

# RT-Llama: Providing Middleware Support for Real-Time SOA

*Mark Panahi, University of California, USA*

*Weiran Nie, University of California, USA*

*Kwei-Jay Lin, University of California, USA*

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## ABSTRACTS

*Service-oriented architectures (SOA) are being adopted in a variety of industries. Some of them must support real-time activities. In this article, the authors present RT-Llama, a novel architecture for real-time SOA to support predictability in business processes. Upon receiving a user-requested process and deadline, our proposed architecture can reserve resources in advance for each service in the process to ensure it meets its end-to-end deadline. The architecture contains global resource management and business process composition components. They also create a real-time enterprise middleware that manages utilization of local resources by using efficient data structures and handles service requests via reserved CPU bandwidth. They demonstrate that RT-Llama's reservation components are both effective and adaptable to dynamic real-time environments.*

*Keywords: Real-Time Enterprise (RTE), Real-Time Systems, Service-Oriented Architecture (SOA)*

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## INTRODUCTION

Service-oriented architecture (SOA) is the prevailing software paradigm for dynamically integrating loosely-coupled services into one cohesive business process (BP) using a standard-based software component framework (Bichler & Lin, 2006; Huhns & Singh, 2005). SOA-based systems may integrate both legacy and new services, created by either enterprises internally or external service providers.

However, current SOA solutions have not addressed the strict predictability demands

that many enterprise applications require, from banking and finance to industrial automation and manufacturing. Such enterprises, many of whom already embrace SOA for a large part of their systems, would greatly benefit from a comprehensive SOA solution that can also encompass their real-time applications. In other words, as SOA gains prominence in many domains, the confluence of real-time and SOA systems is inevitable. We must prepare SOA for meeting the predictability requirements of real-time enterprise systems.

For example, the auto industry is looking at applying SOA to their development of the AUTOSAR (AUTomotive Open System AR-

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chitecture) standardization project (AUTOSAR, 2008) to address the needs of future automotive systems, called “service integrated systems”. Such systems can facilitate: 1) the integration of various on-board services (e.g., cruise control, brakes, etc.), 2) both vehicle-to-vehicle and vehicle-to-roadside for traffic information, and 3) communication with the dealer about vehicle maintenance. This must be accomplished while also maintaining the real-time requirements of such systems, particularly with on-board service integration.

SOA brings both advantages and challenges to real-time integration. By its very nature, SOA was designed to be flexible to deal with dynamic environments. As such, different service component candidates may have very different timing behaviors. Moreover, the distributed nature of execution environments makes it almost impossible to make any kind of “guarantees.” However, such flexibility and dynamism may be leveraged to allow 1) different choices of candidate services to better meet deadlines during BP composition and 2) dynamic run-time adjustments to reconfigure a BP to make up for lost time when some services have taken much longer than expected. We therefore want to study the real-time support in SOA both to realize its benefits and to meet its challenges.

In this article, we present the RT-Llama project (as an extension of Llama (Lin, Panahi, Zhang, Zhang, & Chang, 2009; Zhang, Lin, & Hsu, 2007)) which meets the real-time enterprise challenge by enabling SOA users to schedule an entire BP, thus eliminating the risk of missed deadlines due to the over-utilization of resources. RT-Llama differs from previous service-oriented architectures (Panahi et al., 2008) in that it allows end-to-end BP deadline guarantees through advance reservations of local resources.

In order to make this work, we 1) design global resource management and composition components that reserve resources in advance for each service in a BP to help guarantee its

end-to-end deadline; 2) leverage an efficient data structure for managing reservation utilization data, a dynamic adaptation of the TBTree (Moses, Gruenwald, & Dadachanji, 2008) called the dTBTree; 3) implement a CPU bandwidth management system for each host, dividing a CPU into multiple temporally-isolated virtual CPUs, allowing different classes of service with various levels of predictability; and 4) develop pre-screening mechanisms to decrease the likelihood of unsuccessful distributed service reservations.

The rest of the article is organized as follows. We first review the challenges of bringing real-time to SOA and describe the RT-Llama RT-SOA architecture. We then present the performance study of the RT-Llama implementation. Finally, we compare our work on RT-Llama to related efforts.

## BACKGROUND

### Motivation

RT-SOA is a relatively new and challenging field of study. While some aspects of SOA make its transition to real-time simpler, still other aspects pose serious challenges. One real-world problem that can use an RT-SOA solution is algorithmic trading. Algorithmic trading is defined in Wikipedia as “a sequence of steps by which patterns in real-time market data can be recognized and responded to.” The performance requirements of algorithmic trading demand not only fast transactions but also predictable ones (Martin, 2007). Therefore, it is an application which should be implemented as RT-SOA. Examples of algorithmic trading strategies include: 1) trading several positions in coordination and 2) breaking larger trades into smaller sequential trades to minimize market impact.

As an example scenario, we assume that a customer has a choice for each trade among several brokerage firms. Each brokerage firm offers three levels of service:

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