Computers and Electrical Engineering 000 (2017) 1–12

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

# An end-to-end framework for context-aware business process outsourcing to the cloud☆

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ARTICLE INFO

*Article history:*
Received 14 September 2016
Revised 2 May 2017
Accepted 6 May 2017
Available online xxx

*MSC:*
00-01
99-00

*Keywords:*
Business process outsourcing
Cloud
NSGA II
Context-aware decision

ABSTRACT

Highly motivated by the advantages of cloud computing, enterprises are considering outsourcing their business processes to the cloud to reduce their cost, increase their flexibility, and enhance their performance. The purpose of this paper is to propose a comprehensive end-to-end framework for business process outsourcing to the cloud, that considers the dynamic business process context. The framework comprises different methods able to efficiently take into account accurate and up-to-date business process context to identify the best process fragment to outsource and the most suitable cloud service to adopt. The optimality of the identified solutions is insured by NSGA II (Elitist Non-Dominated Sorting Genetic Algorithm) for which we proposed a set of context-based objective functions. In addition, the framework considers the business process context prior and post the outsourcing decision in order to change a decision to account for context changes. The performance of the framework is experimentally illustrated.

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## 1. Introduction

Cloud computing offers multiple advantages to Small and Medium-size Enterprises (SME) such as enhancing the performance and flexibility of their business processes and reducing their costs. These advantages motivate several enterprises to consider outsourcing their applications (business processes) to this emerging computing environment. However, the outsourcing endeavor is highly complex and its success dependents on the judicious decision about what to outsource and how to select the best cloud services. Indeed, not all business processes can be outsourced to the cloud because of, for instance, security reasons or the business logic. In addition, the need for/benefits of outsourcing may change depending on circumstances internal to the enterprise such as load peak periods. In other words, to be successful, the outsourcing decision must account for the dynamic context of the enterprise and it must be tailored to its needs and business goals and logic.

The main objective of this paper is to investigate the overall requirements of Business Process Outsourcing (BPO) to the cloud with a particular focus on the necessity of context-awareness. This investigation is insured through the proposition of a comprehensive end-to-end framework that offers assistance to SME both prior and post to the outsourcing decision making. More specifically, an SME can use the proposed framework to find answers related to the following outsourcing questions: (*1*) What are the most suitable business process activities (fragments) to outsource and what cloud service to

☆ Reviews processed and recommended for publication to the editor-in-chief by guest editor Dr. Slim Kallel.

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http://dx.doi.org/10.1016/j.compeleceng.2017.05.009
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Please cite this article as: M. Rekik et al., An end-to-end framework for context-aware business process outsourcing to the cloud, Computers and Electrical Engineering (2017), http://dx.doi.org/10.1016/j.compeleceng.2017.05.009

adopt? (*2*) Does the outsourcing decision suit particular time period? and (*3*) Post outsourcing, does the outsourced BP guarantee the estimated outsourcing factor values (cost, response time, security risk, etc.)?

To provide for assistance in answering the above question, we elaborated the framework through: (*i*) the extension of the well-known cloud simulator CloudSim to support business process execution simulation; (*ii*) the identification of a set of optimal solutions using NSGA II (*Elitist Non-Dominated Sorting Genetic Algorithm*) and by proposing a set of pertinent objective functions. In this paper, optimality is examined in terms of cost reduction, business process performance enhancement, and risk minimization; and (*iii*) the integration of context awareness prior to and post outsourcing to guarantee the decision's suitability and flexibility.

The remainder of this paper is organized as follows: Section 2 overviews related works. Section 3 describes in detail the proposed CloudSim extension. Section 4 shows how NSGA II and its appropriate objective functions can be used to identify the business process activities to outsource and the cloud service to adopt. The context awareness, which presents a prominent characteristic of our framework, is presented is Section 5. We evaluate the performance and the effectiveness of the outsourcing decision in Section 6. Finally, Section 7 summarizes the work status and highlights its extensions.

## 2. Related work

Generally, enterprises outsource their business processes to reduce investment costs, enhance their business process performance, and/or focus on the core competencies while being aware of the potential outsourcing risks [1–3]. However, deciding about business process outsourcing is a complex task that depends on and impacts the business, economic and IT facets of the enterprise. Indeed, according to Yang et al. [4], enterprise chief information experts spend almost 80% of their time in evaluating the business process outsourcing decision. To reduce this complexity, several works have tackled different facets of the outsourcing problem: some works presume that decision about which BP to outsource is known and focus on defining means for transforming the initial, in-premise process [5]; others identify decision factors that influence the outsourcing decision [4,6,7]; yet others suppose a monolithic application outsourcing and focus on deciding on which cloud services are the most appropriate [8,9].

Focusing on BP transformation, Duipmans et al. [5] propose an automated transformation support to decompose (in cloud versus in premise) business processes according to data and activity distributions predefined by the users. Similarly, Povoa et al. [10] propose a data constraint-driven approach to split the business processes between the cloud and in-premise sides. By focusing on data and activities, these works presume that the outsourcing decision depends on factors related to cost, privacy and execution time.

Besides the above factors, researchers proposed several other factors such as reducing costs, persistent storage, elastic computing, intra-cloud, and wide-area networking [8,9]. In addition, Rai et al. [6] highlight multiple factors that urge enterprises to outsource to the cloud such as optimum resource utilization, unlimited scalability of resources and less maintainability. In contrast to the BP transformation focused works (which outsource BP parts), these researchers focus on cloud adoption to support the execution of *monolithic* applications. However, the control flow patterns (*e.g.* sequential, parallel, multi-choice patterns) characterizing a BP make the evaluation of its outsourcing convenience more challenging compared to outsourcing monolithic applications. Indeed, the control flow patterns impose additional effort to compute the business process cost, performance and risk. In addition, it creates further outsourcing alternatives which make the decision problem computationally complex. On the other hand, some researchers tackled the outsourcing decision in terms of cloud service selection.

In summary, none of the above works tackled the outsourcing decision problem in a comprehensive way: *(1)* a priori, account for all factors defining the enterprise context to assist in identifying BP fragments candidate to outsourcing, and to assist in selecting the most appropriate cloud services; and *(2)* posteriorly, evaluate the adopted solution face to the dynamics of the enterprise context. Proposing such a comprehensive, end-to-end decision support framework is the main contribution of this paper. In the following sections, we detail the components of the proposed framework.

## 3. CloudSim extension to simulate business process execution

Simulation is a commonly used means to perform prominent calculations and computing tasks and to produce a description of a system's results as they would really be generated. In the context of our research, simulation of business process execution on different cloud service configurations can be used to determine optimal solutions for the outsourcing problem. More specifically, in our research, simulation provides for estimates of the response time and cost of business processes execution. These estimates assist in identifying both the most convenient activities to outsource and the cloud services to adopt.

Towards this end, we adopt the well-known CloudSim tool to simulate business process execution in the different cloud service configurations. CloudSim is an open source java-based simulator. It allows an easy modeling of virtualized environments, supporting on-demand resource provisioning [11].

To the best of our knowledge, CloudSim supports only simulation of *monolithic* applications deprived of the control flow patterns which characterize business processes. These control flow patterns illustrate the business process behavior through the different control flows that link business process activities (*e.g.*, the exclusive choice and parallel patterns) [12]. They affect the calculation of the outsourcing decision factors such as cost, execution time, etc.

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