

Chapter 112

A Comparative Study and Algorithmic Analysis of Workflow Decomposition in Distributed Systems

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ABSTRACT

Workflow is an essential mechanism for the automation of processes in distributed transactional systems, including mobile distributed systems. The workflow modeling enables the composition of process activities along with respective conditions, data flow and control flow dependencies. The workflow partitioning methods are used to create sub-partitions by grouping processes on the basis of activities, data flow and control flow dependencies. Mobile distributed systems consisting of heterogeneous computing devices require optimal workflow decomposition. In general, the workflow partitioning is a NP-complete problem. This article presents a comparative study and detailed analysis of workflow decomposition techniques based on graphs, petri nets and topological methods. A complete taxonomy of the basic decomposition techniques is presented. A detailed qualitative and quantitative analysis of these decomposition techniques are explained. The comparative analysis presented in this article provides an insight to inherent algorithmic complexities of respective decomposition approaches. The qualitative parametric analysis would help in determining the suitability of workflow applicability in different computing environments involving static and dynamic nodes. Furthermore, the authors have presented a novel framework for workflow decomposition based on multiple parametric parameters for mobile distributed systems.

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1. INTRODUCTION

Today's scientific computations involve hundreds and thousands of execution steps which are not necessarily originated from a single origin. The computations can be distributed and shared by heterogeneous groups in an execution environment. The assembly and execution of computational steps are challenging tasks in heterogeneous distributed systems (Benoit et al., 2013). The workflow is a mechanism of describing the operational aspect of a work process denoting the function of the task along with its control flow pattern (Boutamina & Maamri, 2015). The formal definition of workflow is given as, "Workflows represent declaratively the components or codes that need to be executed in a complex application, as well as the data dependencies among those components" (Brezillon, 2011).

A workflow can be broadly categorized into two types such as: 1) abstract workflow and, 2) concrete workflow (Deelman et al., 2003). In the abstract workflow, dependencies among different tasks are being defined but are not bound to a particular service. While in the concrete workflow, distributed task dependencies are strictly bound to specific services. The workflow specification consists of three items: Process, Data, and Invocation (Ailamaki et al., 1998). Process is composed of workflow tasks and their internal relationships. It should be flexible enough to allow different forms of interrelationship e.g. tasks operating in series or in parallel, tasks providing input to or receiving input from other tasks etc. The data item is referred to the sets of input values and output values associated to a workflow. Invocation is the procedure that initiates the execution of each task at specific instant of time. There can be explicit invocation by a human to initiate a task or implicit invocation of tasks which starts after the execution of another task by satisfying a predefined condition.

From the functional aspects, workflows can be categorized as, business workflows, scientific workflows, experimental workflows and manufacturing workflows (Joglekar et al., 2014). The control and activity-oriented nature of business workflows is specifically used to represent the conditions and working policies of a business process activity (Maalouf et al., 2014). The nature of the scientific workflows is data oriented and therefore it is used to represent computations as well as data flow in a scientific experiment (Zheng et al., 2017). However, experimental type workflows are usually used to keep track of the executed steps while conducting scientific experiments. Manufacturing workflows are used to represent the execution steps during a product manufacturing in a manufacturing industry. The manufacturing workflows not only define the preferred operating variables but also provide the fixed sequence of steps required to manufacture a given product. The workflow automation and workflow management are emerging research areas and have offered enormous benefits both for the scientists and businesses. Automating workflows in mobile distributed systems is challenging due to heterogeneity and mobility of the underlying network devices. In mobile distributed systems the workflow automation is beneficial for saving energy and to achieve high performance (Kocurova et al., 2011). Because the workflow automation can identify and remove unnecessary steps saving computational resources while enhancing overall resource utilization in mobile distributed systems. Parallel and sequential executions of tasks can effectively reduce computation time and ensure their correct completion. In order to design workflows, a well-structured workflow model is required with maximum support for automating all kinds of processes (Georgakopoulos et al., 1995). A workflow model is the computer-based representation of a business activity by defining conditions for initiation and termination of a process (Benoit, Çatalyürek et al., 2013). The workflow model also defines activities required to be performed in a business process along with control flow patterns and data flow dependencies (Meilin et al., 1998). A well-structured workflow model has properties such as, reliability, soundness, fault tolerance, exception handling, and

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