Chapter 92
Interoperability Frameworks for Distributed Systems

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ABSTRACT

One of the fundamental problems to tackle when interconnecting distributed systems is to entail the minimum coupling possible while ensuring the minimum interoperability requirements. This chapter presents a solution to the coupling problem based on the concepts of compliance and conformance, in which compatibility between interacting services does not rely on a shared schema, but rather on the features that are actually used. To help systematizing the various aspects relevant to interoperability, this chapter proposes a multidimensional interoperability framework, which includes the following dimensions: Lifecycle (with typical development stages), interoperability (based on compliance and conformance, with various layers of abstraction), and concerns (to deal with non-functional aspects such as security, quality of service, and social and legal issues).

INTRODUCTION

A system is *distributed* with respect to another if their lifecycles are not dependent, i.e., if one can evolve (to a new version) without having to change, to suspend or to stop the behavior or interface of the other.

Different systems usually need to interact, raising the concept of *interoperability* (ISO/IEC/IEEE, 2010), which literally means the *ability* (of two or more systems) to *operate together*. An *interoperability framework* is a set of principles, assumptions, rules and guidelines to analyze, to structure and to classify the concepts and concerns of interoperability.

What these words really mean largely depends on the domain which the systems belong to, although there is a pervasive, underlying notion that these systems are active, reacting upon stimuli sent by others and cooperating to accomplish higher-level goals than those achievable by each single system.

Interoperability has been studied in domains such as enterprise cooperation (Popplewell, 2014; Rezaei, Chiew, & Lee, 2014), e-government services (Sharma & Panigrahi, 2015), military operations (Hussain, Mehmood, Haq, Alnafjan, & Alghamdi, 2014), cloud computing (Zhang, Wu, & Cheung, 2013), healthcare applications (Robkin, Weininger, Preciado, & Goldman, 2015), digital libraries (Agosti, Ferro, & Silvello, 2016) and metadata (Chen, 2015).

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In this article, we adopt a more general perspective, exploring interoperability in the generic context of distributed systems, independently of what they are or which domain is the most relevant to them. The following section describes some of the most relevant existing interoperability frameworks. The section after that one introduces the basic concepts that establish a foundation for interoperability in distributed contexts. Next, a multidimensional interoperability framework is proposed and its advantages discussed. Finally, future research directions are hinted and conclusions drawn.

BACKGROUND

The Open Systems Interconnection (OSI) reference model (ISO/IEC, 1994), constitutes one of the first systematizations of distributed interoperability, considering seven layers (Table 1). This standard deals mostly with communication issues, with the objective of sending data and reproducing it at the receiver. How those data are interpreted by the receiver and how it reacts to the data is left unspecified, encompassed by the topmost layer, Application. However, interoperability must ensure not only the exchange of data but also the meaningful use of information (ISO/IEC/IEEE, 2010), which means that this layer must be detailed.

Table 1 depicts the basic structure of several interoperability frameworks (referred to by acronym or first author) that use this layered approach, establishing a rough horizontal correspondence between layers.

The C4IF framework (Peristeras & Tarabanis, 2006), is based on four layers: Connection (basic use of a channel), Communication (data formats), Consolidation (meaning through semantics) and Collaboration (through compatible processes). It simplifies the lower levels (distinguishing only connectivity and communication) and refines the application layer, distinguishing information semantics from behavior.

Table 1. Comparison between several layered interoperability frameworks

<table>
<tr><th>OSI
(1994)</th><th>C4IF
(2006)</th><th>Lewis
(2008)</th><th>Stamper
(2000)</th><th>LCIM
(2009)</th><th>EIF
(2010)</th><th>Monfelt
(2011)</th></tr>
<tr><td rowspan="6">Application</td><td rowspan="3">Collaboration</td><td rowspan="3">Organizational</td><td rowspan="2">Social world</td><td rowspan="2">Conceptual</td><td rowspan="2">Political</td><td>SWOT</td></tr>
<tr><td>Cultural</td></tr>
<tr><td rowspan="2">Pragmatic</td><td>Ethical</td></tr>
<tr><td>Legal</td><td>Legal</td></tr>
<tr><td rowspan="2">Dynamic</td><td rowspan="2">Organizational</td><td>Managerial</td></tr>
<tr><td>Pragmatic</td><td>Organizational</td></tr>
<tr><td rowspan="2">Consolidation</td><td rowspan="2">Semantic</td><td rowspan="2">Semantic</td><td rowspan="2">Semantic</td><td rowspan="4">Semantic
(includes
syntactic)</td><td>Adaptation</td></tr>
<tr><td>Application</td></tr>
<tr><td>Presentation</td><td rowspan="3">Communication</td><td rowspan="2">Syntactic</td><td rowspan="2">Syntactic</td><td rowspan="2">Syntactic</td><td>Presentation</td></tr>
<tr><td>Session</td><td>Session</td></tr>
<tr><td>Transport</td><td rowspan="4">Machine</td><td rowspan="3">Empirics</td><td rowspan="4">Technical</td><td rowspan="4">Technical</td><td>Transport</td></tr>
<tr><td>Network</td><td rowspan="3">Connection</td><td>Network</td></tr>
<tr><td>Link</td><td>Link</td></tr>
<tr><td>Physical
Medium</td><td>Physical
world</td><td>Physical Medium</td></tr>
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