FACULTY
OF MATHEMATICS
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The Board of Doctoral Studies
Faculty of Mathematics and Physics
Charles University
Ke Karlovu 3
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Prague, August 28th, 2018

Re: Vladimír Matěna, Doctoral Thesis – Advisor‘s Reference

The submitted PhD thesis concentrates on awareness of realistic network properties in the field of smart Cyber-Physical Systems (sCPS). These are distributed software-intensive systems of collaborating components that closely interact with real world. The software engineering of sCPS poses a difficult challenge due to their high level of complexity, dynamism, and uncertainty. Though there exist approaches that attempt to address modeling and architecting these classes of systems, they typically assume idealized communication model which neglects the influence of network properties such as latency, throughput limitations, and failures.

This thesis addresses this fact by investigating the effects of real network properties on sCPS architectures. It does so in the context of Ensemble Based Component Systems (EBCS), which is a novel approach for modeling software architectures of highly dynamic systems.

In this context, the thesis (1) analyzes the requirements on inter-component communication stemming from the typical coordination problems in the use-cases that come from various projects performed at the department of the candidate, (2) proposes extensions to ensemble-based architectural models to provide application-specific knowledge that is crucial to optimize inter-component communication (while abstracting from a particular communication stack), (3) enables further research and experiments with network-aware models and algorithms in the sCPS domain by providing easy to use frameworks and testbeds and that can be reused even by other researches in the field.

With respect to the above goals, the major scientific contributions of the thesis lie in:

- Analysis of limitations of the network on a set of scenarios different in system type, entity count and business logic.
- Proposal of methods that restrict/manage communication in search of tradeoff between network utilization and overall system utility. These encompass adaptive communication using Dynamic communication boundary and usage of Groupers.

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- Extension of the jDEECo component framework, which adds support for proper realistic network required to study effects of realistic communication and addition of mature network simulation as well as support for deployment on real hardware.
- Creation of the CDEECo++ runtime which supports deployment of real-time DEECo application an embedded hardware.
- Creation of PyDEECo runtime for quick prototyping and fast simulation of DEECo systems.
- Introduction of a test-bed based on the jDEECo environment, Robotic Operating System (ROS), Stage simulator, and OMNeT++ network simulator. The test-bed implements an Autonomous Cleaning Robots Coordination problem and matching scenario was accepted as an artifact by the research community focusing on the adaptation.

As to the contents, the thesis is structured follows. The thesis starts with a brief introduction of the sCPS and motivation in Chapter 1. Description of background of the thesis follows in Chapter 2 and goals of the thesis are outlined in Chapter 3. Before proceeding to the contribution of the thesis, the considered use cases are described and analyzed in Chapter 4 and Chapter 5. Then the solution is outlined in Chapter 6. Analysis of network effects on ensemble formation are presented as the first part of the solution (Chapter 7). Then the Communication groups are described as an approach to limit network utilization while maintain the same system utility (Chapter 8). Adaptive communication aiming to abstract low level network requirements at the architecture level is described next (in Chapter 9), while the analysis of network effects on real-time systems follows in Chapter 10. Then the implemented frameworks are described in Chapter 11 and a test-bed that combines the component framework and a simulation environment in n easy to use package is described in Chapter 12. The evaluation of the work presented in the thesis is given in Chapter 13 and the related work is presented in Chapter 14. The conclusion and discussion of open issues then follows in Chapter 15.

The thesis thus maps the entire work of Vladimír Matěna during his PhD. In total, he has co-authored 8 peer-reviewed papers published at international conferences and workshops, one peer-reviewed paper in a journal with impact factor, and one reviewed book chapter.
In particular, these include the Microprocessors and Microsystem journal (IF: 1.049), a chapter in Engineering adaptive software systems by Springer, CBSE 2015 (core A, proceedings by ACM), SEAA 2017 (core B, proceedings by IEEE), ICPE 2018 (proceedings by ACM), SEAMS 2016 (proceedings by ACM), ISOLA 2016 (Core C, proceedings by Springer), and a workshop at ECSA 2015 (proceedings by ACM). The thesis is based on 4 of these papers.

In my view, Vladimír Matěna has proved the ability to make substantial, high-quality research contributions in the field of software engineering, especially in the area of software engineering of cyber-physical systems. The research was done systematically and according to sound scientific principles with strong emphasis on evaluation based on prototypes and use-cases. Considering all these facts, I strongly recommend to accept the thesis for defense and to grant a PhD degree to Vladimír Matěna.

Doc. RNDr. Tomáš Bureš, Ph.D.
Advisor