Performance Modeling with Structured Actions

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Abstract. The paper presents the concept of structured actions for modeling performance aspects within process-algebraic calculi. A structured action is parameterized with an interaction time, a priority, a set of requested resources, and a monitoring signal. The paper introduces the new performance-oriented LOTOS extension LOTOTIS and shows its use by specifying the Tick-Tock Case Study. Finally, it investigates the LOTOTIS upward compatibility with LOTOS.

1 Motivation

The first concern with a distributed system is its correct behavior according to the intended system functionality. The second concern is to have a proper performance with reasonable costs. While functional correctness has been considered primarily in the past, recent application of computer systems, for instance multimedia applications in broadband communication networks, showed that performance characteristics are of the same importance as the functional correctness of a distributed system. There is a need to predict performance characteristics within the design phase, to optimize system performance within the prototyping and implementation phase, as well as to control and to maintain performance during runtime.

How to develop functionally correct distributed systems starting with a formal requirement specification down to the system implementation is a well studied area. In contrast to that, it is not unusual that a system is fully implemented (or at least implemented as a prototype) and tested for functional correctness before any attempt is made to investigate its timing behavior and its performance. In case of inconvenient performance the whole development process is restarted resulting in long periods of system development, late system delivery, and high costs. In addition, there will be no guarantee that the newly designed system will have better performance than the first one.

The main problem why performance investigation are made very late in the development process, is the separation between formal specifications and performance analysis. Traditional specification techniques are lacking quantified time and other features for performance modeling. They describe only the causal ordering of events, i.e. their logical relations. On the other hand, classical performance models like queueing systems lack the description of the functional behavior, so that logical relations are often omitted. The current state of the

G. Hommel (ed.), Quality of Communication-Based Systems, 85–104.

art is to develop a performance model that is independent from the functional model. However, neither the functional behavior can be described independently of timing constraints nor the performance characteristics of a system can be derived from a performance model containing no logical relations. Furthermore, to proof that functional and performance model coincide with each other is hard if not even impossible. Henceforth, there is no possibility to investigate the functional correctness in combination with a sufficient performance. Both concerns are derived out of two independent models. The solution is to incorporate new concepts into formal specification techniques, so that the performance of distributed systems can be derived from their formal specifications. Costly re-prototyping or even re-implementation can be avoided, if performance can be predicted already within the design phase.

This paper identifies four concepts needed for performance analysis from formal specification namely quantified time, quantified nondeterminism, quantified parallelism, and monitoring. An overview and comparison of existing performance-oriented LOTOS extensions is given. Subsequently, the concept of structured actions and the new LOTOTIS approach is presented. Due to lack of space we decided to renounce the formal semantics definition. Instead, we show the applicability of our approach by specifying the Tick-Tock Case Study. Finally we investigate the upward compatibility of LOTOTIS with LOTOS.

2 Concepts Needed for Performance Modeling

The classical formal description techniques (FDTs) — LOTOS, ESTELLE, and SDL — are definitely not expressive enough to do performance analysis from formal descriptions, because they were exclusively developed for the specification of the functional behavior. In particular, all of them are lacking quantified time. Looking at the needs to express performance issues in formal specifications we identified four main concepts which are

Quantified Time Doubtless, the precondition for any performance evaluation is the possibility to express quantified time. In addition to the modeling of the causality order between events, time distances between events have to be quantified.

Quantified Nondeterminism Due to their complex behavior distributed systems are inherently nondeterministic. Their specifications represent nondeterminism by means of choices between several possible behaviors of that systems. For the sake of performance evaluation, we have to quantify these choices explicitly.

Quantified Parallelism A classic assumption of formal specification techniques is that all active behavior components — processes in case of process algebras, automata in case of finite state machines or transitions in case of Petri nets — can be executed in parallel. This corresponds to an unrestricted parallelism of the system. However, this is not adequate for performance