



## Hierarchical aggregation of Service Level Agreements

Irfan Ul Haq<sup>\*</sup>, Altaf Ahmad Huqqani, Erich Schikuta

Department of Knowledge and Business Engineering, University of Vienna, Rathausstrasse 19/9, 1010 Vienna, Austria

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### ABSTRACT

IT-based Service Economy requires Service Markets to flourish for the trade of services. A market does not represent a simple buyer-seller relationship, rather it is the culmination point of a complex chain of stake-holders with a hierarchical integration of value along each point in the chain. To enable a Service Economy, Service Markets must be practically realized, which in turn requires an enabling infrastructure to support service value chains and service choreographies resulting from service composition scenarios. In such scenarios, services compose together hierarchically in a producer-consumer manner to form service supply-chains of added value. Service Level Agreements (SLAs) are defined at various levels in this hierarchy to ensure the expected quality of service for different stakeholders. Automation of service composition directly implies the aggregation of their corresponding SLAs.

In this paper we elaborate on the requirements of hierarchical aggregation of SLAs corresponding to service choreographies leading to business models such as Business Value Networks. During the hierarchical aggregation of SLAs, certain SLA information pertaining to different stakeholders is meant to be restricted and can be only partially revealed to a subset of their business partners. We introduce the concept of SLA-Views to protect such privacy concerns. We then formalize the notion of SLA Choreography and define an aggregation model based on SLA-Views to enable the automation of hierarchical aggregation of Service Level Agreements. The aggregation model has been designed to comply with the WS-Agreement standard.

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### 1. Introduction

Service Economy to prosper requires IT-based Service Markets for stake holders to do business autonomously and autonomously helping them establish networks of business relationships. Services are traded under formal contracts known as Service Level Agreements (SLA). SLA in Service Oriented Infrastructure (SOI) is an automatically processable contract between a service and its client; the client being a person, organization or yet another service. Services scattered across various Virtual Organizations (VOs) under multiple administration domains can compose together making SLAs between each other to form service choreographies. In novel eBusiness platforms (such as Grids and Clouds) SLA is essentially important for the service consumer as it compensates consumer's high dependency on the service provider. With the advent of on-demand service infrastructure, there is a high potential for third party solution providers such as Composite Service Providers (CSP), aggregators or resellers [1,2] to tie together services from different external service providers to fulfill the pay-per-use demands of their customers. A cumulative contribution of such Composite Service Providers will emerge as service value chains. In service value chains services corresponding to different partners are aggregated in a producer-consumer manner resulting in hierarchical structures of added value. Service Level Agreements (SLAs) guarantee the expected quality of service (QoS) to different stakeholders at various levels in this hierarchy. This in turn leads to a hierarchical structure of SLAs that may span across several Virtual Organizations (VOs) with no centralized authority. We have termed it as Hierarchical SLA Choreography or simply *SLA Choreography*, in accordance with the underlying Service Choreography. A major challenge to enable IT-based Service Markets

<sup>\*</sup> Corresponding author.

E-mail addresses: [irfan@email.com](mailto:irfan@email.com) (I. Ul Haq), [huqqana3@univie.ac.at](mailto:huqqana3@univie.ac.at) (A.A. Huqqani), [erich.schikuta@univie.ac.at](mailto:erich.schikuta@univie.ac.at) (E. Schikuta).

thus is to foster these hierarchical service composition scenarios and their underpinning business networks and supply chains. From business' point of view, the most important asset is the extraction of value from every node of such business networks in a transparent and secure manner.

Service composition directly implies the need of composition of their corresponding SLAs. So far, SLA composition has been considered as a single layer process [3]. This single layer SLA composition model is insufficient to describe supply-chain based business networks. In a supply-chain a service provider may have sub-contractors and some of those sub-contractors may have further sub-contractors making a hierarchical structure. This supply-chain network across various Virtual Organizations may emerge as a Business Value Network. Business Value Networks [4] are ways in which organizations interact with each other forming complex chains including multiple providers/administrative domains in order to drive increased business value. NESSI (Networked European Software and Services Initiative), which is a consortium of over 300 ICT industrial partners, has highlighted the importance of Business Value Networks [4] as a viable business model in the emerging service oriented ICT infrastructures.

In addition to the notion of Business Value Networks, NESSI has pointed out various other possibilities for similar inter-organizational business models; Hierarchical Enterprises, Extended Enterprises, Dynamic Outsourcing, and Mergers to name a few. The process of SLA aggregation in such enterprises is a hierarchical process. Research community has just started taking notice [5] of the importance to describe this hierarchical aggregation. To enable these supply-chain networks as Service Oriented Infrastructures (SOI), the case of the Service Level Agreements needs to be elaborated and its issues resolved. SLA@SOI [5] is a European project that focuses on SLA issues in SOI. On its agenda is the provision of such service aggregators, that offer composed services, manageable according to higher-level customer needs. In SLA@SOI's vision, service customers are empowered to precisely specify and negotiate the actual service level according to which they buy a certain service. Although SLA@SOI discusses the importance of service chains, but it does not highlight their relevance in terms of value multiplication.

It is not sensible to expose the complete information of SLAs across the whole chain of services to all the stakeholders. Not only because of the privacy concerns of the business partners, but also disclosing it could endanger the business processes creating added value. To achieve this balance between trust and security, we introduce the concept of SLA-Views. The inspiration for this concept comes from the notion of business process views [6,7] and workflow views [8]. We apply the concept of views on SLA-Choreography. Each business partner will have its own view comprising of its local SLA information. The holistic effect of these views will emerge as the overall SLA-Choreography. In this paper we present a formalized approach based on the concept of SLA-Views and adherent to WS-Agreement standard, to automate the aggregation process of hierarchical SLAs in Business Value Networks. The overall contribution of the paper consists of:

- a privacy model based on the concept of SLA-Views,
- a formal description of hierarchical SLA-Choreographies based on SLA-Views in Business Value Networks,
- a formal model for SLA aggregation in hierarchal SLA-Choreographies, and
- the customization of WS-Agreement to support the hierarchical SLA aggregation model.

In Section 2, we give a survey of the related work. Section 3 introduces the hierarchical choreography of SLAs. Section 4 formalizes the concept of SLA View and SLA Choreography. Section 5 describes the formal model of hierarchical aggregation of SLAs and Section 6 discusses the special case of Guarantee Terms. Section 7 highlights some business applications of the aggregation model and section 8 presents a motivational example based on this model. Finally, section 9 concludes the paper with an overview of our achievements and strategy for our future work.

## 2. Related work

The related work spans across three dimensions: aggregation models of SLAs, formal description of SLAs and the privacy of stake-holders in business cooperations.

### 2.1. SLA aggregation

A Service Level Agreement is a contract between a service and its client; the client being a person or yet another service. Service composition in workflow also demands SLA composition. Only little research [3,9] has been done towards dynamic SLA aggregation of workflows. Blake and Cummings [3] have defined three aspects of SLAs which are Compliance, Sustainability and Resiliency. Compliance means suitability, i.e. the consumer receives what is expected. Sustainability is the ability to maintain the underlying services in timely fashion. Resiliency directly corresponds to the maintenance of services to ensure their performance over an extended period of time. The authors then subdivide these three categories into six aspects of SLA but this makes their approach rather specific, because it does not cover the whole range of SLA aspects. They put forth a model to compose SLAs of services mapping to a workflow, but they restrict the services to one level only. Frankova [9] has also highlighted the importance of this issue but has just described a vision and not any concrete model. Unger et al.'s work [10] is directly relevant to our focus of research. They focus on aggregation of SLAs in context with Business Process Outsourcing (BPO). They synchronize their work with Business Process Execution Language (BPEL) and WS-Policy. Their model is based on SLO aggregation of SLAs on a single level. One of the limitations of their approach is that they take into account services related to one process in one enterprise because they focus on BPO. Our approach describes cross-VO SLA aggregation and strictly adheres to WS-Agreement. Theilman et al. [11] also take into account the significance of multi-level SLAs and highlight the importance of SLA orchestration. They propose an SLA management framework based on the notions of SLA orchestration, transformation and aggregation. They too take into account

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