Chapter 11

Execution and Resource Management in QoS–Aware Virtualized Infrastructures

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ABSTRACT

Both real-time systems and virtualization have been important research topics for quite some time now. Having competing goals, research on the correlation of these topics has started only recently. This chapter overviews recent results in the research literature on virtualized large-scale systems and soft real-time systems. These concepts constitute the fundamental background over which the execution environment of any large-scale service-oriented real-time architecture for highly interactive, distributed, and virtualized applications will be built in the future. While many aspects covered in this chapter have already been adopted in commercial products, others are still under intensive investigation in research labs all over the world.

INTRODUCTION

Traditional real-time methodologies focus on hard real-time safety-critical systems, where applications have associated a set of temporal constraints (e.g., deadlines) which must never be violated, as otherwise the system as a whole will fail – with potentially fatal consequences such as loss of human lives. However, a class of soft real-time applications exists, for example in the multimedia domain, in which an approach to meet the desired timing constraints under all circumstances is neither needed nor practical. In fact, for those applications, violations of the temporal constraints lead to degradations in Quality of Service (QoS), rather than an entire system failure. Thus, they are
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usually tolerated as long as their frequency and severity remains within sensible limits.

Different service-oriented architecture (SOA) and cloud management approaches exist that possess specific features to provide increased service reliability, scalability, host virtualization, application failure detection, global resource management, and optimized server utilization. However, in case of deployment of real-time interactive distributed applications, such features need to be complemented by taking the timing constraints that are in place for the applications into proper consideration during the various decision processes and run-time mechanisms. The challenge that has to be addressed is that the goals of virtualization and real-time-compliance are competing: Virtualization is used to exploit multiplex gains by sharing physical resources among multiple tasks so that statistically the resource usage is maximized. On the other hand, real-time systems are designed to guarantee response times even for the worst case scenario, resulting in resource underutilization in the average case.

The remainder of this chapter is structured as follows. First, an overview of real-time scheduling is given. Section two discusses how virtualization mechanisms improve resiliency and utilization optimization. The third part of the chapter covers host virtualization mechanisms. The chapter concludes with an overview of mechanisms to give real-time guarantees in virtualized environments.

REAL-TIME SCHEDULING

Real-time theory and methodologies are gaining applicability in the field of soft real-time systems. In this domain, applications possess precise timing and performance requirements, but occasional failures in meeting them may be easily tolerated by the system, causing a graceful degradation in the quality of the provided service.

The real-time literature on soft real-time technologies for General purpose operating systems (GPOSes) is growing, and the major research branches are those in relation to: multiprocessor scheduling, soft real-time scheduling, QoS control in distributed real-time applications and adaptive QoS control, as detailed below.

Scheduling Real-Time Task Sets on Multiprocessor Platforms

Even if the concept of multiprocessing has always been present in the real-time community, only recently it is receiving a significant attention, thanks to the increasing industrial interest on such platforms, and their consequent increasing availability. While the scheduling problem for uniprocessor systems has been widely investigated for decades, producing a considerable variety of publications and applications, there are still many open problems regarding the schedulability analysis of multiprocessor systems. As pointed out by Liu in his seminal paper (C. L. Liu, 1969): “few of the results obtained for a single processor generalize directly to the multiple processor case: bringing in additional processors adds a new dimension to the scheduling problem”.

Unfortunately, predicting the behaviour of a multiprocessor system requires in many cases a considerable computing effort. To simplify the analysis, it is often necessary to introduce pessimistic assumptions. This is particularly needed when modelling globally scheduled multiprocessor systems, in which the cost of migrating a task from one processor to another can significantly vary over time. The presence of caches and the frequency of memory accesses have a significant influence on the worst-case timely parameters that characterize the system. To bind the variability of these parameters, often real-time literature focuses on platforms with multiple processors but with no caches, or whose cache miss delays are known. Also, the cost of pre-emption and migration on multi-processor systems is a very important issue that still needs to be properly considered in real-time methodologies. Some research in the
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