Profiting from Instant Data Integration on the Cloud

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Abstract. This PhD project addresses data integration in multi-cloud environments. Current data integration systems imply consuming data from data services deployed in cloud contexts and integrating the results. The project takes a new angle of the problem by considering at real-time the four dimensions (Data providers, data consumer, the infrastructure, and the data itself), their characteristics and constraints including quality, security, privacy traduced in SLAs, and proposing an SLA-based data integration approach in a multi-cloud environment. The objective is to enhance the quality and performance on data integration taking into consideration the economic model imposed by the cloud. At this stage, Our first results have shown that quality and performance can be enhanced, and the cost of the integration can be minimized by using our approach.

Keywords: Data integration. Query rewriting. Query rewriting algorithm. Cloud computing. SLA.

1 Introduction

Current data integration systems imply consuming and integrating data from data services which deliver data under different quality conditions related to freshness, trust, cost, reliability, availability, among others. Selecting data services, producing query rewritings and executing query plans are computationally expensive. These data integration tasks can take advantages from multi-cloud architectures considering their elasticity, *pay-per-use* model and parallel processing.

However, multi-cloud environments bring new challenges to data integration due to 4 principal dimensions (data provider, data consumer, infrastructure, and the data) that impose at real-time their associated constraints and characteristics such as access policies, access constraints, processing capacity, memory limits, among others. To better understand our problem, let us suppose the following scenario. During Brazilian Olympic games 2016, Lucas is an spectator willing to collect information about the weather forecast near his actual location with a time interval of two days in advance. According to the weather different matches could be proposed, in different stadiums with different options of seats to buy (such as sunny seats or not, in the middle or in the sides, and in the side of a specific team). Lucas may also have several preferences such privacy issues, time interval, budget, using free services or not, for instance. To achieve his needs, there are several data provider services distributed on different clouds that can be integrated to produce an answer for his query or part of it. Thus, given a user query, the integration process deals with different matching problems: (i) matching the *query* and *data provider services* - the data provider services have to produce a result for the query; (ii) matching the *user preferences* and the *quality guarantees* provided by the data provider - the user preferences and requirements concern the data itself, the data services and the type of subscription the user has with the clouds; (iii) matching the *user preferences* and *user' type of subscriptions* - the user may have several subscriptions with different clouds that should influence the way to choose the services if the underlying cloud offers more resources to the user, and this cloud can be running out of budget for consuming the necessary resources; and (iv) the *data provider services* and *their type of subscriptions* - the data provider services also have subscription with the clouds, and they can also be out of budget and resources according to their subscription.

In cloud computing, the quality conditions that the user can expect from a service are defined in contracts called service level agreements (SLA). Current SLA models are not sufficient to cover the data integration requirements. Usually, SLAs describe only cloud resources, and do not tackle the data integration aspects. Thus, we strongly believe that: (*i*) a new kind of SLA is need to unify all information regarding the constraints and requirements as a meaning for the integration process; and (*ii*) by using the new SLA, the integration history could be reused as much as possible to enhance the quality and performance in the current data integration solutions. Considering the problems and challenges aforementioned, this PhD project contributes designing a SLA model and an approach for data integration adapted to the cloud economic model. The originality of our approach consists in guiding the entire data integration solution - while selecting, filtering and composing cloud services, and delivering the results - taking into account (*a*) user preferences statements; (*b*) SLA contracts exported by different cloud providers; and (*c*) several QoS measures associated to data collections properties (for instance, trust, privacy, economic cost); and (3) validation of our approach in a multi-cloud scenario.

The reminder of this paper is organized as follows. Section 2 discusses the related works. Section 3 ... Section 4 ...

2 Related works

The related works concerning the problem stated in the previous section can be divided in three topics: (*i*) data integration approaches in the cloud or in service-oriented contexts; (*ii*) query rewriting approaches; and (*iii*) service level agreements for cloud computing.

The authors in [5, 7] perform data integration in service-oriented contexts, particularly considering data services. However, they only take into consideration the requirement of computing resources for integrating data focusing on performance aspects. [10] only focused on data privacy in order to integrate data obtained from different data services. [9] proposed an inter-cloud data integration system considering privacy requirements and the cost for protecting and processing data. Although [9, 10] tackled in their approaches quality aspects of the integration, we believe there are other crucial elements that should be studied regarding the requirements and constraints of data consumers, data providers, the associated infrastructures and the data itself, and how to filter services and produce the best query plan considering these requirements and constraints.

As traditional databases theory, data integration on cloud and service-oriented context deals with query rewriting issues. Researches [1–3, 6] have refereed it as a service composition problem in which given a query the objective is to lookup and compose data services that can contribute to produce a result. In general, these works share the same performance problem depending on the size of the query and on the number of available services. Although [1, 3] have considered preferences and scores to produce rewritings, the multi-cloud context brings new challenges once new requirements and constraints are introduced. Thus, new heuristics should be considered in the rewriting process in order to make it efficient.

Service level agreements (SLA) have been widely adopted in different domains in order to specify what service consumer can expect from the service delivered by a service provider. Research contributions in cloud computing mainly concern (i) SLA negotiation phase (step in which the contracts are established between customers and providers) and (ii) monitoring and allocation of cloud resources to detect and avoid SLA violations. We strongly believe that SLAs could be used in order to cover the limitations discussed in the previous paragraphs and to enhance the quality in the current data integration solutions. In this sense, to the best of our knowledge, we have not identified other works that uses SLA to guide the entire data integration on a multi-cloud context.

3 SLA-based Data Integration Approach

The figure 1 illustrates our data integration metamodel. The *Multi-Cloud* is configured as a set of *Cloud Infrastructures*. *Data producers* and *data consumers* subscribe to *cloud infrastructures*. Their subscription credentials are illustrated thanks to a *SLA* (*Consumer SLA* or *Producer SLA*) defining what the *cloud infrastructure* offers to them through their subscription. *Data* are provided and consumed by *Data Producers* and *Data Consumers*, respectively.

The metamodel describes the 4 principal dimensions (*Data consumer*, *Data Producer*, *Cloud Infrastructure* and *Data*) considered in our proposed data integration meta-process (Figure 2). Three general steps compose it: query man-

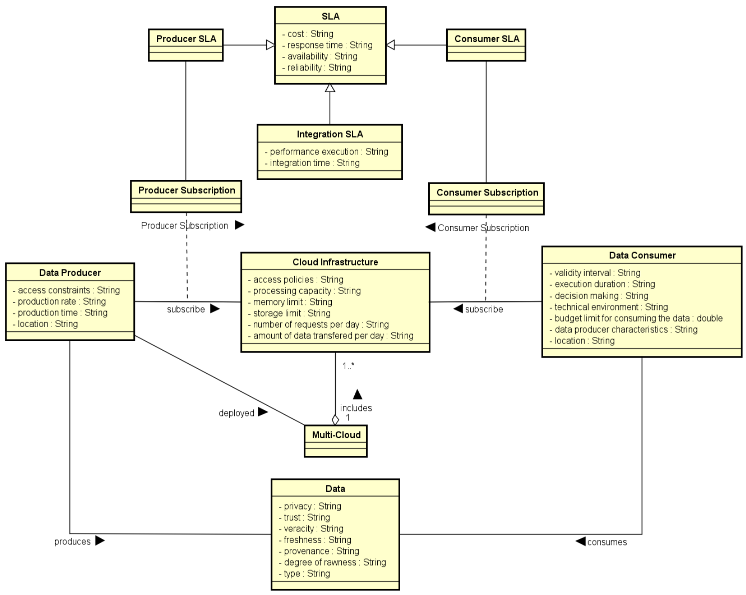


Fig. 1: Data integration metamodel

agement, SLA management and query rewriting. Each step in the meta-process includes different actions used in our data integration process. The query management step includes activities concerning the query specification and preferences definition according to the user. The SLA management includes a set of activities associated to the SLA manipulation such as: search for previous integration SLA, create a new integration SLA, reuse an integration SLA, SLA enforcement, update an integration SLA and store an integration SLA. The query rewriting includes activities concerning the rewriting process according to the user requirements and the characteristics, and constraints of each entity in our data integration metamodel such as: search for data producers, filter data producers according to the SLAs, generate integration plan, execute integration plan, retrieve data, integrate results and deliver results.

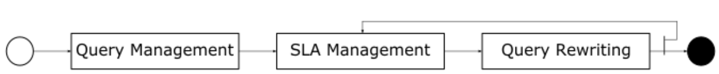


Fig. 2: Data integration meta-process

Taking into consideration at real-time the entities presented in our meta-model and our meta-process, we propose a SLA-based data integration process adapted to the multi-cloud (Figure 3) below. A users specifies a query according to his/her needs and requirements. In addition, he/she defines a set of preferences and associate them to the query. Given a query and user preferences, previous integration SLAs (that are associated to a previous integration) that matches with the actual query and preferences are searched. If a match is found, the information about this previous integration is reused and a new integration SLA is created using this information. On the other hand, if no match is found, a new integration SLA is created without any previous information. Then, a set of query rewriting activities are performed to generate the execution plan. Results are computed and the integration SLA is updated and stored to be used in a next integration request. The query rewriting activities sub-process include (i) searching for data producers that can produce an answer to the query; (ii) filtering data producers according to the user preferences, to the consumer SLAs and to the producer SLAs. This means it is necessary to verify if the data producer is out of resources or not, and if the consumer has enough resources to process the data provided by the producer; (iii) generating the execution plan according to the SLAs; (iv) enforcing the SLAs associated to the involved services; and (v) executing the integration plan. Computing results sub-process retrieves data, integrates results and deliver them.

4 Preliminary results

We have developed a prototype of our query rewriting algorithm which takes into consideration users' requirements and services' quality aspects extracted from SLAs called *Rhone*.

Currently, our approach runs in a local controlled environment simulating a single-cloud including a service registry of 100 concrete services. Experiments were produced to analyze the algorithm's behavior concerning performance, and quality and cost of the integration. The figures 4a and 4b summarize our first results.

The experiments include two different approaches: (i) the *traditional approach* in which user preferences and SLAs are not considered; and (ii) the *preference-guided approach* (P-GA) which considers the users' integration requirements and SLAs.

The results P-GA are promisingly. The *Rhone* increases performance reducing rewriting number which allows to go straightforward to the rewriting solutions that are satisfactory avoiding any further backtrack and thus reducing successful integration time (Figure 4a). Moreover, using the P-GA to meet the user preferences, the quality of the rewritings produced has been enhanced and the integration economic cost has considerable reduced while delivering the expected results (Figure 4b). However, the *Rhone* still need to be tested in a large scale case and in a context of parallel multi-tenant to test efficacy.

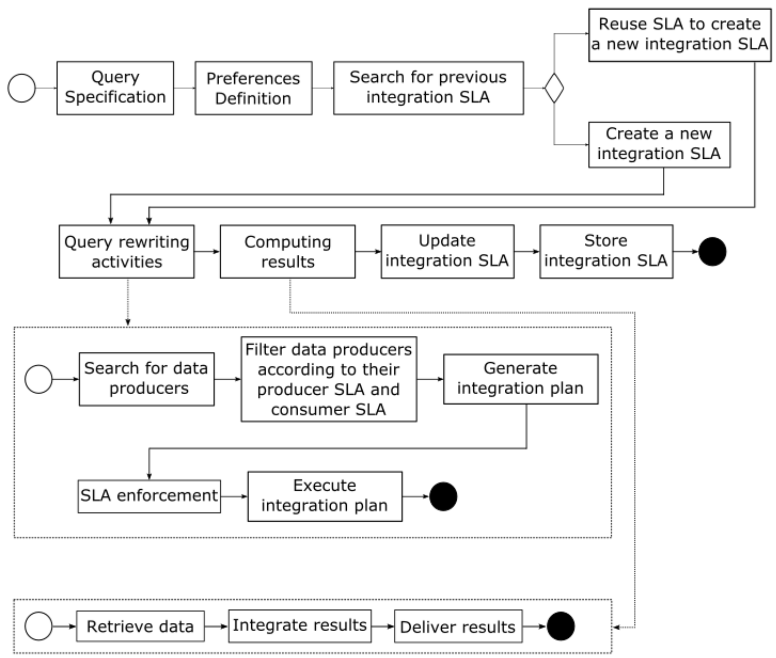
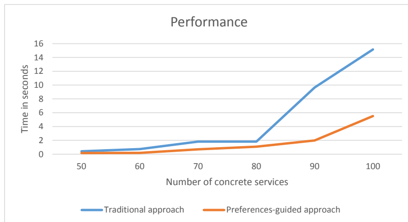


Fig. 3: Data integration process

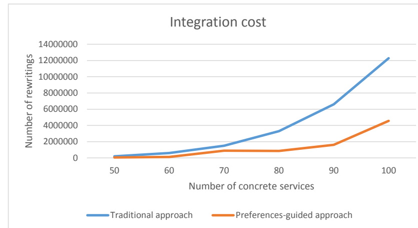
5 Conclusions and Research plan

This paper introduces a new vision of data integration adapted to the cloud context and to the end-user pay-per-use economic model. It also proposes a new approach for data integration based on user requirements and SLA. In addition, a query rewriting algorithm called *Rhone* serves as proof for the feasibility of data integration process guided by cloud constraints and user preferences . Our first results are promisingly. The *Rhone* reduces the rewriting number and processing time while considering user preferences and services' quality aspects extracted from SLAs to guide the service selection and rewriting. Furthermore, the integration quality is enhanced, and it is adapted to cloud economic model reducing the total cost of the integration.

SLA incompatibilities are not treated in this paper. Currently we are working on this issue, and improving our SLA model and schema for data integration adapted to the multi-cloud context. Another important part is how to make efficient the rewriting process by reducing the composition search space. Finally, how should be a parallel execution of the query plan to let the execution efficient in the multi-cloud. In addition, we are focusing on evaluating and validating the entire quality-based data integration approach on a multi-cloud environment.



(a) Performance evaluation.



(b) Integration cost.

Fig. 4: *Rhone* execution evaluation.

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