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A sufficient and necessary temporal violation handling point selection strategy in cloud workflow

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HIGHLIGHTS

- Development of a temporal consistency model for workflow activities in the queuing systems.
- Time redundancy is considered into the execution process of cloud business workflows.
- Proof of sufficiency and necessity for the temporal violation handling point selection strategy.

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ABSTRACT

To deliver high QoS (quality of service) for business process participants, workflow temporal verification is conducted to provide satisfactory on-time completion rate of business process in the cloud. Temporal violation handling is the last task in a typical workflow temporal verification framework to deal with detected time delays. However, there are very few existing studies regarding temporal violation handling for cloud business workflows. In this paper, queuing theory is first employed to simulate time features of parallel workflow instances. Then, propagation effect based temporal consistency model for business workflows and temporal consistency model for workflow activities in the same queuing system are presented respectively. Finally, a promising temporal violation handling point selection strategy for cloud business workflows is proposed and proved to satisfy the property of sufficiency and necessity. Compared with other representative strategies, experimental results show that our novel handling point selection strategy can reduce the monitoring and handling cost while maintaining the target on-time completion rate agreed between users and service providers.

1. Introduction

Business processes are the series of interactions between businesses and their customers, vendors and other related partners. A business workflow is an instance of well-defined business process that are often repeated as part of a standard enterprise operations [1]. In general, these business workflows can be managed by a workflow system and executed in a fully or semi-automatic fashion. With the fast trend of globalization, increasing popularity of e-commerce and e-government systems requires effective and efficient processing of massive service requests within a deadline, which has become ever more important [2].

In many business domains, tens of thousands or even millions of business workflows happen frequently and the total number of workflow instances is extremely large on a daily basis. A business process can be very simple in some cases, for example, buying a newspaper or paying two dollars for a cup of coffee only needs a few steps to complete the whole process [1]. Some processes are more complex, for example, purchasing an item with credit card involves a series of tasks before the purchase can be completed, and there could be million or even more workflow instances in a securities exchange corporation which need to be handled during the peak time of the stock market [3]. No matter how simple or complex the processes are, a common characteristic is that the

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amount of these workflow instances is enormous. Some of these business processes are often time constrained [4] that should be completed before fixed time points. For instance, securities exchange in the stock market is a typical complex instance-intensive business process which involves a large number of instances between different organizations [5]. For example, the clearing process and money transfers in the stock market may need to be finished before 3:00 am each workday. This can be referred as the time to completion (TTC) issue. It is defined by the span from the start to the completion without iteration [6]. As the time span is strictly constrained and thus any time delays may cause lower quality of service (QoS). Failures of on-time completion for money transfer in stock market may cause huge financial losses as it could result in the failure of making deals, which is definitely a disastrous situation in the stock market. So on-time completion (OTC) of time-constrained large number of workflow instances is critical for delivering satisfactory QoS in today's e-business and e-government process systems.

Different from traditional scientific workflows, instance-intensive business workflows usually involve a large number of workflow instances [6]. Each instance normally has a few steps [7] and some steps of the workflow instance can be executed concurrently. Business processes are typical instance-intensive workflows which are characterized by a large number of concurrent and often relatively simple workflow instances [8]. Business processes normally have a specific deadline and need to achieve the target on-time completion rate for certain business objectives [9]. As shown in Fig. 1, temporal constraints are serving as a type of service level agreement (SLA) as part of QoS requirement [10]. There are two types of temporal constraints that we need to consider in business workflows. The first type is global constraint which applies to the entire workflow process. The second type is local constraint which applies to each individual workflow activity. For the reason that large number of business processes are dynamically changing all the time, it is very necessary to employ cloud computing resources to deal with the functional requirement of business workflows. Many existing studies [11–14] have demonstrated that cloud computing is a good facility for offering virtualized, on-demand self-service, broad network access, resource pooling, rapid elasticity and measured service [15]. So cloud computing is an ideal hosting environment for running a batch of parallel business workflow instances [4,13] such as securities exchange. It can supply scalable and sufficient resources to complete business workflows within the deadline of each workday.

As shown in Fig. 1, the four basic components for temporal verification of business workflows are temporal constraints setting, temporal checkpoint selection, temporal consistency verification and temporal violation handling in a workflow life cycle. To facilitate the use of cloud resources, three big challenges should be resolved at the moment to improve on-time completion rate for business workflows. **First,** where do we set checkpoints so as to monitor the execution process? Too much monitoring may cause huge waste while too less may cause many temporal violations undetected. Hence checkpoints need to be selected at appropriate time points. **Second,** how do we verify the execution consistency state of large number of business workflow instances? Temporal violations often inevitably occur in workflow applications due to the uncertainty and dynamic nature of cloud environment. Hence the temporal consistency verification is a key issue when temporal violations are detected at checkpoints. **Third,** when do we handle workflow temporal violation? Time redundancy exists in workflow instances when there is no time deficit. It is normally unnecessary to trigger temporal violation handling for a minor time deficit as there is a high probability that it will be automatically compensated for by the time redundancy of the subsequent activities. Hence, whether temporal violation handling (TVH) is necessary or not depends on different situations.

Based on the above challenges, we need a trade-off solution to guarantee both the overall throughput (OT) of business workflow instances and each individual response time (IRT) of workflow activities. First, queuing model is employed so that large number of business processes can be executed in parallel. Then a propagation-aware temporal consistency model is applied to account for the effect of time delay propagation in queuing system. Afterward, an overall temporal verification framework is presented for parallel business workflows, which verifies the system temporal consistency state at selected checkpoints by the temporal consistency model. Finally, a new minimum time redundancy-based handling point selection strategy is proposed to deal with temporal violations in business processes with minimum number of handling points.

The overall workflow temporal verification framework based on queuing theory can guarantee on-time completion for a batch of business workflows in a constrained time. More importantly, the novel temporal violation handling point selection strategy has been proved to satisfy the property of sufficiency and necessity by two theorems, which can reduce the cost for monitoring the execution process remarkably.

To sum up, our significant contributions in this paper are as follows.

(1) For the first time, we develop a novel temporal consistency model for workflow activities in the same queuing system, which facilitate to verify the consistency state of workflow activities in the same queuing system.

(2) For the first time, time redundancy of completed workflow activities is considered in the execution process of a large number of parallel workflow instances.

(3) For the first time, we propose novel temporal violation handling point selection strategy for cloud business workflows and prove the property of sufficiency and necessity.

The remainder of the paper is organized as follows. Section 2 introduces some related work. Section 3 illustrates a motivating example of business process with constrained time. Section 4 proposes temporal consistency models based on queuing theory. Section 5 presents a novel temporal verification framework for cloud business workflows. Section 6 elaborates the detail experimental results. Section 7 concludes the paper and puts forward some future work.

2. Related work

In recent years, there are many works on temporal verification for a large number of cloud business workflows. Some traditional cloud workflow researches mainly focus on single process of managing and executing large-scale scientific computing issues in many complex e-science applications [16,17]. Scientific workflow is often composed by a series of computation and data intensive tasks which are normally time-constrained such as the climate and astrophysics applications [18,19]. Generally, temporal constraints in these scientific workflow applications are specified at build time as a class of temporal QoS contracts between clients and service providers. Many different criteria are applied to meet these QoS requirements [3]. However, compared with computation-intensive scientific workflows, business workflows are composed by a large number of instance-intensive tasks which are also normally time-constrained and can be executed in parallel mode [18,19]. Temporal verification for business processes in a workflow life cycle requires more researches on methods and techniques so as to provide better QoS such as checkpoint selection, temporal consistency verification and violation handling.

Considering checkpoint selection for monitoring business workflows, existing researches can mainly be classified as response-time based and throughput based temporal checkpoint

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