Guidelines to SLA modeling and establishment in heterogeneous communications networks

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Abstract

The question of how to specify, provide and measure service quality for network end-users has been of utmost interest for service and network infrastructure providers and their clients as well. The Service Level Agreement (SLA) is a beneficial tool in formalizing the interrelationships resulting from a negotiation among all participating actors with the target of achieving a common comprehension concerning delivery of services, its priorities, quality, responsibilities, and other relevant parameters. A horizontal SLA is an agreement between two service-providers existing at the same architectural layer (as for example two Internet Protocol (IP) or two Optical Transport Network (OTN) domains). A vertical SLA is an agreement between two individual providers at two different architectural layers (for instance, between an optical network and the core MPLS network). A service has to be defined without ambiguity utilizing Service Level Specifications (SLS) and three information types must be described: i) The QoX metrics as well as their corresponding thresholds; ii) A method of service performance measurement; iii) Service schedule.

In this work we present preliminary simulation results that enable the development of a generic methodology for SLA modeling and establishment that will lead to a win-win situation for all involved actors. As an example, we put special attention in the benefits obtained by Optical Networks operators.

Keywords

Optical networks, Computer networks, heterogeneous networks, Service level agreements, Service level objectives, Quality of experience, Quality of service

I. Introduction

The question of how to specify, provide and measure service quality for network end-users has been of utmost interest for service providers, their clients as well as network infrastructure providers [1] [2] [3] [4]. During the last decade the liberalization and deregulation process started in the telecommunication's environment. The increasing competition, favored conjointly by client's performance needs, imposes huge pressures on service and network infrastructure providers that in order to differentiate their products from the other competitors try to improve Quality of Service (QoS).

The Service Level Agreement (SLA) is a beneficial tool in formalizing the interrelationships among all entities, that is the consequence of a negotiation among all participating actors with the target of achieving a common comprehension concerning delivery of services, their priorities, quality, responsibilities, and other relevant parameters [5] [6]. To measure the agreed SLA performance among entities, many monitoring tools and protocols have been developed by well-known companies. For example, Cisco's Service Level Assurance Protocol (Cisco's SLA Protocol) is a protocol for performance evaluation which is deployed extensively. This is used for service level parameters measurement such as network delay variation, latency, as well as frame and packet loss ratio. This protocol characterizes the Cisco SLA Protocol Measurement-Type UDP-Measurement to enable the interoperability of service providers [7].

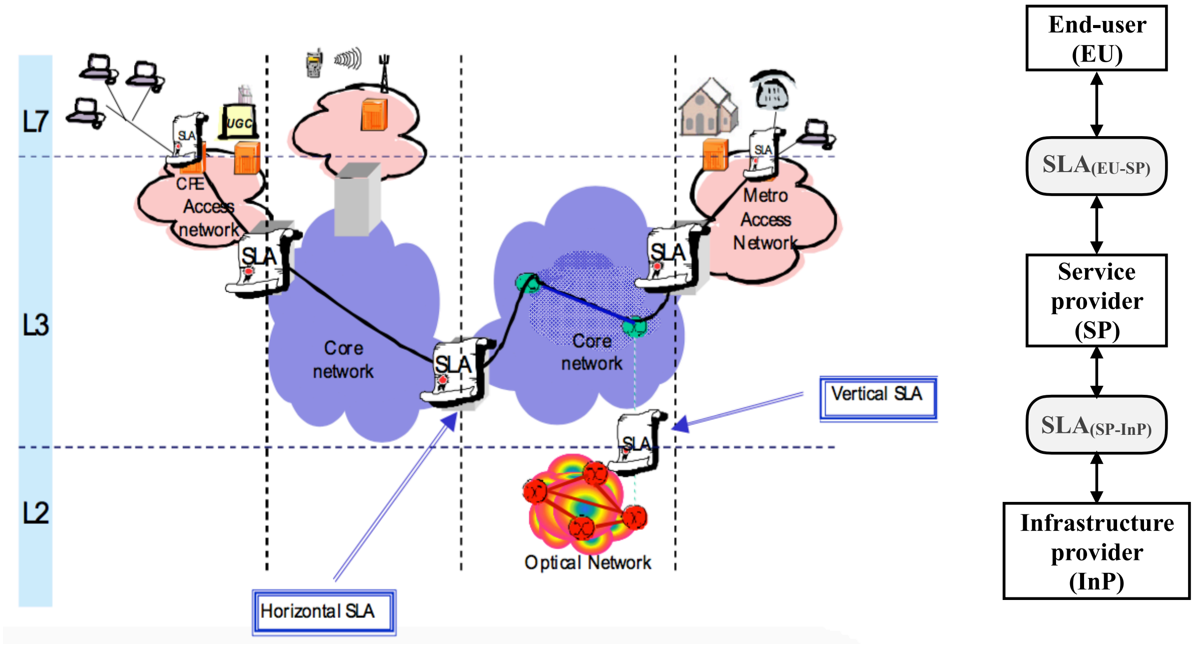
An end-to-end solution for management of SLA is required to define services, parameters of Service Level Specifications (SLS) and a classification of the services. The focus on the level of service instead of a network level enables the definition of SLA, services and/or Quality of Service (QoS) independently from the underlying network's technology. A service has to be defined without ambiguity using SLS and three information types must be described: i) The QoX metrics as well as their corresponding thresholds; ii) A method of service performance measurement; iii) Service schedule. QoX represents different quality requirements such as QoS, Quality of Transmission (QoT), Grade of Service (GoS), Quality of Resilience (QoR), Quality of Energy (QoEn), Quality of Knowledge (QoK) and Quality of Information (QoI) [8].

In this work we present preliminary simulation results that enable the development of a generic methodology for SLA modeling and establishment that will lead to a win-win situation for all involved actors. As an example, we put special attention in the benefits obtained by Optical Networks operators.

II. SLA actors and elements

Based on the topological architecture of the network, an SLA contract can be categorized into horizontal and vertical SLA as shown in Fig. 1-(a) [9]. A horizontal SLA is an agreement between two service providers (SPs) existing at the same architectural layer (as, for example, two Internet Protocol (IP) domains [10] [11] or two domains of Optical Transport Network

(OTN) [12]). A vertical SLA is an agreement between two individual providers at two different architectural layers (for instance between an optical network and the core MPLS network). Fig. 1-(b) illustrates the actors and governing SLAs adopted in this work.



(a) **(b)**

Fig. 1. a) A network topology including horizontal and vertical SLAs, adapted from [9]; b) Actors and governing SLAs adopted in this work.

1) Actors: A typical SLA involves two entities such as a contract either between *End-User (EU)* and *Service Provider (SP)*, or between SP and *Infrastructure Provider (InP)*. The complete scenario includes all three mentioned actors.

The term SP refers to corporations that supply data and communication services to their customers. SPs may manage networks by themselves, or they may integrate the other SPs services to deliver an entire service to their clients/customers [8] [13] – in this work referred as EUs. The SP can operate in different business forms such as an Internet Service Provider (ISP), a carrier, Application Service Provider (ASP) or an operator. As shown in Fig. 1-(b), the SP provides an L3 virtualized SDN-based service to the EUs. The relationship between the EUs and SPs is governed by an specific SLA designated as $\text{SLA}_{\text{(EU-SP)}}$.

The term InP refers to corporations that provide physical resources through a managed service platform that provides an operational infrastructure and the computing services for development, deployment and management of the applications in enterprise class. For the purposes of this work, as shown in Fig. 1-(b), the InP provides an optical transport service to the SPs. The relationship between the InPs and SPs is governed by an specific SLA designated as $\text{SLA}_{\text{(SP-InP)}}$.

There is no direct relationship between the EU and the InP but the level of satisfaction experienced by the EU clearly depends on the QoX provided by the InP.

For all involved actors in an SLA negotiation, a win-win situation can be defined as quality requirements that are satisfied for all actors, the EU is charged a fair price and the InP and SP adequately remunerated.

2) Elements: An SLA must be *Specific* and detailed enough to define expectations for services and eliminate any confusion. The *Comprehensiveness* is an essential element of the agreement and the SLA contract must cover all provided services by the SP and all possible contractual obligations for all actors involved. Moreover, the SLA should be directly related to the service to be offered and it must be *Relevant* to evaluating performance against that goal. In the agreement, unrealistic goals can demotivate the customers and non-delivery will only lead to failures on agreed terms. Therefore, the expectations set must be *Realistic*. By keeping the language simple and *Non-technical*, for reference of EUs, the contract would be easily understandable. The responsibility should be clearly defined as a set of *Division of work* in the agreement. The SLA must contain a *Time-frame* against which the service will be delivered. The *Escalation Metrics* must be clearly defined. Once the actor enters into the agreement, the client must be aware whom to refer in case the services were not rendered properly. Once all elements are considered in the agreement, the agreement document must be the *Authoritative* document binding all actors.

III. SLA MODELING AND RESULTS

Service Level Objectives (SLOs) are agreed as a means of performance measuring of the provider and simultaneously they are outlined as a way to avoid disputes between the two actors based on misunderstanding. The establishment of a reliable, safe and QoE-aware networking requires a set of services that goes beyond pure networking services. There is oftentimes confusion in the use of SLO and SLA. SLOs are particular and measurable characteristics of the SLA like throughput, response time, availability, or quality [14]. Apart of SLO application domain, the objectives can be categorized as: i) performance service level objectives; ii) security service level objectives; iii) data management service level objectives; iv) personal data protection service level objectives [15] [16].

Due to the space limitations and for the sake of simplicity we focus only on the performance SLOs which are: i) Availability, ii) Response time, iii) Capacity, iv) Capability indicators, v) Support and vi) Reversibility.

The input variables of the proposed modeling are:

- QoX: represents the Quality of Service provided by the InP. In fact, it should be described by a vector where the components would be QoS, QoT, QoEn and so on. This variable encompasses in a only numerical value the quality associated to the performance SLOs;
- SP.SP.EU: represents the service's selling price between the SP and the EU;
- SP.InP.SP: represents the service's selling price between the InP and the SP;
- penalty: the penalty to be applied to the SLAs revenue when the SLOs are not achieved.

All the input variables are in the range between 0 and 1.

To describe the impact of each input variable on the SLO satisfaction we adopt the concept of *utility function*. There are two possible cases, namely:

- lower-is-better: $u_1(x) = \dfrac{e^{-ax}}{1-e^{-a}} - e^{-a}$, that is a monotonic decreasing function, $0 \leq u_1(x) \leq 1$; $a > 0$ controls the decay speed; $0 \leq x \leq 1$.
- higher-is-better: $u_2(x) = \dfrac{e^{ax}}{e^{a}-1} - 1$, that is a monotonic increasing function, $0 \leq u_2(x) \leq 1$; $a > 0$ controls the increase speed; $0 \leq x \leq 1$.

For the EU the higher the QoX the better will be his/her QoE. Then the utility function associated to QoX is characterized by $u_2(x)$. On the other hand, the lower the SP.SP.EU the better will be his/her QoE. Therefore, as far as the EU's QoE is concerned, it should be characterized by $u_1(x)$.

To fully characterize the EU's, SP's and InP's different perspectives and objectives we adopt the following set of functions that is not necessarily exhaustive:

- EU's perspective:
  - $U1 = u_1(SP.SP.EU)$
  - $U2 = u_2(QoX)$
  - $U3 = \min(U1, U2)$
  - $U4.P = u_2(\text{penalty}) \Rightarrow\ U4 = \max(U3, U4.P)$
- SP's perspective:
  - $U5 = u_2(SP.SP.EU)$
  - $U6 = u_2(SP.SP.EU - SP.InP.SP)$
  - $U7.QoX = u_2(QoX) \Rightarrow\ U7 = \min(U6, U7.QoX)$
  - $U8.P = u_2(\text{penalty}) \max(U7.QoX, U8.P)$
- InP's perspective:
  - $U9 = u_2(SP.InP.SP)$
  - $U10.QoX = u_2(QoX) \Rightarrow\ U10 = \min(U9, U10.QoX)$
  - $U11 = \max(U9, U10.QoX)$
  - $U12.P = u_2(penalty) \Rightarrow\ U12 = \max(U11, U12.P)$

As the main objective is to identify the conditions that lead to a win-win situation, i. e., all actors have their objectives satisfied, we propose a global metrics defined by a multi-utility function given by:

$$MUF(U_{\text{EU}}, U_{\text{SP}}, U_{\text{InP}}) = \alpha_{\text{EU}} \times U_{\text{EU}} + \alpha_{\text{SP}} \times U_{\text{SP}} + \alpha_{\text{InP}} \times U_{\text{InP}}$$

- $\alpha_i \leq 1, i \in \{\text{EU, SP, InP}\}, \sum_{i \in \{\text{EU, SP, InP}\}} \alpha_i = 1$ define the priorities assigned to each actor objective;
- $U_{\text{EU}} \in \{U1, U2, U3, U4\}$, $U_{\text{SP}} \in \{U5, U6, U7, U8\}$, $U_{\text{InP}} \in \{U9, U10, U11, U12\}$;

- $MUF(U_{\text{EU}}, U_{\text{SP}}, U_{\text{InP}}) \leq 1$.

The simulations have been performed considering all possible combinations of the EU, SP and InP perspectives and four priority cases:

- Equal priorities: $\alpha_{\text{EU}} = \frac{1}{3}$, $\alpha_{\text{SP}} = \frac{1}{3}$, $\alpha_{\text{InP}} = \frac{1}{3}$;
- EU is the priority: $\alpha_{\text{EU}} = 0.8$, $\alpha_{\text{SP}} = 0.1$, $\alpha_{\text{InP}} = 0.1$;
- SP is the priority: $\alpha_{\text{EU}} = 0.1$, $\alpha_{\text{SP}} = 0.8$, $\alpha_{\text{InP}} = 0.1$;
- InP is the priority: $\alpha_{\text{EU}} = 0.1$, $\alpha_{\text{SP}} = 0.1$, $\alpha_{\text{InP}} = 0.8$;

The input variables, QoX, SP.SP.EU, SP.InP.SP and penalty, have been discretized into 10 equal spaced values.

The solution space has 256 possible cases of 10,000 observations each that is being analyzed and modeled to identify patterns that enable the establishment of win-win SLAs.

It is important to realize that in a real life situation the EU may not be able to enunciate his/her QoE satisfaction criteria objectively and that SP and InP do not disclose their respective commercial strategies. This makes the definition and establishment of an SLA a decision-making process under uncertainty. If this uncertainty is not adequately taken into account it may provoke intermittent breaches of the SLAs due to an inadequate assignment of network resources. The understanding of the proposed simulations will lead to the identification of patterns that may accommodate the network fluctuations without producing either SLA violations or network services disruptions.

IV. Conclusions and future work

In this work we have reviewed the main concepts associated to an SLA, its actors and elements. We have also characterized the SLOs as i) performance service level objectives; ii) security service level objectives; iii) data management service level objectives; iv) personal data protection service level objectives. The focus has been on performance service level objectives. We have considered the different perspectives from EU, SP and InP and their respective objectives have been modeled as utility functions. We have also proposed a global metrics in terms of a multi-utility function where weights are assigned to define the priority associated to each actor. The solution space has 256 possible cases of 10,000 observations each that is being analyzed and modeled to identify patterns that enable the establishment of win-win SLAs.

This is ongoing research effort to define a methodology to model, establish, deploy and monitor SLAs that ensure the satisfaction of involved actors. The main difficulty is to define the methods to deal with the uncertainty present in the EU enunciations of his/her objectives, the opacity related to the commercial strategies of the SP and InP, the realtime evaluation of long term availability of network resources due to the randomness of the demand. In order to tackle this challenging problem machine/deep-learning techniques associated to psychoanalysis-driven semantic analysis of EU, SP and InP enunciations will be evaluated.

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