Chapter 2
An Interoperability Framework for Enterprise Applications in Cloud Environments

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ABSTRACT
Enterprise Information Systems (EIS) are increasingly designed with cloud environments in mind, as a set of cooperating services deployed in a mix of platforms, including conventional servers and clouds, private and public. If enterprise value chains are considered, in which their EIS need to cooperate, solving all the interoperability problems raised by the need to meaningfully interconnect all these services constitutes a rather challenging endeavor. This chapter describes the concept of enterprise as a service, a collection of dynamically assembled services with a lifecycle centered on the customers, and proposes a multidimensional interoperability framework to help systematizing the various aspects relevant to interoperability. Besides lifecycle, this framework presents other dimensions, namely concreteness (with various levels of abstraction), interoperability (based on structural compliance and conformance), and concerns (to deal with non-functional aspects such as security, reliability and quality of service).

INTRODUCTION
A cloud can simply be defined as a remote platform supporting the deployment and use of computer-based resources and services, in a setting characterized by elastic, dynamic and automated resource provisioning, paid as used and managed in a self-service way (Armbrust et al., 2010).

Through virtualization, a pool of physical resources (servers, storage, networks, and so on) supports the dynamic allocation, provisioning, decommissioning and release of virtual resources, forming an apparently elastic fabric of resources that are used on demand and paid as used. However, users want the services that resources support, not the resources themselves. Resources are increasingly seen as a commodity (Carr, 2004), allowing some IT enterprises, the providers, to specialize in providing IT-based services and resource infrastructures cheaper, more reliably,
better managed, faster provisioned and in a more scalable way than any of the organizations that just require these services and resources for their business activities, the consumers.

This dichotomy between consumers and providers, a marriage of convenience as any outsourcing agreement, is known as *utility computing* (Brynjolfsson, Hofmann & Jordan, 2010). Providers take care of many issues on behalf of the consumers, namely expertise, risks, costs and management, in what concerns resources and generic services. Consumers still have to tackle a part of the overall solution, namely application-specific services, but they can concentrate more in their core business and less on the IT technologies that support it.

After an initial period of slow growth, in which concerns about security, privacy, performance and availability acted as inhibiting factors, cloud computing is finally blossoming. For consumers, it is now easier, cheaper, and faster to get computing resources from a cloud than by resorting to conventional IT systems and applications. In most cases, the advantages now outweigh the risks and other disadvantages. All large IT providers are now investing heavily in cloud computing.

This is clearly a market driven by providers, with consumers still cautious about the transition, but the scenario is evolving at a fast pace, both for individual and enterprise consumers. Gartner analysts forecast that the public cloud services market will grow at a compound annual growth rate (CAGR) of 17.3% over the 2014-2018 five-year period (Anderson et al, 2014, May 13). Gartner also expects that end-user spending on public cloud services will grow 19% in 2014, up to $158 billion, with annual growth rates of 45% and 33% for infrastructure (IaaS) and platform (PaaS) cloud services, respectively (Anderson et al, 2014, March 31). These rates clearly indicate a shift in spending, from traditional IT systems to cloud services.

Two relevant factors gave their contribution to the bootstrap and boom of cloud computing:

- For individual consumers, social networking and multiplatform mobility (laptops, tablets and smartphones) raised the need to store information in a server somewhere, always available to be accessed seamlessly and in a synchronized way across platforms;
- For enterprise consumers, the market pressure caused by increasing global competition and ever.shortening turnaround times, combined with a sluggish global economy, emphasized the basic principle of concentrating on core business and (dynamically) outsourcing the rest.

However, the problem that drove the appearance of the Web, interoperability, remains unsolved. The goal is to endow distributed systems with the ability of meaningfully exchanging information in interaction patterns known as choreographies. The problem, unfortunately, is even worse today than 25 years ago:

- The Web provided uniform e global access to media information and created the market, instead of reacting to it. This gave time to standards (HTTP, HTML and, later, XML) to become universally used before diversity could set in. This is why today we can use any browser to access any Web site. Even in the service realm, with either SOA or REST, the scenario is essentially standardized, although standards are not enough to ensure interoperability (Lewis, Morris, Simanta & Wrage, 2008). The usual integration problems are exacerbated by the dynamic cloud environments, in which an application can migrate, which may entail a change in the access URI or in non-functional characteristics, such as security settings, policies and quality of service;
- Cloud computing provides global access to all kinds of computer-based resources, in a very dynamic environment, but these
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