SLA Contract for Cross-layer Adaptation and Monitoring

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Abstract. This paper discusses a framework for contract-based monitoring and adaptation with respect to customers' goals seen as an important part of Service Level Agreement (SLA) contracts. Within standard SLA contracts concepts, as mutual agreements between service providers and users, we introduce Key Goal Indicators (KGIs). These are parameters that state how well service-based processes achieve the customers' goals. The SLA contract includes parameters of KPI, KGI and IT infrastructure type. Possible violations of each type is checked in the monitoring phase and an action is taken to adapt the violated condition through an adaptation mechanism. We describe the phases of a methodology for creating, monitoring, and adapting an SLA contract, in particular, leveraging on aspects of Quality of Service (QoS) violations.

Keywords: Service Level Agreement, Key Goal Indicator, Contract, Business Process Execution, Monitoring, Adaptation.

1 Introduction

Propagation of service systems have influenced the implementation of business processes in organizations. Organizations expect their service systems to be aligned with the execution of their business processes and with their business strategies. The former issue refers to the degree of performance of the business, while the latter issue refers to the degree of success in the achievement of customers' goals. Therefore, service designer need to understand the business processes of the organization and their influencing factors in order to implement service systems that achieve the business goals of the organization. Besides, the need to consider customer parameters when evaluating business services has become increasingly noticeable [9].

Considering adaptation, requirements of service systems change so fast that the research community is studying how to build systems that are able to monitor and adapt on the fly to (some of) these changes. When this happens, the system does not need to undergo a new development cycle, thus increasing its availability and, to a certain extent, its robustness. However, the presence of parameters pertaining to the business, the service, and the user levels have dramatically increased the complexity of cross-layer monitoring and adaptation. So far, research in the area of monitoring

and adaptation has been focusing on the definition of the mechanisms for supporting monitoring and adaptation [12, 13]. What is currently missing is a structured cross-layer adaptation and monitoring framework associated to these mechanisms. In particular, [14] demonstrates a quality framework for service monitoring and adaptation. In this paper, we discuss the SLA contract as a possible candidate for cross-layer model to be applied for cross-layer monitoring and adaptation of service based applications.

Service Oriented Architecture (SOA) promises a better realization of business processes. In order to achieve this aim, business processes need to be aligned with the SOA. To keep the promises of SOA, the ability to deliver services according to pre-defined agreements is increasingly becoming an essential. These agreements are defined in Service Level Agreement (SLA). We believe that the value of a service is not only influenced by service parameters but also highly influenced by the business of the organization, by the customers who are going to use the services, and by the IT infrastructure. Therefore, business service parameters are not always appropriate to express the users' satisfaction. We emphasize the importance of the customers perspective and their parameters as a complimentary measurement for parameters defined from the business service perspective. For that reason, we introduce Key Goal Indicators (KGI) which are parameters that state how well services or processes achieve the customers' goals. It is worth it to state that IT infrastructure factors have to be considered since they have properties that influence the parameters of users and services.

In order to have a comprehensive SLA contract, it is increasingly important to consider the three factors together, namely KPI, KGI and IT infrastructure, as long as they have a close inter-relation. As a result, parameters of an SLA contract should be a merge of KPI, KGI and IT infrastructure type. The SLA contract is a fundamental part for monitoring and adaptation of service based applications. In fact, this contract will be checked in the monitoring phase to see if there is any deviation or violation from the predefined contract occurring at the run time. Besides, the SLA contract is continuously checked for the purpose of optimization. Such a violation could be due to the defiance of IT infrastructure, business service and user parameters. Taking advantage of the comprehensive SLA contract, we propose a contract based framework for monitoring and adaptation of service based applications. Our approach consists of five major phases: (1) Identifying KPI, KGI and IT infrastructure parameters (2) Mapping of parameters into a contract (creation of an SLA contract and contract set up through negotiation); (3) Evaluation and monitoring (4) Adaptation, (5) Updating of the contract.

The remainder of the paper is organized as follows. Section 2 introduces Key Goal Indicators. In section 3, we propose our framework for cross-layer monitoring and adaptation. Finally, section 4 discusses related work and some concluding remarks.

2 Key Goal Indicator

A Service Level Agreement is a contract which is introduced in the business level to set up common understanding between parameters regarding the relationship between

business service providers and business service users. The value of a service is highly influenced by the business of the organization, by the customers who are going to use the service, and by the IT infrastructure. Therefore, we distinguish between the *formulation* and *evaluation of the business service performance* and the *formulation* and *evaluation of the customers' goals*. From the business level, the output of a service provider is evaluated by Key Performance Indicators (KPIs) that show the degree of performance of a business service. On the other hand, from the users' perspective, the evaluation is done through Key Goal Indicators (KGIs) which show how well the services are successful in the achievement of the customers' goals. In this sense, the *Output* of the service provider is differentiated from the Outcome obtained by the service users, as stated in [6]. Typical examples of service and business indicators are response time, process duration, process cost and service availability while some parameters related to KGIs could be financial return, satisfaction, reputation and trust. There are parameters in common between service, business and user such as time and cost; however, they are observed from different perspectives. Furthermore, there are also domain-dependent business process parameters and users parameters.

In order to have a comprehensive SLA contract, it is increasingly important to consider the mixture of the three aforementioned factors, namely KPI, KGI and IT infrastructure, as long as they have a close inter-relation. Such an SLA contract is extremely practical in the process of cross-layer monitoring and adaptation.

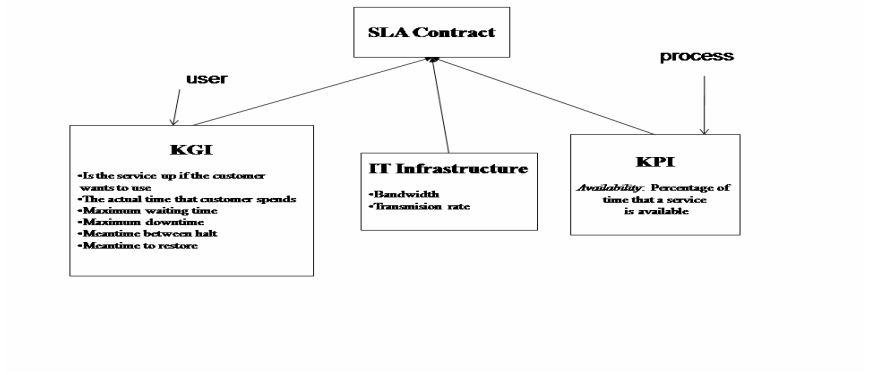

Fig. 1. An example for KGI and related KPI and IT Infrastructure parameters

Here we give an example to show that common service parameters are not sufficient to evaluate the user satisfaction, unless they are formulated in a more user-related way. Availability, generally defined as the percentage of the time that a service is available for use, from the user's perspective, expresses that customers only care if the service is available when they want to use it, for example in their work hours or in their free time. Suppose that there are two service types. One service is working for a month and then stops for one whole day. The other service works for about 8 hours and then has a 15 minutes downtime. Although the overall availability of both services is equivalent, users may not have the same level of satisfaction for

both services, depending on the time of the day the user is accessing the service. Some of the most appropriate parameters related to customer's perspective include: Is the service up if the customer wants to use it; the actual time spent by the customer activating the service, the maximum waiting time, the maximum downtime, the meantime between halt and the meantime to restore.

As evident from the example, service parameters alone are not enough to express user satisfaction, which is typically related to KGI issues, and they do not consider the perspective of customers. Therefore, parameters of an SLA contract should be a mix of KPI, KGI and IT infrastructure. Fig. 1 illustrates an example of an SLA contract taking into account user parameters (KGI), IT infrastructure parameters and KPIs.

3. Contract-based monitoring and adaptation

Monitoring and adaptation of service based application is a complex issue due to the heterogeneity and dynamicity of services. Research works in the area of monitoring and adaptation has been focusing on the definition of the techniques and mechanisms for supporting monitoring and adaptation at both run time and design time [12, 13]. The problem is these works are rather fragmented and only deal with the technical service level aspects. Therefore, there is a need for an structured cross-layer adaptation and monitoring framework associated to those mechanisms. As we argued in the previous section, user perspective should be taken into account together with the business service aspects. In this work, we discuss the SLA contract as a possible candidate for cross-layer model to be applied for cross-layer monitoring and adaptation of service based applications.

We propose a comprehensive SLA contract between business service provider and users considering KPI, KGI and IT infrastructure factors. The SLA contract is a fundamental part for monitoring and adaptation of service based applications. In fact, the SLA contract is checked at run time in the monitoring for deviations or violations from predefined contract parameters and is continuously checked for optimization. A violation could be due to the defiance of IT structure, service, business and user parameters. We propose a framework and a step-wise approach towards monitoring and adaptation of SBAs. Our approach consist of five major phases:

(1) Identifying KPI, KGI and IT infrastructure parameters;
(2) SLA Contract creation;
(3) Evaluation and monitoring;
(4) Adaptation;
(5) Contract Update.

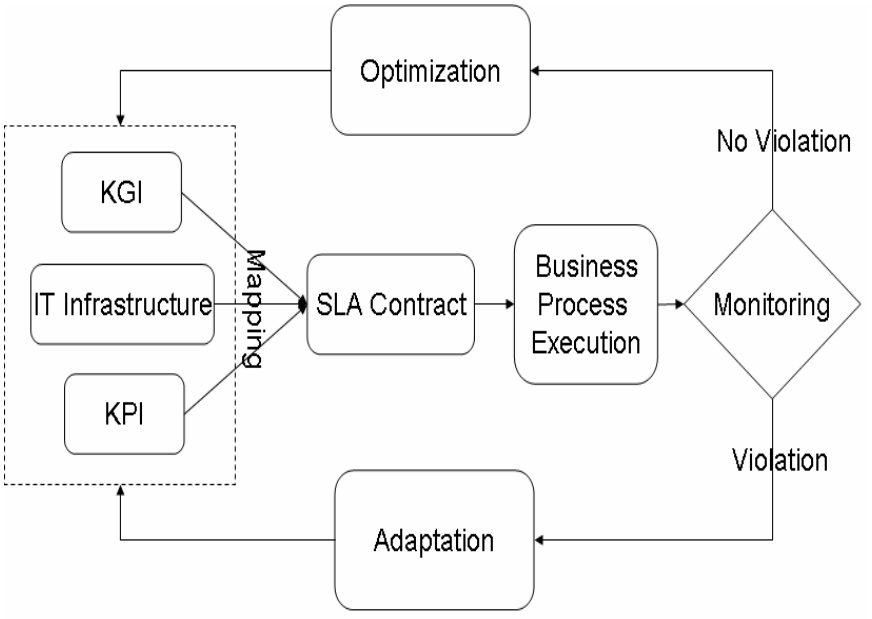

Fig. 2. Framework for SLA contract-based monitoring and adaptation

Fig. 2 demonstrates our proposed framework which is an SLA contract-based approach for monitoring and adaptation of service based applications. In the first phase, the corresponding parameters related to KPI, KGI and IT infrastructure are specified. This should be done through a requirement engineering phase with an early participation of users in order to understand their actual needs. The second phase is the SLA contract creation which includes the aggregation of parameters defined in the first phase through a mapping phase. The parameters in the contract are specified by parameters from the service provider with respect to the customer's parameters and the limitations that IT infrastructure parameters impose. Therefore, the contract has parameters resulting from a mapping process combining business services, IT infrastructure, and user parameters and set up through negotiation.

Once the contract is created, it is considered as a token which is applied in the business process execution and then passed by to the Monitoring phase. The SLA contract is evaluated in the monitoring phase and checked for possible violations from the predefined values of any type of parameters, of the linking rules and of the constraint set up in the contract. According to the source of violation, detected via a diagnosis, an appropriate action is taken to adapt the violated condition to the new values, through an adaptation mechanism. Therefore, if SLA contract is not respected, an adaptation strategy should be taken (e.g., penalties are applied and the service provider is substituted) and new requirement-driven values are set up. The last phase of the framework is the contract update which is the reformulation of the contract (or parts thereof) driven by the new conditions and requirements.

3.1 SLA Contract Creation

Creating an SLA contract is a major step in our framework. In the following, we discuss about various issues with respect to parameters identification, mapping and contract creation. The true goal of SLA is to guarantee a valuable service to users. Hence, it is desirable to identify service parameters that are highly related to user satisfaction. [1] and [5] list some of different parameters that can be considered in the SLA contract, in particular, leveraging on aspects of Quality of Service (QoS). Considering IT infrastructure elements such as server, database and hardware, the characteristics of these elements have influence and sometimes limitation on the specification of other parameters. Therefore, these parameters should be taken into account in the SLA contract.

Service providers and Customers need to work together early on to determine parameters – meaningful and technically measurable – in order to have a comprehensive SLA contract. In order to express the user requirement and parameters, here we called KGI, we leverage the concept of QoS contract. Also, the concept of Rule will be defined to determine whether a QoS violation takes place. The rule is used to allow the contract owner to define his set of feasible values with respect to a fixed value stored in the contract. An example of QoS contract is shown in [1]. If the contract is not respected, a QoS contract violation arises, and it has to be managed, e.g., by raising a QoS fault. The QoS parameters is composed of a set of parameters customizable by means of contract between a client (service consumer) and service provider. These contracts define the level of QoS acceptable for the interaction between the given client and service provider. If a contract is not respected, [1] introduce the notion of QoS fault. Upon QoS fault, recovery mechanisms can be employed to repair the fault, each with a given cost.

The contract should also take into account parameters related both to service/business and to the object delivered through the business service [2]. Such consideration involves both the quality of the conveyor of the service and of the associated object. For example, when purchasing a financial product, the user evaluates both the response time of the banking service and the quality of the financial product. An understanding is required concerning both the quality aspects definition and how quality parameters are combined by users [2,7]. A modeling framework, for the definition of contracts between the user and service provider, should be outlined and discussed with the preparatory steps which enable a set of variables for contract publication.

Lets consider a simple internet banking process which has an online purchase service. The example is explained in detail in [2]. On such a process, they define a contract on both the process and the objects associated with the process (contract link process and object qualities). This way, the user's goals is described with respect to the quality in using the process (e.g., how quick the interaction is or how secure the purchase is), in the phases which are carried out by external partners (e.g., the delivery of the receipt letter, which is the responsibility of a courier), and the user's perceived quality of the product (e.g., the rating and the price of the financial products). We do not consider object level in our contract since it is discussed in [2], instead we insert a user level which has parameters from users point of view. An example of an SLA contract for an Internet Banking Process is given in Table 1.

Table 1. Example of an SLA contract

Contract Elem.	Process Level	Internet Banking Process
Contract Elem. CE1	Service Level	Online Purchase Service
	Availability	95%
	Response time	5 Min
	Downtime	15 Min
Contract Elem. CE2	User Level	Online Purchase Service
	Acceptable downtime	20 Min
	Availability	High, Medium
Linking Rule		CE1 ^ CE2
Integrity Constraint		Downtime(CE1)< Downtime(CE2)

The contract instance of Table 1 is composed of two contract elements. CE1 predicates at the Service Level on the availability, response time, and downtime of the business process. CE2 reports the User Level about the downtime and the availability as perceived by users. A linking rule defines that the two contract elements are not exclusive, while the integrity constraint guarantees that the downtime of the purchased object deliveries be no higher than the downtime of the whole business process. It has to be noticed that this last constraint is not actually shown to customers, but rather is used by the provider to check the integrity of a generated contract.

Moreover, we specify Linking Rules in the contract in order to combine contract elements. Let us consider the example of "availability". We argued that the availability parameters such as response time and downtime, described from the service provider, are not sufficient to evaluate the user satisfaction. In our contract model, a linking rule is defined to consider both parameters from service level and parameters related to customer satisfaction. An *integrity constraint* could be applied to guarantee that the downtime of the online service shouldn't be higher than the maximum acceptable downtime that the user specified in the contract.

3.2 Monitoring and Adaptation

After the SLA contract is created, the business service will be executed by a business process engine with respect to the contract. Then, the contract is evaluated in the monitoring phase to check for the possible deviations or violations. Several approaches have been proposed for the SLA monitoring [15, 16]. Nevertheless, they only take into account technical service parameters and do not consider user parameters. In particular, [1] proposes an approach to evaluate the SLA contract with respect to QoS violation through monitoring. Various mechanisms for monitoring QoS and reacting to possible QoS violation through adaptation have been discussed as

factors enabling the achievement of performance targets as pre-defined in service level agreements. They present an approach and consider a QoS fault detection module (called Controller in the approach) and a recovery manager module to face QoS mismatches. The former is devoted to catch a fault, while the second works to choose the proper set of recovery action to be performed to recover from the QoS violation.

In our approach, we evaluate the contract from both service and user level. We particularly monitor the contract from any deviation of the KGI parameters which are parameters from the users point of view. First of all, KGI parameters should be identified properly in the first phase. Second, these parameters should be mapped into the contract considering other service, business and IT infrastructure parameters. We take advantage of linking rules and integrity constraint to identify if the contract is not respected. For example in Table 1, considering service availability, downtime of the online service shouldn't be higher than the maximum acceptable downtime that user specified in the contract. We also suggest the idea of having user profile in the contract. Violations could be categorized according to the user profile indicating which one should be considered a major violation and which one a minor violation. Based on such a violation which will be recognized in the monitoring phase, appropriate adaptation strategy is decided and new requirement will be driven. A categorization of SLA violations with further details about adaptation strategies is reported in Table 2.

Table 2. Sample adaptation strategies against various SLA violations

SLA Violation	***Adaptation***	***Example***
KGI violation		
High	Change Provider	Downtime>10sec
Low	Discount, Redo	Downtime>5sec
KPI violation		
High	Substitute Service	Response Time>100ms
Low	Re-Invoke Service	Response Time>10ms
IT Level Violation		
High	Change Router	Wrong Packet Switches
Low	Split on Cloned Server	Network Packet Transfer>10μsec

Adaptation is done when violations to the SLA contract are detected. A violation can involve KGIs as well as other parameters. Focusing on KGIs, a violation to a user requirement can be categorized as High, requiring radical recovery and heavy penalties, or Low, requiring adjustments and contract renegotiation of some parameters or compensating actions. Under a High violation, recovery actions can be undertaken, such as changing the service provider, while under a Low violation, a bonus can be negotiated to compensate the problem and a redo of the service is simply performed. Adaptation can be designed via fault handlers encoded in the

process, or can be executed at run time by the execution engine by performing self-healing repair actions, decided by the engine on the basis of a set of predefined repair actions to be executed depending on the severity of the violation.

Adaptation strategies convey a contract re-negotiation and a consequent update of the contract, which depend on the part of the contract which was violated. For example, if a Rule has been violated, the adaptation has to consider the insertion of a further Rule in the new contract or of a new constraint. Moreover, the User Profile has to be considered when KGIs are violated, in order to update the contract coherently with the user's goals.

4. Related work and Concluding remarks

Monitoring and adaptation of service based application are increasingly becoming more and more complex due to the rapid change in the parameters and requirements of users, business and services. In this paper, we have proposed an SLA contract including parameters from user, business service and IT infrastructure as an alternative approach for the cross-layer monitoring and adaptation of SBAs. Given the proposed contract, we created a framework for such a monitoring and adaptation. Several issues have been discussed in this paper but still there are challenges that need to be addressed. In the following we address open challenges corresponding to the phases in our framework.

The first phase is identifying parameters from different perspectives. Identifying and mapping between service and KPI parameters have been studied in recent literatures [3]. [4,8,10, 11] represent some qualitative and quantitative approaches . We argued what is missing here is that the business and service parameters are not sufficient in terms of user satisfaction and they should take into account parameters considering users perspective. Therefore, in this study we emphasized the user parameters as part of SLA and introduced the concept of Key Goal Indicators. Extracting users' parameters and formulate and mapping them to the technical business service parameters are interesting issues for future work. In particular, [9] distinguishes between quality of service, quality of experience and quality of business.

The second phase is creating the contract. Issues such as violations, penalties, linking rules and constraints are introduced and discussed in this paper. The contract should identify and describe the violations condition, more specifically what is considered a violation and what is not. Moreover, penalties should take into account in the contract. Penalties should be described in order to have a clear relationship between customers and providers. Number of violations in a time period could be applied to identify penalties. Contracts are evaluated in the monitoring phase, and if the contract is not respected, penalties will be applied and appropriate adaptation strategy will be taken. The last phase is contract update. How to update and when to update a contract are challenges that need to be studied. Possible update strategies could be based on a timely approach, according to the number of violation or a hybrid approach.

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