Using Portfolio Theory to Diversify the Dynamic Allocation of Web Services in the Cloud

Faisal ALRebeish
University of Birmingham
Birmingham
United Kingdom
Fam018@cs.bham.ac.uk

Rami Bahsoon
University of Birmingham
Birmingham
United Kingdom
R.bahsoon@cs.bham.ac.uk

ABSTRACT

In this paper, we view the Cloud as market place for trading instances of Web Services, which can be bought or leased by web applications. Applications can buy diversity by selecting web services from multiple cloud sellers in a cloud based market. We argue that by diversifying the selection, we can improve the dependability of the application and reduce risks associated with Service Level Agreements (SLA) violations. We propose a novel dynamic adaptive search based software engineering approach, which uses portfolio theory to construct a diversify portfolio of web service instances, traded from multiple Cloud providers. The approach systematically evaluates the Quality of Service (QoS) and risks of the portfolio, compare it to the optimal traded portfolio at a given time, and dynamically decide on a new portfolio and adapt the application accordingly.

Categories and Subject Descriptors

C.2.4 [**Distributed Systems**]: Cloud Computing Distributed applications.

Keywords

Modern Portfolio Theory; Risk, Dynamic Search Based Software Engineering (SBSE); Cloud Based Market; Cloud Computing; Design Diversity.

1. INTRODUCTION

Web services have gained growing interest due to its importance in developing business to business (B2B) or web applications. Simultaneously, Cloud computing promises the delivery of reliable, affordable and on-demand services, which could be leased or traded [1]. The popularity of the Cloud and its distinctive economics computation advantages, make a cloud-based market a plausible and an attractive option for publishing and trading Web Services. On the other hand, offering Web Services through a cloud based market underlies risks associated with probable service failure caused, for instance, by undependable service provision of the cloud service provider, hardware malfunctions or unpredicted fluctuation in demands for the traded service as a shared resource, lack of trust in the provision and so forth. All these factors may increase the risks associated with Service Level Agreements (SLAs) violations for web applications benefiting from the cloud based market.

We view the Cloud as a marketplace for trading instances of abstract Web Services, which web applications can explore, trade for and use as substitutable entities.

GECCO'13 Companion, July 6–10, 2013, Amsterdam, the Netherlands.
ACM 978-1-4503-1964-5/13/07.

That is, for a given *abstract service A*, there exist multiple *concrete services* $A_i \ldots A_n$ in the market offering comparable functionality but differing in their price and Quality of Service (QoS) provisions. We view the selection of concrete web service instances from cloud based market as a dynamic "search problem", which needs to be optimized for reducing probable risks. We look at such optimization from the buyer's (i.e. a web-based application) point of view. As a novel perspective, our risk based fitness function advocates diversifying the selection and consequently the allocation of traded Web Services instances. The intuition is that by diversifying through selecting multiple instances from multiple providers, we can improve dependability and reduce the probable risks of SLA violations. The challenge would be to find an efficient and effective solution for investing in such diversity, while reducing risks. Diversity in design is a mature topic [2] and it has been used as a strategy to increase the reliability and dependability of software systems. This can be achieved by creating two or more independent versions of the same service where all of the independent versions tend to meet the specification. However, each independent version has its unique design decisions and is implemented in a distinctive way. In this case, if a fault occurs in one of the versions, there is great chance that the other solutions continue to be intact.

The novelty of the approach emerges from two main points: (i) utilizing the concept of portfolio [3] to diversify the selection of Web Services from multiple Cloud providers (sellers) in order to reduce the probable risks of SLA violations. To the best of our knowledge, we are not aware of any economics-driven selection approach, which explicates diversity in the allocation of multiple instances of Web Services, as a mechanism for ensuring SLA compliance benefiting from cloud-based markets. (ii) The use of portfolio theory, as online SBSE for diversifying the allocation of Web Services in the Cloud aimed at optimizing SLA for risk compliance (i.e. expected return takes the form of improved dependability through diversity) subject to QoS and cost constraints in a given adaptation cycle.

2. Portfolio Based Web Service Allocation

A cloud market place will facilitate the process of buying and selling instances of Web Services, where Web Services will be offered with different prices and QoS. Let us consider a web application that need to allocate multiple instances of Web Services from a cloud based market. Previous work have used auction-based methods to dynamically allocate all the instance of web service from a single or multiple providers that have the lowest price and optimal QoS[4]. In contrast, our approach tries to secure the instances by constructing a diversify portfolio of multiple instances of a web service by considering multiple providers in a compliant cloud based market, whether federated or not. The objective is to minimize the global level of risk.

The aggregated QoS q_i for service S_i is calculated in equation **1** with one constraint represented in equation **2**, where w_A, w_E and w_{Se} represents the priority weights of the quality parameters of the web service: availability, execution time and security.

$$q_i = w_A A_i + w_E Et_i + w_{Se} Se_i \quad (1)$$

$$w_A + w_E + w_{Se} = 1 \quad (2)$$

The expected return of web service portfolio E_p that is built by allocating instances of web service from m providers can be calculated as in equation **3** with one constraint represented in equation **4**. w_i represents the weight of the Web Services that is allocated from the web service provider S_i and C_i represent the cost of web service S_i. q_i Represent the aggregated QoS of the Web Services S_i .

$$E_p = \sum_{i=1}^{m} w_i \frac{q_i}{C_i} \quad (3)$$

$$\sum_{i=1}^{m} w_i = 1 \quad (4)$$

The risk of SLA violation R_i is quantified as the percentage between the numbers of SLAs that have been violated to total number of the total SLA delivered by the service provider S_i. The global risk of the portfolio R_p is calculated as is in equation **5**, where the local risk R_i is the risk associated with the Web Service S_i.

$$R_p = \sqrt{\sum_{i=1}^{m} w_i^2 R_i^2} \quad (5)$$

In order to optimize the global risk of the portfolio R_p and find the optimum solution, we need to find how much weight w_i should be invested in each web service S_i to construct a low risk portfolio. We can achieve that by applying a non-linear optimization method that is called Generalized Reduced Gradient (GRG2) to equation **5** as the fitness function and **3** and **4** as constrains. The goal of this optimization process is to find the optimum percentage of Web Service instances from a specific provider so we can construct the minimum risk portfolio.

Consider that a cloud-based application is expected to perform adaptations when there is a change in the market prices or risks, the basic steps of our portfolio based optimization can be stated as follows:

1- For the first adaptation cycle only, the buyer sets minimum accepted aggregated QoS, the required number of Web Services and the maximum price that she is willing to pay $\boldsymbol{C_{max}}$ as well as the weight of quality attributes w_A, w_E and w_{Se} of the web service.

2- The buyer agents explores the market and gets the Web Services offers that satisfy the SLAs and the maximum cost constraints of a cloud-based application.

3- The buyer agent access the *Knowledgebase* maintained by the market regulator to retrieve the likely risks R_i of SLA violation and q_i aggregated QoS associated with each web service provider.

4- Apply Generalized Reduced Gradient (GRG2) nonlinear optimization to equations **3, 4** and **5** to find the weight of each asset on the web service portfolio so we can construct a diversify portfolio with the minimum global risk.

5- Compare the risk of the new optimum portfolio with risk of the currently allocated portfolio:

   a) If new optimum portfolio improves on reducing the risk, while satisfying both the QoS and cost constraints, we will perform the allocation of Web Services based on the recommended weights from the optimization process.

   b) Else we will keep the currently allocated portfolio.

3. CONCLUSION

In this paper, we have introduced a novel dynamic and adaptive search based optimization approach for Web Services selection and allocation in the cloud. We viewed the cloud as a marketplace for trading instances of abstract Web Services, which web applications can explore, trade for and use as substitutable entities. We have used a portfolio based optimization to improve SLA compliance by diversifying the selection and consequently the allocation of traded instances of Web Services from multiple providers. Our approach represents efficient and effective solution for investing in diversity, while reducing risks SLA violations.

4. REFERENCES

[1] Buyya, R. Yeo, C. S. Venugopal, S. Broberg, J. Brandic, I. 2009. Cloud Computing and Emerging IT Platforms:Vision, Hype, and Reality for Delivering Computing as the 5th Utility. *Future Generation Computer Systems*. (Jun. 2009), 599–616.

[2] Littlewood, B. Popov, P. Strigini, L.2001 Modeling software design diversity: a review. *Computing Surveys.* (Jun. 2001), 177-208.

[3] Markowitz, H. M. 1959. *Portfolio Selection: Efficient Diversification of Investments.* John Wiley & Sons, New York.

[4] Nallur, V. Bahsoon, R. *2010*. Design of a market-based mechanism for quality attribute tradeoff of services in the cloud. *In Proceedings of the ACM Symposium on Applied Computing (SAC '10).* (2010)**,** 367-371.