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Titre du projet de thèse: Trusted SLA-Guided Data Integration on Multi-Cloud Environment

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1. Objectifs et l'Originalité du sujet de thèse (2 pages maxi)

Data integration is a widely studied issue in the database domain. It consists in merging data from different databases and providing a unified view of this data to the user [10]. Commonly, data integration is referred in the literature as a problem of answering queries using views. Many authors have reported their algorithms for this purpose [8]. Levy *et al.* proposed the *bucket algorithm* [11]. Duschka and Genesereth introduced the *inverse-rules algorithm* [7]. Pottinger and Halevy presented the *MiniCon algorithm* in [13]. [13] extended some ideas of [7], and developed an implementation more efficient than the others. In general, algorithms in this domain share the same performance problem while combining views to produce a rewriting.

Current data integration implies consuming data from different data services and integrating the results while meeting users' quality requirements. Such requirements include the data that is retrieved and integrated, but also the properties of the data, its producers and the conditions in which such data is produced and processed. For example, whether the user accepts to pay for data, its provenance, veracity and freshness and how much is the user ready to pay for the resources necessary for integrating her expected result. Data services provide data according to specific APIs that specify method headers with input parameters describing the data to be retrieved and the type of results they can produce. Moreover data provision can be done by services according to different data quality measures. Such measures describe the conditions in which a service can provide or process data. These measures can be expressed in a service level agreement (SLA). An SLA states, what the user can expect from a service or system behavior. For example, whether it implements an authentication process, if it respects data consumer's privacy and the quality of the data the service can deliver, like freshness, veracity, reputation and other non-functional conditions like the business model that controls data delivery.

Data provision and data processing services may need a considerable amount of storage, memory and computing capacity that can be provided by cloud architectures. Furthermore, users could need to integrate the data provisioned by services in a homogeneous and general result. The integration process can also require important computing resources that can be obtained from the cloud too. Data provision and processing services can be deployed in the cloud. Their SLA includes the measures about the cloud services that they require to execute their requests. The cloud, itself exports a general SLA that specifies the conditions in which users can access the services (infrastructure, platform and software) deployed in it. A user willing to use the cloud services establishes a contract with the cloud provider guided by an economic model that defines the services she can access, the conditions in which they can be accessed (duplication, geographical location) and their associated cost. Different cloud providers have different possible contracts to establish with users (i.e., platinum, silver, gold, ivory users). Thus, for a given requirement, a user could decide which cloud services (from one or several cloud providers) to use for retrieving, processing and integrating data according to the type of contracts she can establish with them.

Data integration can be seen in the cloud computing as a service composition problem. In our previous work [5], we have identified that QoS aspects has started to considered while integrating data, and the cloud has become a popular environment to perform data integration. Moreover, data integration combined with SLA is an open issue in the cloud. Barhamgi *et al.* proposed a query rewriting approach which processes queries on data provider services [3]. Benouaret *et al.* introduced a service composition framework to answer preference queries [4]. In that approach, two algorithms based on [3] are presented to rank the best rewritings based on previously computed scores. Ba *et al.* presented an algorithm based on *MiniCon* that produces and order rewritings according to user preferences [2]. As in the database domain, these approaches requires an important amount of resources to process the rewriting and integration.

In consequence, data consumption is determined by quality constraints specified by the user (data consumer) and different contracts (i.e., SLA's) of the clouds providing the required services. User's constraints define the storage and computing capacity of the device that consumes the data, the data transmission bandwidth and cost, whether the data consumption is critical (time constraints) and energy consumption. The SLA of the cloud determines the type of quality a user can expect from its services, according to the contract (subscription) signed between her and the cloud provider. The user profile, her quality requirements and her execution context determine the conditions in which she is expecting to consume data by using such cloud services.

Thus, the **first challenge** is to compute what we call an integrated SLA that matches the user's

integration preferences (including quality constraints and data requirements) with the SLA's provided by cloud services, given a specific user cloud subscription. The user may have general preferences depending on the context she wants to integrate her data such as economic cost, bandwidth limit, free services, and storage and processing limits. The SLA's associated to the cloud services can be of different types: user - data service, data service - cloud provider, data provision service - data processing service, and cloud provider - cloud provider. In this context, matching the user integration preferences with the services that can contribute to produce a result can lead to search and identify in the chain of SLAs. Probably it is possible to find an incompatibility between the preferences and a SLA in the chain, in this case it is necessary to propose a strategy to solve the problem.

Furthermore, in order to fulfill requirements and satisfy user expectations, it is possible to have a collaboration between different clouds. This collaboration implies the agreement through SLAs between services deployed in different cloud providers. In consequence, matching user preferences with SLA's can lead to deal with heterogeneous SLA specifications (different schemata, different measures semantics and granularities). Computing an integrated SLA can imply dealing with heterogeneous SLA specifications and SLA-preferences incompatibilities.

The **second challenge** is to guide data integration taking into consideration the integrated SLA. Here, the data integration process includes (i) looking up services that can be used as data providers, and for services required to process retrieved data and build an integrated result; (ii) performing data retrieval, processing and integration and (iii) deliver results to the user considering her preferences (quality requirements, context and resources consumption). The integrated SLA can guide services filtering in the look up phase; it can help to control the amounts of data to retrieve and process according to consumption rights depending on the user subscription to the participating cloud providers and how to deliver data considering the user's context.

Several researches have reported their studies on SLA in different domains [1]. In the cloud context, Rak *et al.* proposed an approach to specify security requirement and to associate them to cloud services [14]. Mavrogeorgi *et al.* introduced a SLA management framework that allows the creation and enforcement of customized SLAs [12]. Leitner *et al.* presented an approach to monitor and predict SLA violations before they impacted the provider's SLA [9]. In general, proposals regarding SLAs in the deployment of services focus on two aspects: (i) approaches focusing on the life cycle of the SLA mainly interested in the contract negotiation phase between the cloud and the service consumer; and (ii) works monitoring contracts and cloud resources in order to avoid SLA violations, and consequently penalties due to its violation. In this sense, to the best of our knowledge, we have not identified any other approach that proposes the use of SLA associated to a data integration solution in a multi-cloud environment.

This thesis project intends to address data integration in a multi-cloud hybrid context. The originality of our approach consists in guiding the entire data integration solution taking into account (i) user preferences statements; (ii) SLA contracts exported by different cloud providers; and (iii) several QoS measures associated to data collections properties (for instance, trust, privacy, economic cost). The objective is to propose data integration strategies adapted to the vision of the economic model of the cloud.

In our work we consider an example from the domain of energy management. My directors are working on two national projects in this domain. So for instance, we assume we are interested in queries like: Give a list of energy providers that can provision 1000 KW-h, in the next 10 seconds, that are close to my city, with a cost of 0,50 Euro/KW-h and that are labeled as green? The question is how can the user efficiently obtain results for her queries such that they meet her QoS requirements, they respect her subscribed contracts with the involved cloud provider(s) and such that they do not neglect services contracts? Particularly, for queries that call several services deployed on different clouds. This work is part of an international collaboration with the DiMAp, Federal University of Rio Grande do Norte.

The project development is occurring naturally and well. In fact, this happens due to several aspects: (i) the close relationship and the easy access to my directors; (ii) the good frequency of meetings. Normally, we have at least one meeting for a week in order to evaluate the status of the work; (iii) the research center infrastructure and team; and (iv) the monthly group meetings where we can discuss about the development of the projects with other colleagues. In addition, there are meetings in another laboratory, LIRIS. These moments are important because we can have an external view and comments about our research.

2. Synthèse du travail effectué dans l'année (2 pages maxi)

During the second year, we have been working on the development of our data integration approach. Given a query and a set of user preferences associated to it, the query execution process is divided in three phases. The figure 1 illustrates our data integration approach.

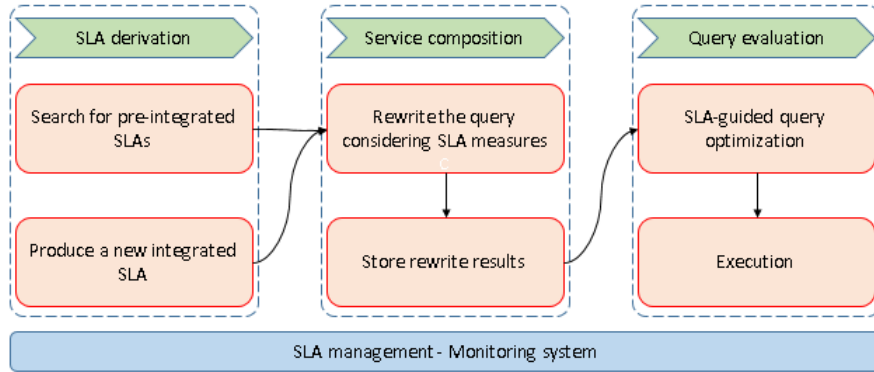


Figure 1: SLA-guided data integration approach

The first phase is the SLA derivation in which a SLA for the user request is created. It consists in looking for a (stored, integrated) SLA derived for a similar request. If a similar SLA is found, the request is forwarded to the query evaluation phase. Otherwise, a new SLA to the integration (called integrated SLA) is produced. The query is expressed as a service composition with associated user preferences. In the second phase, service composition, the query is rewritten in terms of different services considering the user preferences and the SLAs of each service involved in the composition. The rewriting result is stored for further uses. Finally, in the query evaluation phase, the query is optimized in terms of user preferences and SLAs concerning the consumed resources and the economic cost of the query. Once optimized, the query processed in the execution engine. In addition, we are assuming a SLA management module and monitoring system responsible to verify if the SLA contracts are being respected. Firstly, we have worked on the phases two in order to have an algorithm that will allow us to run important experiments to evaluate our approach.

[2] have proposed an algorithm for refining services composition. Their goal was to use user preferences to select and rank services in order to avoid the exponential problem while combining and producing compositions. Composition are incrementally produced until to reach a (predefined) desired number. In collaboration with our colleagues in Brazil (authors in [2]), we have worked on an adapted version of [2] to our data integration solution extending their data structure to map services to the query, and adding the concepts of user preferences to the query and quality measures to the services. However, while performing the integration we have identified some design issues that made it useless to our approach: (i) their concept of user preferences are scores associated to services previous defined by the user while, for us, user preferences are quality requirements expected by the user concerning the whole integration; (ii) their algorithm accepts rewriting including calls to services that are not interest for the composition. Assuming that on the cloud each service has a price associated to its request, these composition that calls useless services produces an extra cost to the user. This adaptation process helped us to identify important issues to be applied to our own implementation such as developing an better approach to produce the combinations of services.

Based on the related work, we have developed and formalized the *Rhone* service-based query rewriting algorithm guided by service level agreements (SLA). The *Rhone* assumes that there are a set of quality measures associated to services which we suppose they are previously extract from their SLA. These measures will guide the service selection and the entire rewriting process. Our work address this issue and proposes the algorithm with two original aspects: (i) the user can express her quality preferences and associated them to his query; and (ii) service's quality aspects defined in SLAs guide the service selection and the whole rewriting process taking into consideration that services and rewritings should meet the user requirements, and the different cases of incompatibilities of SLAs, uncompleted SLA and the integration SLA. Given a set of abstract services, a set of concrete services and a user query (both defined in terms of

abstract services), and a set of user quality preferences, the *Rhone* derives a set of service compositions that answer the query and that fulfill the quality preferences regarding the context of data service deployment. The algorithm consists in four steps: (i) *Selecting concrete services*. Similar to [11, 13] our algorithm selects services based on the abstract services that exists in the query, but it includes two differences: first, a concrete service cannot be select if it contains an abstract service that is not present in the query; and second, the service' quality aspects (extracted from its SLA) must be in accordance with the user quality preferences; (ii) *creating mappings from concrete services to the query (called concrete service description (CSD))* inspired in [13] including also the information concerning the services' SLA; (iii) *combining CSDs*; and (iv) *producing rewritings* until fulfilling the user requirements according to the services' SLA. Each phase of the algorithm and each concept (query, concrete services, mapping rules, for instance) were formally specified and described.

In order to evaluate our approach and the *Rhone* algorithm, we began configuring a multi-cloud environment. We have searched for open source solutions instead of privates once they are (i) quite expensive; and (ii) do not allow to extend and access directly the different level of SLAs. The OpenStack was selected as our technology. We have installed and configured the different modules necessities to the OpenStack. However, we have some issues: (i) the configuration and deployment of cloud infrastructure require important technical skills while configuring the network resources; (ii) it requires a powerful machine. Due to these reasons we have configured a simulation of cloud run our experiments.

The first version of the *Rhone* was implemented using Java according to its formal definition. The algorithm was tested in a cloud simulation containing 35 services in its service registry. We have tested different types of query varying on the size and on the number of user preferences. Although our algorithm shares the same time performance problem as the previous approaches while combining compositions, the preliminary experiments have shown that the *Rhone* can enhance the quality in data integration by considering the user preferences and service's quality aspects extracted from service level agreements. Our approach avoid selecting and using services to produce compositions that are not interest to the user once they do not fulfill his quality requirements. In addition, as result we have submitted short paper to EDBT 2016.

We developed an improved version of the algorithm that better manages the manner in which lists of objects are managed. We have applied this version to a new set of experiments running 100 concrete services. With the results obtained from this experiment and the final version of our formalization, we are working on a new paper that included an extensive description of the algorithm and its evaluation to be submitted to ADBIS 2016 (deadline 27th March).

Currently, we have been working on the SLA model to data integration, on the schema for user SLA, cloud SLA and integration SLA, and on a scenario description to illustrate our approach. The result of this work is going to be described in a VLDB PhD workshop (to be submitted until 4 April).

3 Production scientifique

Daniel Carvalho, Nadia Bennani, Genoveva Vargas-Solar, Chirine Ghedira, Placido Souza Neto. **Can Data Integration Quality be Enhanced on Multi-cloud using SLA?**. DEXA 2015, Sep 2015, Valencia, Spain. Lecture Notes in Computer Science 9262, Springer 2015.

Paper proposal presentation. **Trusted SLA-Guided Data Integration on Multi-cloud Environments**. Seminar presented to the Information System group from the Magellan's Research Center. In March 5th 2015.

Poster presentation. **SLA-Guided Data Integration on Multi-cloud Environments**. Poster presented in the « Journée Scientifique de l'Arc 6 » held in 20th November 2015 at Grenoble, France.

PhD proposal and query rewriting algorithm presentation. **Trusted SLA-Guided Data Integration on Multi-cloud Environments**. Seminar presented to the Service-Oriented Computing team meeting from LIRIS, Lyon 1. In 3rd December 2015.

Query rewriting algorithm and ongoing works presentation. **A Service-based Query Rewriting Algorithm**. to the Information System group from the Magellan's Research Center. In 4th February 2016.

4. Perspectives (1 page maxi)

Once we have been working on the second phase of our data integration approach, we are going to carry on completing what is missing on the other phases. This concerns to (i) propose the user, service and cloud SLA schema for data integration; (ii) develop and describe our data integration architecture; and (iii) build the module that threats the SLA and extracts its measures information to be used in the *Rhone* rewriting algorithm. As we mentioned before, the work concerning the SLA is the core of our approach. Here, while matching user preferences with SLA's, we are dealing with heterogeneous SLA specifications (different schemata, different measures semantics and granularities), different cases of SLA specifications and SLA-preferences incompatibilities. In addition, an optimization of our algorithm is also necessary to be able to process a huge amount of services.

With this work done, we are going to integrate both parts: the SLA module and the Rhone algorithm. The evaluation of the approach is essential and it can be presented to partners in energy domain to validate the feasibility of our approach. Once the modules are connected, a set of experiments in a multi-cloud environment will be performed to evaluate our solution. The results analysis will be the basis to another scientific article. In parallel, we will start writing the thesis document. The table below describes our intended calendar. In green, you can see activities that we have done (previously described in the section 2). In blue, future activities.

	2 nd year												8	6 months 3 rd year					
	9	10	11	12	1	2	3	4	5	6	7	9		10	11	12	1	2	
1. Adapting [9] to our approach																			
2. State of the art on query rewriting algorithms																			
3. Proposal and Formalization of the Rhone query rewriting algorithm																			
4. Implementation of the Rhone in Java																			
5. Configuration of the cloud environment and preliminary experiments																			
6. Short paper submission to EDBT																			
7. Improving and optimizing the Rhone and new experiments																			
8. Proposal of SLA schema, model and approach to data integration																			
9. Paper ADBIS: describing the Rhone algorithm and its formalization																			
10. Paper VLDB PhD workshop: describing our SLA schema, model and approach																			
11. Refinement of the SLA schema for users, services and clouds																			
12. Refinement and improving of SLA-guided architecture for data integration																			
13. Building the module responsible to threat SLAs																			
14. Integrating different modules of our architecture																			
15. Simulating the multi-cloud and running first experiments																			
16. Producing a scientific paper																			

Avis du Responsable de l'ARC

Avis du Conseiller scientifique de la Région Auvergne-Rhône-Alpes

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