a consumer identifying a policy they require be satisfied, e.g. a standard privacy policy on handling personal information, and a provider that is prepared to accept a policy request would indicate acceptance as part of the service contract by continuing with the interaction. In each of these cases, the actions of the participants are consistent with an implicit service contract without the existence of a formal agreement between the participants.

In the case of business services, it is anticipated that the service contract may take an explicit form and the agreement between business consumer and business service provider is formalized. Formalization requires up-front interactions between service consumer and service provider. In many business interactions, especially between business organisations within or across corporate boundaries, a consumer needs a contractual assurance from the provider or wants to explicitly indicate choices among alternatives, e.g., only use a subset of the business functionality offered by the service and pay a prorated cost.

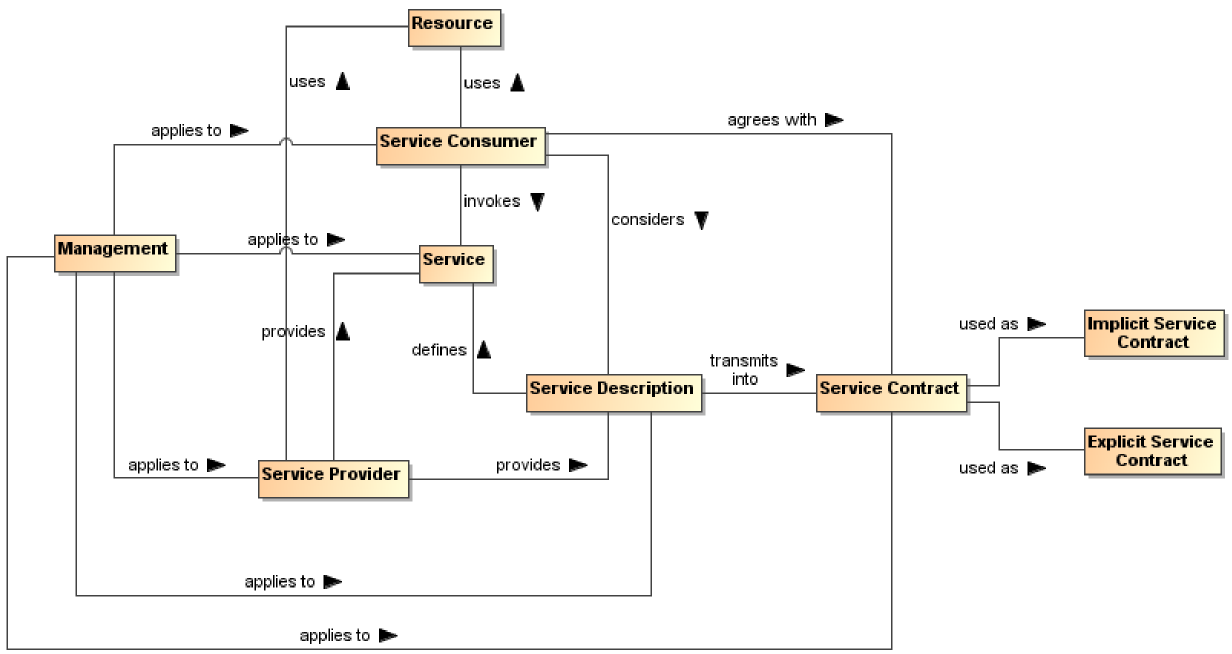


Figure 48 Management of the service interaction

Consequently, an implicit service contract is an agreement (1) on the consumer side with the terms, conditions, features and interaction means specified in the service description "as is" or (2) a selection from alternatives that are made available through mechanisms included in the service description, and neither of these require any a priori interactions between the service consumer and the service provider. An explicit service contract always requires a form of interaction between the service consumer and the service provider prior to the service invocation. This interaction may regard the choice or selection of the subset of the elements of the service description or other alternatives introduced through the formal agreement process that would be applicable to the interaction with the service and affect related joint action.

Any form of explicit contract couples the service consumer and provider. While explicit contract may be necessary or desirable in some cases, such as in supply chain management, commerce often uses a mix of implicit and explicit contracts, and a service provider may offer (via service description) a conditional shift from implicit to explicit contract. For example, Twitter offers an implicit contract on the use of its APIs to any application with the limit on the amount of service invocations; if the application needs to use more invocations, one has to enter into the explicit fee-based contract with the provider. A case where an implicit contract transforms into explicit contract may be illustrated when one buys a new computer and it does not work. The buyer returns the computer for repairing under manufacture warranty as stated by an implicit purchase contract. However, if the repair does not fix the problem and the seller offers a replacement by upgraded model, the buyer may agree to an explicit contract that limits the rights of the buyer to make the explicit agreement public.

Control of the quality of the service execution, often represented as a service level agreement (SLA), is performed by service monitoring systems and includes both technical and operational business controls.

SLA is a part of the service contract and, because of individual nature of this type of contracts, may vary from one service contract to another, even for the same consumer. Typically, a particular SLA in the service contract is a concrete instance of the SLA declared in the service description.

Management of the service contracts is based on management policies that may be mentioned in the service description and in the service contracts. Management of the service contracts is mandatory for consumer relationship management. In the case of explicit service contracts, the contracts have to be created, stored, maintained, reviewed/controlled and archived/destroyed as needed. All the activities are management concerns. Explicit service contracts may be stored in specialised repositories that provide appropriate level of security.

Management of the service interfaces is based on several management policies that regulate

- availability of interfaces specified in the service contracts,
- accessibility of interfaces,
- procedures for interface changes,
- interface versions and well as the versions of all parts of the interfaces, and
- traceability of the interfaces and their versions back to the service description document.

Management of the SLA is integral to the management of service monitoring and operational service behavior at run-time. A SLA usually enumerates service characteristics and expected performances of the service. Since SLA carries connotation of "promise", monitoring is needed to know if the promise is kept. Existence of an SLA itself does not guarantee the consumer will be provided with the service level specified in the service contract.

The use of SLA in SOA ecosystem can be wider than just an agreement on technical performances. An SLA may contain remedies for situations where the promised service cannot be maintained, or the real world effect can't be achieved due to developments subsequent to the agreement. A service consumer that acts accordingly to realize the real world effect may be compensated for the breach of the SLA if the effect is not realized.

Management of the SLA includes, among others, policies for the SLA changes, updates, and replacement. This aspect concerns service Execution Context because the business logic associated with a defined interface may differ in different Execution Contexts and affect the overall performance of the service.

5.3.3.3 Policies

"Although provision of management capabilities enables a service to become manageable, the extent and degree of permissible management are defined in management policies that are associated with the services. Management policies are used to define the obligations for, and permissions to, managing the service" **[WSA]**. Management policies, in essence, are the realisation of governing rules and regulations. As such, some management policies may target services while other policies may target the management of the services.

In practice, a policy without any means of enforcing it is vacuous. In the case of management policy, we rely on a management infrastructure to realize and enforce management policy.

5.3.3.4 Service Description and Management

The service description identifies several management objects such as a set of service interfaces and related set of SLAs: service behavioral characteristics and performances specified in the SLA depend on the interface type and its Execution Context. In the service description, a service consumer can find references to management policies, SLA metrics, and the means of accessing measured values that together increase assurance in the service quality. At the same time, service description is an artifact that needs to be managed.

In the SOA ecosystem, the service description is the assembled information that describes the service but it may be reported or displayed in different presentations. While each separate version of the service has one and only one service description, different categories of service consumers may focus their interests on different aspects of the service description. Thus, the same service description may be displayed not only in different languages but also with different cultural and professional accents in the content.

New service description may be issued to reflect changes and update in the service. If the change in the service does not affect its service description, the new service version may have the same service description as the previous version except for the updated version identifier. For example, a service description may stay the same if bugs were fixed in the service. However, if a change in the service influences any aspects of the service quality that can affect the real world effect resulting from interactions with the service, the service description must reflect this change even if there are no changes to the service interface.

Management of the service description and related explicit service contracts is essential for delivery of the service to the consumer satisfaction. This management can also prevent business problems rooted in poor communication between the service consumers and the service providers.

Thus, management of the service description contains, among others, management of the service description presentations, the life-cycles of the service descriptions, service description distribution practices and storage of the service descriptions and related service contracts. Collections of service descriptions in the enterprise may manifest a need for specialised registries and/or repositories. Depending on the enterprise policies, an allocation of purposes and duties of registries and repositories may vary but this topic is beyond the current scope.

5.3.4. Management for Monitoring and Reporting

The successful application of management relies on the monitoring and reporting aspects of management to enable the control aspect. Monitoring in the context of management consists of measuring values of managed aspects and evaluating that measurement in relationship to some expectation. Monitoring in a SOA ecosystem is enabled through the use of mechanisms by resources for exposing managed aspects. In the SOA framework, this mechanism may be a service for obtaining the measurement. Alternatively, the measurement may be monitored by means of event generation containing updated values of the managed aspect.

Approaches to monitoring may use a polling strategy in which the measurements are requested from resources in periodic intervals, in a pull strategy in which the measurements are requested from resources at random times, or in a push strategy in which the measurements are supplied by the resource without request. The push strategy can be used in a periodic update approach or in an “update on change” approach. Management services must be capable of handling these different approaches to monitoring.

Reporting is the complement to monitoring. Where monitoring is responsible for obtaining measurements, reporting is responsible for distributing those measurements to interested stakeholders. The separation between monitoring and reporting is made to include the possibility that data obtained through monitoring might not be used until an event impacting the ecosystem occurs or the measurement requires further processing to be useful. In the SOA framework, reporting is provided using services for requesting measurement reports. These reports may consist of raw measurement data, formatted collections of data, or the results of analysis performed on measurement data from collections of different managed aspects. Reporting is also used to support logging and auditing capabilities, where the reporting mechanisms create log or audit entries.

5.3.5 Management for Infrastructure

All of the properties, policies, interactions, resources, and management are only possible if a SOA ecosystem infrastructure provides support for managed capabilities. Each managed capability imposes different requirements on the capabilities supplied by the infrastructure in SOA ecosystem and requires that those capabilities be usable as services or at the very least be interoperable.

Not providing the full list of infrastructural elements of SOA ecosystem, we list an example of such elements here:

1. Registries and repositories for services, policies, and related descriptions and contracts
2. Synchronous and asynchronous communication channels for service interactions (e.g., network, e-mail, message routing with ability of mediating transport protocols, etc.)
3. Recovery capabilities
4. Security controls

Also, a SOA ecosystem infrastructure, enabling service management, should support

1. Management enforcement and control means
2. Monitoring and SLA validation controls
3. Testing and Reporting capabilities

Combination of manageability capabilities and infrastructure elements constitutes certain level of SOA management maturity. While several maturity models exist, this topic is out of the scope of the document.

5.4 SOA Testing Model

Program testing can be used to show the presence of bugs,
but never to show their absence!
Edsger Dijkstra

Testing for SOA combines the typical challenges of software testing and certification with the additional needs of accommodating the distributed nature of the resources, the greater access of a more unbounded consumer population, and the desired flexibility to create new solutions from existing components over which the solution developer has little if any control. The purpose of testing is to demonstrate a required level of reliability, correctness, and effectiveness that enable prospective consumers to have adequate confidence in using a service. Adequacy is defined by the consumer based on the consumer's needs and context of use. As the Dijkstra quote points out, absolute correctness and completeness cannot be proven by testing; however, for SOA, it is critical for the prospective consumer to know what testing has been performed, how it has been performed, and what were the results.

5.4.1 Traditional Software Testing as Basis for SOA Testing

SOA services are largely software artifacts and can leverage the body of experience that has evolved around software testing. IEEE-829 specifies the basic set of software test documents while allowing flexibility for tailored use. As such, the document structure can also provide guidance to SOA testing.

IEEE-829 covers test specification and test reporting through use of the following document types:

- *Test plan* documenting the scope (what is to be tested, both which entity and what features of the entity), the approach (how it is tested), and the needed resources (who does the testing, for how long), with details contained in the:
    - *Test design specification*: features to be tested, test conditions (e.g. test cases, test procedures needed) and expected results (criteria for passing test); entrance and exit criteria
    - *Test case specification*: test data used for input and expected output
    - *Test procedure specification*: steps required to run the test, including any set-up preconditions
- *Test item transmittal* to identify the test items being transmitted for testing
- *Test log* to record what occurred during test, i.e. which tests run, who ran, what order, what happened
- *Test incident report* to capture any event that happened during test which requires further investigation
- *Test summary* as a management report summarizing test run and results, conclusions

In summary, IEEE-829 captures (1) what was tested, (2) how it was tested, e.g. the test procedure used, and (3) the results of the test.

5.4.1.1 Types of Testing

There are numerous aspects of testing that, in total, work to establish that an entity is (1) built as required per policies and related specifications prescribed by the entity's owner, and (2) delivers the functionality required by its intended users. This is often referred to as verification and validation.

Policies, as described in Section 4.4, that are related to testing may prescribe but are not limited to the business processes to be followed, the standards with which an implementation must comply, and the qualifications of and restrictions on the users. In addition to the functional requirements prescribing what an entity does, there may also be non-functional performance and/or quality metrics that state how well the entity does it. The relation of these policies to SOA testing is discussed further below.

The identification of policies is the purview of governance (section 5.1) and the assuring of compliance (including response to noncompliance) with policies is a matter for management (section **Error! eference source not found.**).

5.4.1.2 Range of Test Conditions

Test conditions and expected responses are detailed in the test case specification. The test conditions should be designed to cover the areas for which the entity's response must be documented and may include:

- nominal conditions
- boundaries and extremes of expected conditions
- breaking point where the entity has degraded below a certain level or has otherwise ceased effective functioning
- random conditions to investigate unidentified dependencies among combinations of conditions
- errors conditions to test error handling

The specification of how each of these conditions should be tested for SOA resources, including the infrastructure elements of the SOA ecosystem, is beyond the scope of this document but is an area that evolves along with operational SOA experience.

5.4.1.3 Configuration Management of Test Artifacts

The test item transmittal provides an unambiguous identification of the entity being tested, thus REQUIRING that the configuration of the entity is appropriately tracked and documented. In addition, the test documents (such as those specified by IEEE-829) MUST also be under a documented and appropriately audited configuration management process, as should other resources used for testing. The description of each artifact would follow the general description model as discussed in section 4.1.1.1; in particular, it would include a version number for the artifact and reference to the documentation describing the versioning scheme from which the version number is derived.

[EDITOR'S NOTE: TO WHAT EXTENT SHOULD CM BE EXPLICITLY INCLUDED IN THE MANAGEMENT SECTION?]

5.4.2 Testing and the SOA Ecosystem

[EDITOR'S NOTE: THE EMPHASIS THOUGH MUCH OF THE RA IS THE LARGER ECOSYSTEM BUT WE NEED WORDS IN SECTION 3 TO ACKNOWLEDGE THE EXISTENCE OF THE ENTERPRISE AND THAT AN ENTERPRISE (AS COMMONLY INTERPRETED) IS LIKELY MORE CONSTRAINED AND MORE PRECISELY DESCRIBED FOR THE CONTEXT OF THE ENTERPRISE. THE ECOSYSTEM PERSPECTIVE, THOUGH, IS STILL APPLICABLE FOR THE FOLLOWING REASONS:

1. A GIVEN ENTERPRISE MAY COMPRISE NUMEROUS CONSTITUENT ENTERPRISES THAT RESEMBLE THE INDEPENDENT ENTITIES DESCRIBED FOR THE ECOSYSTEM. AN ENTERPRISE MAY ATTEMPT TO REDUCE VARIATIONS AMONG THE CONSTITUENTS BUT THE *PARTICIPATION IN A SOA ECOSYSTEM* VIEW ENABLES SOA TO BENEFIT THE ENTERPRISE WITHOUT REQUIRING THE ENTERPRISE ISSUES TO BE FULLY RESOLVED.
2. RESOURCES SPECIFICALLY MOTIVATED BY THE CONTEXT OF THE ENTERPRISE CAN BE MORE READILY USED IN A DIFFERENT CONTEXT IF ECOSYSTEM CONSIDERATIONS ARE INCLUDED AT AN EARLY STAGE. THE CHANGE IN A CONTEXT MAY BE A FUNDAMENTAL CHANGE IN THE ENTERPRISE OR THE NEWLY DISCOVERED APPLICABILITY OF ENTERPRISE RESOURCES TO USE OUTSIDE THE ENTERPRISE.

IN THIS DOCUMENT, REFERENCE TO THE SOA ECOSYSTEM APPLIES BUT WITH POSSIBLY LESS GENERALITY TO AN ENTERPRISE USE OF SOA.]

Testing of SOA artifacts for use in the SOA ecosystem differs from traditional software testing for several reasons. First, a highly touted benefit of SOA is to enable unanticipated consumers to make use of services for unanticipated purposes. Examples of this could include the consumer using a service for a result that was not considered the primary one by the provider, or the service may be used in combination with other services in a scenario that is different from the one considered when designing for the initial target consumer community. It is unlikely that a new consumer will push the services back to anything resembling the initial test phase to test the new use, and thus additional paradigms for testing are necessary. Some testing may depend on the availability of test resources made available as a service outside the initial test community, while some testing is likely to be done as part of limited use in the operational setting. The potential responsibilities related to such "consumer testing" is discussed further below.

Secondly, in addition to consumers who interact with a service to realize the described real world effects, the developer community is also intended to be a consumer. In the SOA vision of reuse, the developer composes new solutions using existing services, where the existing services provides access to some desired real world effects that are needed by the new solution. The new solution is a consumer of the existing services, enabling repeated interactions with the existing services playing the role of reusable components. Note, those components are used at the locations where they individually reside and are not typically duplicated for the new solution. The new solution may itself be offered as a SOA service, and a consumer of the service composition representing the new solution may be totally unaware of the component services being used. (See section 4.3.4 for further discussion on service compositions.)

Another difference from traditional testing is that the distributed, unbounded nature of the SOA ecosystem makes it unlikely to have an isolated test environment that duplicates the operational environment. A traditional testing approach often makes use of a test system that is identical to the eventual operational system but isolated for testing. After testing is successfully completed, the tested entity would be migrated to the operational environment, or the test environment may be delivered as part of the system to become operational. This is not feasible for the SOA ecosystem as a whole.

SOA services must be testable in the environment and under the conditions that can be encountered in the operational SOA ecosystem. As the ecosystem is in a state of constant change, so some level of testing is continuous through the lifetime of the service, leveraging utility services used by the ecosystem infrastructure to monitor its own health and respond to situations that could lead to degraded performance. This implies the test resources must incorporate aspects of the SOA paradigm, and a category of services may be created to specifically support and enable effective monitoring and continuous testing for resources participating in the SOA ecosystem.

While SOA within an enterprise may represent a more constrained and predictable operational environment, the composability and unanticipated use aspects are highly touted within the enterprise. The expanded perspective on testing may not be as demanding within an enterprise but fuller consideration of the ecosystem enables the enterprise to be more responsive should conditions change.

5.4.3 Elements of SOA Testing

IEEE-829 identifies fundamental aspects of testing, and many of these should carry over to SOA testing: in particular, the identification of what is to be tested, how it is to be tested, and by whom the testing is to be done. While IEEE-829 identifies a suggested document tree, the availability of these documents in the SOA ecosystem is discussed below.

5.4.3.1 What is to be Tested

The focus of this discussion is the SOA service. It is recognized that the infrastructure components of any SOA environment are likely to also be SOA services and, as such, falls under the same testing guidance. Other resources that contribute to a SOA environment may not be SOA services, but are expected to satisfy the intent if not the letter of guidance presented here. Specific differences for such resources are as yet largely undefined and further elaboration is beyond the scope of the SOA-RAF.

The following discussion often focuses on a singular SOA service but it is implicit that any service may be a composite of other services. As such, testing the functionality of a composite service may effectively be testing an end-to-end business process that is being provided by the composite service. If new versions are available for the component services, appropriate end-to-end testing of the composite may be required in order to verify that the composite functionality is still adequately provided. The level of required testing of an updated composite depends on policies of those providing the service, policies of those using the service, and mission criticality of those depending on the service results.

The SOA service to be tested MUST be unambiguously identified as specified by its applicable configuration management scheme. Specifying such a scheme is beyond the scope of the SOA-RAF other than to say the scheme should be documented and itself under configuration management.

5.4.3.1.1 Origin of Test Requirements

In the Service Description model (Figure 21), the aspects of a service that need to be described are:

- the service functionality and technical assumptions that underlie the functionality;
- the policies that describe conditions of use;
- the service interface that defines information exchange with the service;
- service reachability that identifies how and where message exchange is to occur; and
- metrics access for any participant to have information on how a service is performing.

Service testing must provide adequate assurance that each of these aspects is operational as defined.

The information in the service description comes from different sources. The functionality is defined through whatever process identifies needs and the community for which these needs are addressed. The process may be ad hoc as serves the prospective service owner or strictly governed, but defining the functionality is an essential first step in development. It is also an early and ongoing focus of testing to ensure the service accurately reflects the described functionality and the described functionality accurately addresses the consumer needs.

Policies define the conditions of development and conditions of use for a service and are typically specified as part of the governance process. Policies constraining service development, such as coding standards and best practices, require appropriate testing and auditing during development to ensure compliance. While the governance process identifies development policies, these are likely to originate from the technical community responsible for development activities. Policies that define conditions of use often define business practices that service owners and providers or those responsible for the SOA infrastructure want followed. These policies are initially tested during service development and are continuously monitored during the operational lifetime of the service.

The testing of the service interface and service reachability are often related but essentially reflect different motivations and needs. The service interface is specified as a joint product of the service owners and providers who define service functionality, the prospective consumer community, the service developer, and the governance process. The semantics of the information model must align with the semantics of those who consume the service in order for there to be meaningful exchange of information. The structure of the information is influenced by the consumer semantics and the requirements and constraints of the representation as interpreted by the service developer. The service process model that defines actions which can be performed against a service and any temporal dependencies derive from the defined functionality and may be influenced by the development process. Any of these constraints may be identified and expressed as policy through the governance process.

Service reachability conditions are the purview of the service provider who identifies the service endpoint and the protocols recognized at the endpoint. These may be constrained by governance decisions on how endpoint addresses may be allocated and what protocols should be used.

While the considerations for defining the service interface derive from several sources, testing of the service interface is more straightforward and isolated in the testing process. At any point where the interface is modified or exposes a new resource, the message exchange should be monitored both to ensure the message reaches its intended destination and it is parsed correctly once received. Once an interface has been shown to function properly, it is unlikely to fail later unless something fundamental to the service changes.

The service interface is also tested when the service endpoint changes. Testing of the endpoint ensures message exchange can occur at the time of testing and the initial testing shows the interface is being processed properly at the new endpoint. Functioning of a service endpoint at one time does not guarantee it is functioning at another time, e.g. the server with the endpoint address may be down, making testing of service reachability a continual monitoring function through the life of the service's use of the endpoint. Also, while testing of the service endpoint is a necessary and most commonly noted part of the test regiment, it is not in itself sufficient to ensure the other aspects of testing discussed in this section.

Finally, governance is impossible without the collection of metrics against which service behavior can be assessed. Metrics are also a key indicator for consumers to decide if a service is adequate for their needs. For instance, the average response time or the recent availability can be determining factors even if there are no rules or regulations promulgated through the governance process against which these metrics are assessed. The available metrics are a combination of those expected by the consumer community and those mandated through the governance process. The total set of metrics will evolve over time with SOA experience. Testing of the services that gather and provide access to the metrics will follow testing as described in this section, but for an individual service, testing will ensure that the metrics access indicated in the service description is accurate.

The individual test requirements highlight aspects of the service that testing must consider but testing must establish more than isolated behavior. The emphasis is the holistic results of interacting with the service in the SOA environment. Recall that the execution context is the set of agreements between a consumer and a provider that define the conditions under which service interaction occurs. The agreements are expected to be predominantly the acceptance of the standard conditions as enumerated by the service provider, but it may include the identification of alternate conditions that will govern the interaction.

For example, the provider may prefer a policy where it can sell the contact information of its consumers but will honor the request of a consumer to keep such information private. The identification of the alternate privacy policy is part of the execution context, and it is the application of and compliance with this policy that operational monitoring will attempt to measure. The collection of metrics showing this condition is indeed met when chosen is considered part of the ongoing testing of the service.

Other variations in the execution context also require monitoring to ensure that different combinations of conditions perform together as desired. For example, if a new privacy policy takes additional resources to apply, this may affect quality of service and propagate other effects. These could not be tested during the original testing if the alternate policy did not exist at that time.

5.4.3.1.2 Testing Against Non-Functional Requirements

Testing against non-functional requirements constitutes testing of business usability of the service. In a marketplace of services, non-functional characteristics may be the primary differentiator between services that produce essentially the same real world effects.

As noted in the previous section, non-functional characteristics are often associated with policies or other terms of use and may be collected in service level contracts offered by the service providers. Non-functional requirements may also reflect the network and hardware infrastructure that support communication with the service, and changes may impact quality of service. The service consumer and even the service provider may not be aware of all such infrastructure changes but the changes may manifest in shared states that impact the usability of the service.

In general, a change in the non-functional requirements results in a change to the execution context, but as with any collection of information that constitutes a description, the execution context is unable to explicitly capture all non-functional requirements that may apply. A change in non-functional requirements, whether explicitly part of the execution context or an implicit contributor, may require retesting of the service even if its functionality and the implementation of the functionality has not changed. Depending on the circumstances, retesting may require a formal recertifying of end-to-end behavior or more likely will be part of the continuous monitoring that applies throughout the service lifetime.

5.4.3.1.3 Testing Content and the Interests of Consumers

As noted in section 5.4.1.1, testing may involve verification of conformance with respect to policies and technical specifications and validation with respect to sufficiency of functionality to meet some prescribed use. It may also include demonstration of performance and quality aspects. For some of these items, such as demonstrating the business processes followed in developing the service or the use of standards in implementing the service, the testing or relevant auditing is done internal to the service development process and follows traditional software testing and quality assurance. If it is believed of value to potential consumers, information about such testing could be included in the service description. However, it is not required that all test or compliance artifacts be available to consumers, as many of the details tested may be part of the opacity of the service implementation.

Some aspects of the service being tested will reflect directly on the real world effects realized through interaction with the service. In these cases, it is more likely that testing results will be directly relevant to potential consumers. For example, if the service was designed to correspond to certain elements of a business process or that a certain workflow is followed, testing should verify that the real world effects reflect that the business process or workflow were satisfactorily captured.

The testing may also need to demonstrate that specified conditions of use are satisfied. For example, policies may be asserted that require certain qualifications of or impose restrictions on the consumers who may interact with the service. The service testing must demonstrate that the service independently enforces the policies or it provides the required information exchanges with the SOA ecosystem so other resources can ensure the specified conditions.

The completeness of the testing, both in terms of the features tested and the range of parameters for which response is tested, depends on the context of expected use: the more critical the use, the more complete the testing. There are always limits on the resources available for testing, if nothing else than the service must be available for use in a finite amount of time.

This again emphasizes the need for adequate documentation to be available. If the original testing is very thorough, it may be adequate for less demanding uses in the future. If the original testing was more constrained, then well-documented test results establish the foundation on which further testing can be defined and executed.

5.4.3.2 How Testing is to be Done

Testing should follow well-defined methodologies and, if possible, should reuse test artifacts that have proven generally useful for past testing. For example, IEEE-829 notes that test cases are separated from test designs to allow for use in more than one design and to allow for reuse in other situations. In the SOA ecosystem, description of such artifacts, as with description of a service, enables awareness of the item and describes how the artifact may be accessed or used.

As with traditional testing, the specific test procedures and test case inputs are important so the tests are unambiguously defined and entities can be retested in the future. Automated testing and regression testing may be more important in the SOA ecosystem in order to re-verify a service is still acceptable when incorporated in a new use. For example, if a new use requires the services to deal with input parameters outside the range of initial testing, the tests could be rerun with the new parameters. If the testing resources are available to consumers within the SOA ecosystem, the testing as designed by test professionals could be consumed through a service accessed by consumers, and their results could augment those already in place. This is discussed further in the next section.

5.4.3.3 Who Performs the Testing

As with any software, the first line of testing is unit testing done by software developers. It is likely that initial testing will be done by those developing the software but may also be done independently by other developers. For SOA development, unit testing is likely confined to a development sandbox isolated from the SOA ecosystem.

SOA testing will differ from traditional software testing in that testing beyond the development sandbox must incorporate aspects of the SOA ecosystem, and those doing the testing must be familiar with both the characteristics and responses of the ecosystem and the tools, especially those available as services, to facilitate and standardize testing. Test professionals will know what level of assurance must be established as the exposure of the service to the ecosystem and ecosystem to the service increases towards operational status. These test professionals may be internal resources to an organization or may evolve as a separate discipline provided through external contracting.

As noted above, it is unlikely that a complete duplicate of the SOA ecosystem will be available for isolated testing, and thus use of ecosystem resources will manifest as a transition process rather than a step change from a test environment to an operational one. This is especially true for new composite services that incorporate existing operational services to achieve the new functionality. The test professionals will need to understand the available resources and the ramifications of this transition.

As with current software development, a stage beyond work by test professionals will make use of a select group of typical users, commonly referred to as beta testers, to report on service response during typical intended use. This establishes fitness by the consumers, providing final validation of previously verified processes, requirements, and final implementation.

In traditional software development, beta testing is the end of testing for a given version of the software. However, although the initial test phase can establish an appropriate level of confidence consistent with the designed use for the initial target consumer community, the operational service will exist in an evolving ecosystem, and later conditions of use may differ from those thought to be sufficient during the initial testing. Thus, operational monitoring becomes an extension of testing through the service lifetime. This continuous testing will attempt to ensure that a service does not consume an inordinate amount of ecosystem resources or display other behavior that degrades the ecosystem, but it will not undercover functional errors that may surface over time.

As with any software, it is the responsibility of the consumers to consider the reasonableness of solutions in order to spot errors in either the software or the way the software is being used. This is especially important for consumers with unanticipated uses that may go beyond the original test conditions. It is unlikely the consumers will initiate a new round of formal testing unless the new use requires a significantly higher level of confidence in the service. Rather the consumer becomes a new extension to the testing regiment. Obvious testing would include a sanity check of results during the new use. However, if the details of legacy testing are associated with the service through the service description and if testing resources are available through automated testing services, then the new consumers can rerun and extend previous testing to include the extended test conditions. If the test results are acceptable, these can be added to the documentation of previous results and become the extended basis for future decisions by prospective consumers on the appropriateness of the service. If the results are not acceptable or in some way questionable, the responsible party for the service or testing professionals can be brought in to decide if remedial action is necessary.

5.4.3.4 How Testing Results are Reported

For any SOA service, an accurate reporting of the testing a service has undergone and the results of the testing is vital to consumers deciding whether a service is appropriate for intended use. Appropriateness may be defined by a consumer organization and require specific test regiments culminating in a certification; appropriateness could be established by accepting testing and certifications that have been conferred by others.

The testing and certification information should be identified in the service description. Referring to the general description model of *Figure 12*, tests conducted by or under a request from the service owner (see ownership in section **Error! Reference source not found.**) would be captured under Annotations from wners. Testing done by others, such as consumers with unanticipated uses, could be associated through Annotations from 3rd Parties. The annotations should clearly indicate what was tested, how the testing was done, who did the testing, and the testing results. The clear description of each of these artifacts and of standardized testing protocols for various levels of sophistication and completeness of testing would enable a common understanding and comparison of test coverage. It will also make it more straightforward to conduct and report on future testing, facilitating the maintenance of the service description.

Consumer testing and the reporting of results raises additional issues. While stating who did the testing is mandatory, there may be formal requirements for authentication of the tester to ensure traceability of the testing claims. In some circumstances, persons or organizations would not be allowed to state testing claims unless the tester was an approved entity. In other cases, ensuring the tester had a valid email may be sufficient. In either case, it would be at the discretion of the potential consumer to decide what level of authentication was acceptable and which testers are considered authoritative in the context of their anticipated use.

Finally, in a world of openly shared information, we would see an ever-expanding set of testing information as new uses and new consumers interact with a service. In reality, these new uses may represent proprietary processes or classified use that should only be available to authorized parties. Testing information, as with other elements of description, may require special access controls to ensure appropriate access and use.

5.4.4 Testing SOA Services

Testing of SOA services should be consistent with the SOA paradigm. In particular, testing resources and artifacts should be visible in support of service interaction between providers and consumers, where

here the interaction is between the testing resource and the tester. In addition, the idea of opacity of the implementation should limit the details that need to be available for effective use of the test resources. Testing that requires knowledge of the internal structure of the service or its underlying capability should be performed as part of unit testing in the development sandbox, and should represent a minimum level of confidence before the service begins its transition to further testing and eventual operation in the SOA ecosystem.

5.4.4.1 Progression of SOA Testing

Software testing is a gradual exercise going from micro inspection to testing macro effects. The first step in testing is likely the traditional code reviews. SOA considerations would account for the distributed nature of SOA, including issues of distributed security and best practices to ensure secure resources. It would also set the groundwork for opacity of implementation, hiding programming details and simplifying the use of the service.

Code review is likely followed by unit testing in a development sandbox isolated from the operational environment. The unit testing is done with full knowledge of the service internal structure and knowledge of resources representing underlying capabilities. It tests the interface to ensure exchanged messages are as specified in the service description and the messages can be parsed and interpreted as intended. Unit testing also verifies intended functionality and that the software has dealt correctly with internal dependencies, such as structure of a file system or access to other dedicated resources.

Some aspects of unit testing require external dependencies be satisfied, and this is often done using mock objects to substitute for the external resources. In particular, it will likely be necessary to include mocks of existing operational services, both those provided as part of the SOA infrastructure and services from other providers.

Service Mock

> A service mock is an entity that mimics some aspect of the performance of an operational service without committing to the real world effects that the operational service would produce.

Mocks are discussed in detail in sections 5.4.4.3 and 5.4.4.4.

After unit testing has demonstrated an adequate level of confidence in the service, the testing must transition from the tightly controlled environment of the development sandbox to an environment that more clearly resembles the operational SOA ecosystem or, at a minimum, the intended enterprise. While sandbox testing will use simple mocks of some aspects of the SOA environment, such as an interface to a security service without the security service functionality, the dynamic nature of SOA makes a full simulation infeasible to create or maintain. This is especially true when a new composite service makes use of operational services provided by others. Thus, at some point before testing is complete, the service will need to demonstrate its functionality by using resources and dealing with conditions that only exist in the full ecosystem or the intended enterprise. Some of these resources may still provide test interfaces -- more on this below -- but the interfaces will be accessible using the SOA environment and not just implemented for the sandbox.

At this stage, the opacity of the service becomes important as the details of interacting with the service now rely on correct use of the service interface and not knowledge of the service internals. The workings of the service will only be observable through the real world effects realized through service interactions and external indications that conditions of use, such as user authentication, are satisfied. Monitoring the behavior of the service will depend on service interfaces that expose internal monitoring or provide required information to the SOA infrastructure monitoring function. The monitoring required to test a new service is likely to have significant overlap with the monitoring the SOA infrastructure includes to monitor its own health and to identify and isolate behavior outside of acceptable bounds. This is exactly what is needed as part of service testing, and it is reasonable to assume that the ecosystem transition includes use of operational monitoring rather than solely dedicated monitoring for each service being tested.

Use of SOA monitoring resources during the explicit testing phase sets the stage for monitoring and a level of continual testing throughout the service lifetime.

5.4.4.2 Testing Traditional Dependencies vs. Service Interactions

A SOA service is not required to make use of other operational services beyond what may be required for monitoring by the ecosystem infrastructure. The service can implement hardcoded dependencies which have been tested in the development sandbox through the use of dedicated mocks. While coordination may be required with real data sources during integration testing, the dependencies can be constrained to things that can be tested in a more traditional manner. Policies can also be set to restrict access to pre-approved users, and thus the question of unanticipated users and unanticipated uses can be eliminated. Operational readiness can be defined in terms of what can be proven in isolated testing. While all this may provide more confidence in the service for its designed purpose, such a service will not fully participate in the benefits or challenges of the ecosystem. This is akin to filling a swimming pool with sea water and having someone in the pool say they are swimming in the ocean.

In considering the testing needed for a fully participating service, consider the example of a new composite service that combines the real world effects and complies with the conditions of use of five existing operational services. The developer of the composite service does not own any of the component services and has limited, if any, ability to get the distributed owners to do any customization. The developer also is limited by the principle of opacity to information comprising the service description, and does not know internal details of the component services. The developer of the composite service must use the component services as they exist as part of the SOA environment, including what is provided to support testing by new users. This introduces requirements for what is needed in the way of service mocks.

5.4.4.3 Use of Service Mocks

Service mocks enables the tested service to respond to specific features of an operational service that is being used as a component. It allows service testing to proceed without needing access to or with only limited engagement with the component service. Mocks can also mimic difficult to create situations for which it is desired to test the new service response. For composite services using multiple component services, mocks may be used in combination to function for any number of the components. Note, when using service mocks, it is important to remember that it is not the component service that is being tested (although anomalous behavior may be uncovered during testing) but the use of the component in the new composite.

Individual service mocks can emphasize different features of the component service they represent but any given mock does not have to mimic all features. For example, a mock of the service interface can echo a sent message and demonstrate the message is reaching its intended destination. A mock could go further and parse the sent message to demonstrate the message not only reached its destination but was understood. As a final step, the mock could report back what actions would have been taken by the component service and what real world effects would result. If the response mimicked the operational response, functional testing could proceed as if the real world effect actually occurred.

There are numerous ways to provide mock functionality. The service mock could be a simulation of the operational service and return simulated results in a realistic response message or event notification. It is also possible for the operational service to act as its own mock and simply not execute the commit stage of its functionality. The service mock could use a combination of simulation and service action without commit to generate a report of what would have occurred during the defined interaction with the operational service.

As the service proceeds through testing, mocks should be systematically replaced by the component resources accessed through their operational interfaces. Before beta testing begins, end-to-end testing, i.e. proceeding from the beginning of the service interaction to the resulting real world results, should be accomplished using component resources via their operational interfaces.

5.4.4.4 Providers of Service Mocks

In traditional testing, it is often the test professionals who design and develop the mocks, but in the distributed world of SOA, this may not be efficient or desirable.

In the development sandbox, it is likely the new service developer or test professionals working with the developer will create mocks adequate for unit testing. Given that most of this testing is to verify the new service is performing as designed, it is not necessary to have high fidelity models of other resources being accessed. In addition, given opacity of SOA implementation, the developer of the new service may not have sufficient detailed knowledge of a component service to build a detailed mock of the component service functionality. Sharing existing mocks at this stage may be possible but the mocks would need to be implemented in the sandbox, and for simple models it is likely easier to build the mock from scratch.

As testing begins its transition to the wider SOA environment, mocks may be available as services. For existing resources, it is possible that an Open Source model could evolve where service mocks of available functions can be catalogued and used during initial interaction of the tested service and the operational environment. Widely used functions may have numerous service mocks, some mimicking detailed conditions within the SOA infrastructure. However, the Open Source model is less likely to be sufficient for specialty services that are not widely used by a large consumer community.

The service developer is probably best qualified for also developing more detailed service mocks or for mock modes of operational services. This implies that in addition to their operational interfaces, services will routinely provide test interfaces to enable service mocks to be used as services. As noted above, a new service developer wanting to build a mock of component services is limited to the description provided by the component service developer or owner. The description typically will detail real world effects and conditions of use but will not provide implementation details, some of which may be proprietary. Just as important in the SOA ecosystem, if it becomes standard protocol for developers to create service mocks of their own services, a new service developer is only responsible for building his own mocks and can expect other mocks to be available from other developers. This reduces duplication of effort where multiple developers would be trying to build the same mocks from the same insufficient information. Finally, a service developer is probably best qualified to know when and how a service mock should be updated to reflect modified functionality or message exchange.

It is also possible that testing organizations will evolve to provide high-fidelity test harnesses for new services. The harnesses would allow new services to plug into a test environment and would facilitate accessing mocks of component services. However, it will remain a constant challenge for such organizations to capture evolving uses and characteristics of service interactions in the real SOA environment and maintain the fidelity and accuracy of the test systems.

5.4.4.5 Fundamental Questions for SOA Testing

In order for the transition to the SOA operational environment to proceed, it is necessary to answer two fundamental questions:

- Who provides what testing resources for the SOA operational environment, e.g. mocks of interfaces, mocks of functionality, monitoring tools?
- What testing needs to be accomplished before operational environment resources can be accessed for further testing?

The discussion in section 5.4.4.4 notes various levels of sophistication of service mocks and different communities are likely to be responsible for different levels. Section 5.4.4.4 advocates a significant role for service developers, but there needs to be community consensus that such mocks are needed and that service developers will agree to fulfilling this role. There is also a need for consensus as to what tools should be available as services from the SOA infrastructure.

As for use of the service mocks and SOA environment monitoring services, practical experience is needed upon which guidelines can be established for when a new service has been adequately tested to proceed with a greater level of exposure with the SOA environment. Malfunctioning services could cause serious problems if they cannot be identified and isolated. On the other hand, without adequate testing under SOA operational conditions, it is unlikely that problems can be uncovered and corrected before they reach an operational stage.

As noted in section 5.4.4.2, some of these questions can be avoided by restricting services to more traditional use scenarios. However, such restriction will limit the effectiveness of SOA use and the result will resemble the constraints of traditional integration activities we are trying to move beyond.

5.4.5 Architectural Implications for SOA Testing

The discussion of SOA Testing indicates numerous architectural implications on the SOA ecosystem:

- The distributed, boundary-less nature of the SOA ecosystem makes it infeasible to create and maintain a single mock of the entire ecosystem to support testing activities.
- A standard suite of monitoring services needs to be defined, developed, and maintained. This should be done in a manner consistent with the evolving nature of the ecosystem.
- Services should provide interfaces that support access in a test mode.
- Testing resources must be described and their descriptions must be catalogued in a manner that enables their discovery and access.
- Guidelines for testing and ecosystem access need to be established and the ecosystem must be able to enforce those guidelines asserted as policies.
- Services should be available to support automated testing and regression testing.
- Services should be available to facilitate updating service description by anyone who has performed testing of a service.

6 Conformance

This Reference Architecture Framework is an abstract architectural description of Service Oriented Architecture, which means that it is especially difficult to construct tests for conformance to the architecture. In addition, conformance to an architectural specification does not, by itself, guarantee any form of interoperability between multiple implementations.

However, it *is* possible to decide whether or not a given architecture is conformant to an architectural description such as this one. In discussions of conformance we use the term **target architecture** to identify the (typically concrete) architecture that may be viewable as conforming to the abstract principles outlined in this document.

Target Architecture

> A target architecture is an architectural description of a system that is intended to be viewed as conforming to the SOA-RAF.

While we cannot guarantee interoperability between target architectures (or more specifically between applications and systems residing within the ecosystems of those target architectures), interoperability between target architectures is promoted by conformance to this Reference Architecture Framework as it reduces the semantic impedance mismatch between the different ecosystems.

The primary measure of conformance is whether given concepts as described in document have corresponding concepts in the target architecture. Such a correspondence MUST honor the relationships identified within this document for the target architecture to be considered conforming.

For example, in Section 3.1.3.1 we identify resource as a key concept. A resource is associated with an owner and a number of identifiers. For a target architecture to conform to the SOA-RAF, it must be possible to find corresponding concepts of resource, identifier and owner within the target architecture: say *entity*, *token* and *user* . Furthermore, the relationships between *entity*, *token* and *user* MUST mirror the relationships between resource, identifier and owner appropriately.

Clearly, such correspondence is simpler if the terminology within the target architecture is identical to that in the SOA-RAF. But so long as the ‘graph’ of concepts and relationships is consistent, that is all that is required for the target architecture to conform to this Reference Architecture Framework.

[EDITOR’S NOTE: The conformance section is not complete]

A. Acknowledgements

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B. Index of Defined Terms

The first page number refers to the first use of the term. The second, where necessary, refers to the page where the term is formally defined.

Participant
Peer
Permission
Policy
Policy Conflict
Policy Conflict Resolution
Policy Constraint
Policy Decision
Policy Enforcement
Policy Framework
Policy Object
Policy Ontology
Policy Owner
Policy Subject
Presence
Private State
Protocol
Public Semantics
Qualification
Real World Effect
Regulation
Resource
Responsibility
Right
Risk
Role
Rule
Security
Semantic Engagement
Service Action
Service Consumer
Service Level Real World Effect
Service Mediator
Service Provider
Shared State
Skill
Social Structure
Stakeholder
State
System
System Stakeholder
Trust

View
Viewpoint

C. The Unified Modeling Language, UML

Error! Reference source not found. illustrates an annotated example of a UML class diagram that is sed to represent a visual model depiction of the Resources Model in the *Participation in a SOA Ecosystem* view (Section **Error! Reference source not found.**).

Figure 44 Example UML class diagram—Resources.

Lines connecting boxes (classifiers) represent associations between things. An association has two roles (one in each direction). A role can have cardinality, for example, one or more ("1..*") stakeholders own zero or more ("0..*) resources. The role from classifier A to B is labeled closest to B, and vice versa, for example, the role between resource to Identity can be read as resource embodies Identity, and Identity denotes a resource.

Mostly, we use named associations, which are denoted with a verb or verb phrase associated with an arrowhead. A named association reads from classifier A to B, for example, one or more stakeholders owns zero or more resources. Named associations are a very effective way to model relationships between concepts.

An open diamond (at the end of an association line) denotes an aggregation, which is a part-of relationship, for example, Identifiers are part of Identity (or conversely, Identity is made up of Identifiers).

A stronger form of aggregation is known as composition, which involves using a filled-in diamond at the end of an association line (not shown in above diagram). For example, if the association between Identity and Identifier were a composition rather than an aggregation as shown, deleting Identity would also delete any owned Identifiers. There is also an element of exclusive ownership in a composition relationship between classifiers, but this usually refers to specific instances of the owned classes (objects).

This is by no means a complete description of the semantics of all diagram elements that comprise a UML class diagram, but rather is intended to serve as an illustrative example for the reader. It should be noted that the SOA-RAF utilizes additional class diagram elements as well as other UML diagram types such as sequence diagrams and component diagrams. The reader who is unfamiliar with the UML is encouraged to review one or more of the many useful online resources and book publications available describing UML (see, for example, www.uml.org).

D. Critical Factors Analysis

A critical factors analysis (CFA) is an analysis of the key properties of a project. A CFA is analyzed in terms of the goals of the project, the critical factors that will lead to its success and the measurable requirements of the project implementation that support the goals of the project. CFA is particularly suitable for capturing quality attributes of a project, often referred to as “non-functional” or “other-than-functional” requirements: for example, security, scalability, wide-spread adoption, and so on. As such, CFA complements rather than attempts to replace other requirements capture techniques.

D.1 Goals

A goal is an overall target that you are trying to reach with the project. Typically, goals are hard to measure by themselves. Goals are often directed at the potential consumer of the product rather than the technology developer.

Critical Success Factors

A critical success factor (CSF) is a property, sub-goal that directly supports a goal and there is strong belief that without it the goal is unattainable. CSFs themselves are not necessarily measurable in themselves.

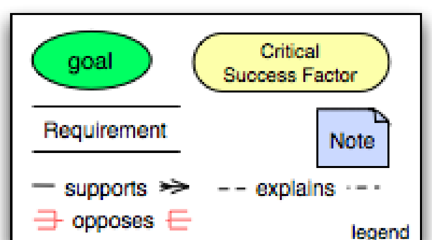
Requirements

A requirement is a specific measurable property that directly supports a CSF. The key here is measurability: it should be possible to unambiguously determine if a requirement has been met. While goals are typically directed at consumers of the specification, requirements are focused on technical aspects of the specification.

CFA Diagrams

It can often be helpful to illustrate graphically the key concepts and relationships between them. Such diagrams can act as effective indices into the written descriptions of goals etc., but is not intended to replace the text.

The legend:



illustrates the key elements of the graphical notation. Goals are written in round ovals, critical success factors are written in round-ended rectangles and requirements are written using open-ended rectangles. The arrows show whether a CSF/goal/requirement is supported by another element or opposed by it. This highlights the potential for conflict in requirements.

E. Relationship to other SOA Open Standards

The white paper “Navigating the SOA Open Standards Landscape Around Architecture” issued jointly by OASIS, OMG, and The Open Group **[SOA-NAV]** was written to help the SOA community at large navigate the myriad of overlapping technical products produced by these organizations with specific emphasis on the “A” in SOA, i.e., Architecture.

The white paper explains and positions standards for SOA reference models, ontologies, reference architectures, maturity models, modeling languages, and standards work on SOA governance. It outlines where the works are similar, highlights the strengths of each body of work, and touches on how the work can be used together in complementary ways. It is also meant as a guide to users for selecting those specifications most appropriate for their needs.

While the understanding of SOA and SOA Governance concepts provided by these works is similar, the evolving standards are written from different perspectives. Each specification supports a similar range of opportunity, but has provided different depths of detail for the perspectives on which they focus. Although the definitions and expressions may differ, there is agreement on the fundamental concepts of SOA and SOA Governance.

The following is a summary taken from **[SOA-NAV]** of the positioning and guidance on the specifications:

- The OASIS Reference Model for SOA (SOA RM) is the most abstract of the specifications positioned. It is used for understanding core SOA concepts
- The Open Group SOA Ontology extends, refines, and formalizes some of the core concepts of the SOA RM. It is used for understanding core SOA concepts and facilitates a model-driven approach to SOA development.
- The OASIS Reference Architecture Foundation for SOA (this document) is an abstract, foundational reference architecture addressing a broader ecosystem viewpoint for building and interacting within the SOA paradigm. It is used for understanding different elements of SOA, the completeness of SOA architectures and implementations, and considerations for reaching across ownership boundaries where there is no single authoritative entity for SOA and SOA governance.
- The Open Group SOA Reference Architecture is a layered architecture from consumer and provider perspective with cross cutting concerns describing these architectural building blocks and principles that support the realizations of SOA. It is used for understanding the different elements of SOA, deployment of SOA in enterprise, basis for an industry or organizational reference architecture, implication of architectural decisions, and positioning of vendor products in a SOA context.
- The Open Group SOA Governance Framework is a governance domain reference model and method. It is for understanding SOA governance in organizations. The OASIS Reference Architecture for SOA Foundation contains an abstract discussion of governance principles as applied to SOA across boundaries
- The Open Group SOA Integration Maturity Model (OSIMM) is a means to assess an organization’s maturity within a broad SOA spectrum and define a roadmap for incremental adoption. It is used for understanding the level of SOA maturity in an organization
- The Object Management Group SoaML Specification supports services modeling UML extensions. It can be seen as an instantiation of a subset of the Open Group RA used for representing SOA artifacts in UML.

Fortunately, there is a great deal of agreement on the foundational core concepts across the many independent specifications and standards for SOA. This could be best explained by broad and common experience of users of SOA and its maturity in the marketplace. It also provides assurance that investing in SOA-based business and IT transformation initiatives that incorporate and use these specifications and standards helps to mitigate risks that might compromise a successful SOA solution.

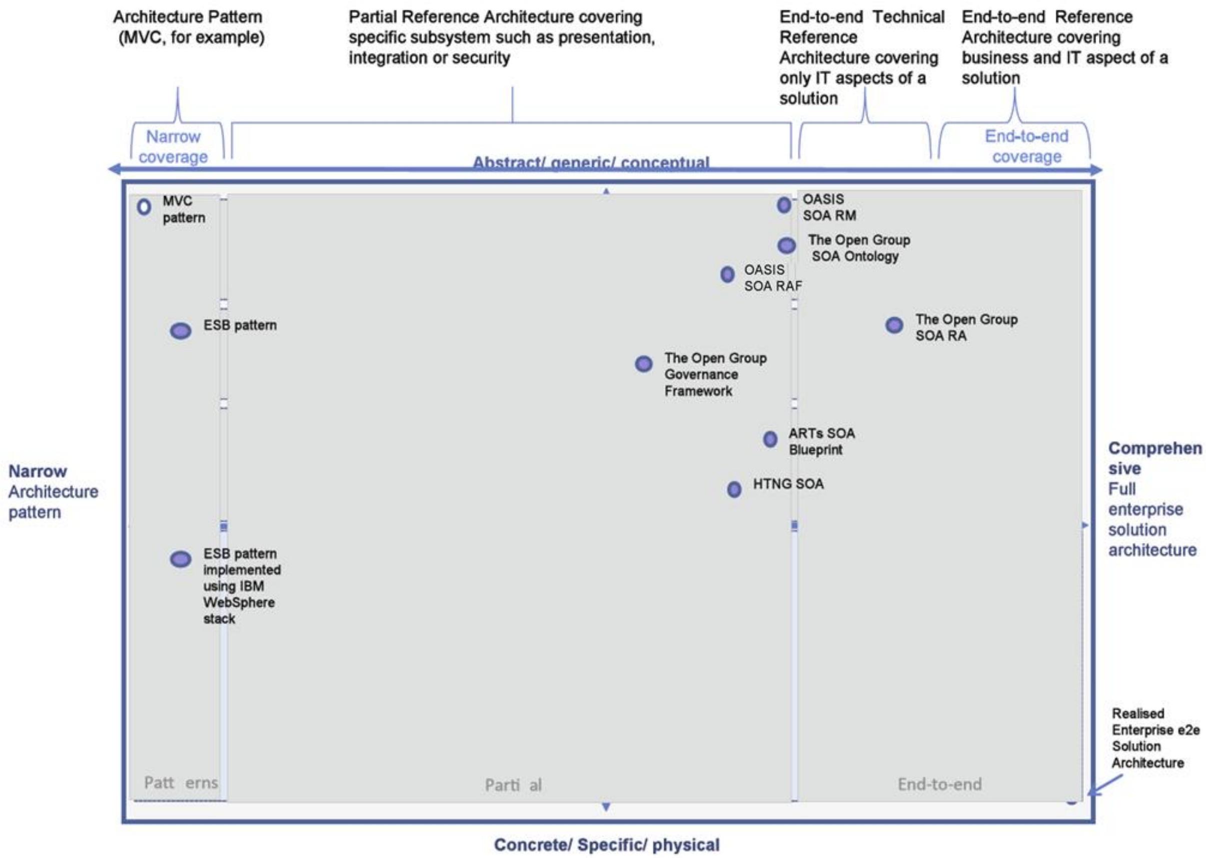


Figure 45- SOA Reference Architecture Positioning (from "Navigating the SOA Open Standards Landscape Around Architecture, © OASIS, OMG, The Open Group).