Formal Development of Hierarchical Agent-Based Monitoring Systems for Dynamically Reconfigurable NoC Platforms

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ABSTRACT

Sophisticated applications deployed on multi-core platforms require many resources as well as dynamic monitoring of the platform to provide efficiently and reliably the needed functionality. In this paper, the authors propose an approach to formal modelling with adequate tool support of an agent-based system whose function is to dynamically monitor the state of the multi-core platform and perform reconfiguration procedures under faults. For this purpose, the authors use the Event-B formalism which allows them to stepwise develop correct-by-construction specifications by mathematical proofs. Furthermore, the formalism enables the decomposition of a specification, which makes it possible to implement a well-structured and hierarchical agent-based monitoring system.

INTRODUCTION

Modern applications deployed on multi-core platforms are very complex and require a large number of resources for their intensive computations. Network-on-Chip (NoC) is considered to be an efficient and scalable interconnect paradigm to provide the required number of resources on multi-core platforms (Benini & De Micheli, 2002). The cores of a multi-core platform are interconnected with one structured net so that they can exchange information efficiently. However, the computations may be interrupted by various faults that can occur on such multi-core platforms, such as faults caused by high temperature of cores or hardware faults that occur in cores. In order to allow an application to complete its computations without interruption it is necessary to provide...
run-time means for monitoring the state of the NoC platform and reacting appropriately on every change of the system state.

For monitoring the functionality provided by the running applications on NoC platforms, as well as monitoring faults in cores, special means are required, namely agents (Rantala, Isoaho, & Tenhunen, 2007). These agents monitor the state of the NoC platform and react to non-desired changes caused by faults by performing different procedures to tolerate these faults. Generally, the bigger the NoC platform the larger the number of agents it requires. In order to manage a large number of agents, it is desirable that they are organised into a hierarchy, which is commonly a three-level structure for centralised schemes (Yin, 2009). It allows agents to exchange the information about the state of the NoC platform as well as to tolerate faults by performing dynamic reconfiguration on local (regional) and global (inter-regional) levels.

NoC platforms with their run-time management systems are likely to be used in many applications, from home use electronics to large safety critical control and data transfer systems (Khatib, 2006). Hence, it is important that they are reliable. One of the appropriate approaches for specifying reliable NoC systems, as well as verifying their design is provided by formal methods. Formal development of NoC platforms and their agent-based monitoring systems allows us to prove their consistency mathematically and specify them in a stepwise and correct-by-construction manner. In this paper, we stepwise develop a specification of a hierarchical agent-based monitoring system for NoC platforms using the Event-B formalism (Abrial, 2010). Event-B makes it possible to model a discrete transition system and prove the consistency of a model following the refinement-based approach. Moreover, it has adequate tool support through the Rodin platform (Source Forge, 2011).

The rest of the paper is organised as follows. In the next section, we consider an agent-based monitoring system for a NoC platform that is dynamically reconfigurable if faults occur. The section “Modelling in Event-B” describes the Event-B formalism used to model the monitoring system allowing us to prove its correctness. In addition, we describe possible decompositions of a model, which help us to cope with the model complexity. In the “Modelling an agent-based monitoring system for NoC platforms in Event-B” section, we present a case study by deriving the specification of the hierarchical agent-based monitoring scheme. Finally, in the “Related work” section, we elaborate on related work and in the “Conclusion” section, we conclude this paper.

AGENT-BASED MONITORING SYSTEM FOR NoC PLATFORMS

The design of an agent-based monitoring and reconfiguration system requires special means to monitor the state of a system and take proper actions if inadequacies occur. Such means are usually implemented as agents (Rantala, Isoaho, & Tenhunen, 2007). When the number of functions performed by agents and/or the number of agents grows, it is reasonable to have a hierarchy of the agents, especially for a large-scale NoC platform. Generally, the hierarchy of the agents has a three-level structure as illustrated in Figure 1 (Yin, 2009).

A cell agent monitors the state of an individual cell (core). It observes the local parameters such as cell temperature, as well as faults that may occur in the cell. In addition, the cell agent promotes information about the state of the cell to higher-level agents.

A cluster agent monitors the state of the region where an application is mapped. In addition, it adjusts different parameters such as frequency and/or power supply for the region. It enables mechanisms for tolerating faults. Also, the cluster agent transfers the information about the current state of the region to the platform agent.

The platform agent manages the whole NoC platform. It performs application mappings onto the NoC platform and reallocates either a whole application or specific application cells...
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