Utility Accrual Scheduling of Distributable Threads: The *Tempus* Approach

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1. Introduction

Dynamic, adaptive, real-time embedded control systems are present at any level(s) of an enterprise—e.g., devices in the defense domain such as multi-mode phased array radars and battle management. These embedded systems often include “soft” as well as “hard” time constraints.

Jensen’s time/utility functions [4] (or TUFs) allow the semantics of soft time constraints to be precisely specified. A TUF specifies the utility to the system, resulting from the completion of an activity, as a function of its completion time. Figure 1 shows examples of TUF time constraints. TUFs have been successfully used in two significant, real-time applications, including an AWACS (Airborne Warning and Control System) surveillance mode tracker system built by MITRE and Open Group, and a coastal air defense system built by CMU and General Dynamics.

When timing constraints are expressed with TUFs, the scheduling optimality criteria are based on factors in terms of maximizing accrued utility from those activities—e.g., maximizing the sum, or the expected sum, of the activities’ attained utilities. Such criteria are called Utility Accrual (or UA) criteria, and sequencing (scheduling, dispatching) algorithms that consider UA criteria are called UA sequencing algorithms.

Motivated by the need for dynamic scheduling, e.g., UA scheduling, in real-time distributed systems, the Object Management Group recently adopted the Real-Time CORBA 2.0 (Dynamic Scheduling) standard [7] (abbreviated here as RTC2¹). RTC2 specifies *distributable threads* (or *DTs*) as a programming and scheduling abstraction for system-wide, end-to-end scheduling in real-time distributed systems. The distributable thread model is a subset of the *distributed thread* model that was created in Jensen’s Archons Project [3].

A DT is a single thread of execution with a globally unique identifier that transparently extends and retracts through an arbitrary number of local and remote objects. Concurrency is at the DT-level.

¹ Real-Time CORBA 2.0 has been recently renamed Real-Time CORBA 1.2.
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part of a DT’s control flow that is subject to the specified time constraints.

The scheduling parameters in Tempus are only meaningful to the node schedulers, and thus can have arbitrary format as long as the node schedulers can interpret them properly. In the current version of Tempus, the set of scheduling parameters must first specify the scheduler to be invoked. Tempus currently implements eight schedulers, including fixed priority schedulers, deadline-driven schedulers such as the Earliest Deadline First (EDF) scheduler, the Dependent Activity Scheduling Algorithm (DASA) scheduler [1], and the Generic Utility Scheduling (GUS) scheduler [5]. In addition, scheduling information associated with the designated scheduler needs to be specified, such as priorities for the fixed priority scheduler and deadlines for the EDF scheduler.

3. Experimental Results

Our test bed contains a network of PCs running RedHat Linux and QNX Neutrino operating systems. The experiments use periodically spawned DTs with downward-step TUF, decreasing TUF, and parabolic TUF time constraints. We conducted experiments using four schedulers, including a RMA scheduler, an EDF scheduler, a DASA scheduler, and a GUS scheduler.

Table 1 shows the mean’s and standard deviations of the Accrued Utility Ratio (AUR) under the four schedulers. AUR is the ratio of accrued utility to the maximal possible utility of all DTs. We observe that (1) the standard deviations of all performance measurements are small regardless of the mean values, which suggest that the performance of Tempus is stable and predictable; and (2) the GUS scheduler outperforms all other schedulers during “low load” as well “high load.”

4. Conclusions

The Tempus middleware thus illustrates the effectiveness of scheduling DTs using propagated scheduling parameters (including arbitrarily-shaped TUFs) for node-local scheduling and resource contention resolution. Ongoing efforts include incorporating TMAR (thread maintenance and repair) protocols [2] into

<table>
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<th>Load</th>
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<th>Std(AUR)</th>
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Table 1. Performance of Scheduling Policies

Tempus and developing scheduling algorithms for DTs that use RTC2’s Case 3 and Case 4 approaches.

References