An Approach to Adaptive Dependability Assessment in Dynamic and Evolving Connected Systems

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ABSTRACT

Complexity, heterogeneity, interdependency and, especially, evolution of system/services specifications, related operating environments and user needs, are more and more highly relevant characteristics of modern and future software applications. Taking advantage of the experience gained in the context of the European project Connect, which addresses the challenging and ambitious topic of eternally functioning distributed and heterogeneous systems, this paper presents a framework to analyse and assess dependability and performance properties in dynamic and evolving contexts. The goal is to develop an adaptive approach by coupling stochastic model-based analysis, performed at design time to support the definition and implementation of software products complying with their stated dependability and performance requirements, with run-time monitoring to re-calibrate and enhance the dependability and performance prediction along evolution. The proposed framework for adaptive assessment is described and illustrated through a case study. To simplify the description while making more concrete the approach under study, the authors adopted the setting and terminology of the Connect project.

Keywords: Adaptation, Dependability, Evolving Heterogeneous Systems, Model-Based Assessment, Monitoring, Performance

DOI: 10.4018/jaras.2013010101
INTRODUCTION

Modern software applications are increasingly pervasive, dynamic and heterogeneous. More and more they are conceived as dynamically adaptable and evolvable sets of components that must be able to modify their behaviour at run-time to tackle the continuous changes happening in the unpredictable open-world settings (Baresi, Ghezzi, & Di Nitto, 2006). Operating in the open-world poses a number of unprecedented challenges to software systems, including:

- The reference specification of expected/correct operation is not a-priori available;
- Specifications are learnt/inferred, thus they can be incomplete, unstable, uncertain, with impact on all the software engineering processes built upon system specification;
- System components are assembled dynamically, with potential strong impact on interoperability in presence of heterogeneity;
- Assessment activities must accommodate change (and must be adaptable themselves), therefore special emphasis is on run-time assessment (possibility coupled with off-line analysis techniques, wherever possible), which is a new paradigm with respect to traditional assessment methods.

As a result of such prominent trends two related needs emerge. On the one side, we observe that the interconnected components, which we refer to as the Networked Systems (NSs), are independently developed. Because of this, the fast pace at which technology advances along diverging tracks can form gaps and establish separately evolving technological islands, between which communication is hampered. Thus the state of practice is that ad hoc bridging solutions need to be continuously developed to fill those communication gaps.

On the other side, the everyday life of modern and future society is growingly depending on the services provided by such highly complex and pervasive systems. In some cases their failures might even lead to catastrophic consequences in terms of damages to human life, environment, economy. Therefore, dependability and performance properties of such systems become increasingly critical.

The European FP7 Future and Emerging Technology Project Connect addresses both needs, aiming at enabling seamless and dependable interoperability among NSs in spite of technology diversity and evolution. The ambitious goal of the project is to have eternally functioning distributed systems within a dynamically evolving open-world context. This is pursued through the on-the-fly synthesis of the Connectors through which heterogeneous NSs can communicate in dependable and secure way. Indeed, effective interoperability requires ensuring that such on-the-fly Connected systems provide the required nonfunctional properties and continue to do so even in presence of evolution, thus calling for enhanced and adaptive assessment frameworks.

In the context of the Connect project, approaches to both off-line (pre-deployment) and run-time analysis are under development to analyse and ensure the synthesis of Connectors with required dependability and performance levels. In particular, an assessment framework is proposed which combines stochastic model-based analysis with continuous on-line assessment of non-functional properties through a lightweight flexible monitoring infrastructure. The goal is to assess complex dependability and performance metrics through accurate analysis that adapts to the evolving context. Although not novel in its basic principles, this off-line and run-time integrated framework is proposed as a general, automated approach to fulfill the dependability and performance assessment needs in dynamic and evolving contexts.

In this paper, we initially point out the challenges of assessing non functional properties in dynamic Connected systems and provide the context for our research objectives. Then we introduce first separately the pre-deployment analysis method and the run-time monitor under development and hence their synergic usage, through which adaptive assessment is pursued. A case study is also included to demonstrate...
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