Chapter 17
RT-Llama: Providing Middleware Support for Real-Time SOA

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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 paper, 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.

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 manufac-
turing. 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 AUTO-
SAR (AUTomotive Open System ARchitecture) 
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 compo-
nent candidates may have very different timing 
behaviors. Moreover, the distributed nature of 
execution environments makes it almost impos-
sible 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 recon-
figure 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 paper, 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 dif-
fers from previous service-oriented architectures 
(Panahi et al., 2008) in that it allows end-to-end 
BP deadline guarantees through advance reserva-
tions of local resources.

In order to make this work, we 1) design global 
resource management and composition compo-
nents 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 dy-
namic adaptation of the TBTree (Moses, Gruen-
wald, & Dadachanji, 2008) called the dTBTree; 
3) implement a CPU bandwidth management 
system for each host, dividing a CPU into mul-
tiple 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 unsuc-
cessful distributed service reservations.

The rest of the paper is organized as follows. 
We first review the challenges of bringing real-
time to SOA and describe the RT-Llama RT-SOA 
arhitecture. 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 Wiki-
pedia as “a sequence of steps by which patterns 
in real-time market data can be recognized and 
responded to.” The performance requirements of
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