Functorial Analysis of Algebraic Higher-Order Net Systems with Applications to Mobile Ad-Hoc Networks

Ulrike Golas[1], Kathrin Hoffmann[1,2], Hartmut Ehrig[1], Alexander Rein[1], and Julia Padberg[2]

[1] Technische Universität Berlin, Germany
ugolas|hoffmann|ehrig|alex@cs.tu-berlin.de
[2] Hochschule für angewandte Wissenschaften Hamburg, Germany
padberg@informatik.haw-hamburg.de

Extended Abstract

Place/transition (P/T) systems and their variants are an established process definition language for the representation, validation and verification of workflow procedures (see, e. g., [1] for an overview), where P/T nets represent process schemes and P/T systems describe the behavior of process instances due to their initial markings. The paradigm of *nets as tokens* has been introduced by Valk [2] in order to allow nets as tokens, called object nets, within a net, called a system net. In elementary object systems, object nets can move through a system net and interact with both the system net and other object nets. This allows to change the marking of the object nets, but not their net structure.

In [3, 4], the concept of reconfigurable place/transition net systems has been introduced which is most important to model changes of the net structure while the system is kept running. In detail, a reconfigurable P/T net system consists of a P/T net with marking and a set of rules. Thereby not only the follower marking can be computed but also the structure can be changed by rule application to obtain a new P/T net system that is more appropriate with respect to some requirements of the environment. For rule-based transformations of P/T net systems we use the framework of net transformations [5] following the double-pushout approach of graph transformation systems. The basic idea behind net transformation is the stepwise development of P/T net systems by given rules. Think of these rules as replacement systems where the left-hand side is replaced by the right-hand side while preserving a context.

The integration of Petri nets with data type descriptions has led to powerful specification techniques. In [3], we have introduced the paradigm nets and rules as tokens by a high-level model with suitable data type part. The model called algebraic higher-order (AHO) net system exploits some form of control not only on rule application but also on token firing. An AHO net system is defined by an algebraic high-level net system with net places and rule places, where the marking is given by suitable low-level net systems respectively rules on these places. As shown in [6], this paradigm has been very useful to model applications in the area of mobile ad-hoc networks.

Mobile ad-hoc networks (manets) consist of mobile nodes forwarding data to other nodes based on the network connectivity independent from a stable infrastructure. The constant change of the network's topology depends on the current position of the nodes and their availability. A typical example of a complex application is a team communicating using hand-held devices and laptops as in emergency scenarios. In such a scenario, each team member performs specific activities while different teams collaborate through the interleaving of all the different workflows. Normally, workflows in mobile environments are not fixed once and for all at design time but constantly adapted at run time predicting disconnections or reorganizing activities. This requires on the one hand a suitable description of the distributed workflows and on the other hand expressive techniques for the adaption.

Research on manets [7] has focused mainly on the infrastructure at the four lower levels of the ISO/OSI-standards. For the application of manets in larger operations it is necessary to abstract from the network layers. In [8], an interface for network services that can be used by applications abstracting from the underlying protocols is suggested. In contrast to approaches using models mainly for the network we propose modeling the application in terms of workflows, such that the adaption of workflows to accommodate the requirements in an ad-hoc setting are met.

Our experience with the case study in [9] has clearly shown the need to integrate data at the level of workflows. The main idea of this paper is to introduce AHO net systems with high-level net systems and corresponding rules as tokens. We relate them to AHO net systems with low-level net systems and rules as tokens, and analyze the firing and transformation properties of the corresponding net class transformation defined as functors between corresponding categories of AHO net systems. All concepts and results are explained with an example in the application area of mobile ad-hoc networks. In contrast to [9], where we have used merely low-level net systems, we present now a pipeline emergency scenario where we use data dependent workflows.

References

[1] Aalst, W.: The Application of Petri Nets to Workflow Management. Journal of Circuits, Systems and Computers **8**(1) (2003) 21–66

[2] Valk, R.: Petri Nets as Token Objects: An Introduction to Elementary Object Nets. In: Proc. of ATPN 1998. Volume 1420 of LNCS., Springer (1998) 1–25

[3] Hoffmann, K., Mossakowski, T., Ehrig, H.: High-Level Nets with Nets and Rules as Tokens. In: Proc. of ATPN 2005. Volume 3536 of LNCS., Springer (2005) 268–288

[4] Ehrig, H., Hoffmann, K., Padberg, J., Prange, U., Ermel, C.: Independence of Net Transformations and Token Firing in Reconfigurable Place/transition Systems. In: Proc. of ATPN 2007. Volume 4546 of LNCS., Springer (2007) 104–123

[5] Ehrig, H., Ehrig, K., Prange, U., Taentzer, G.: Fundamentals of Algebraic Graph Transformation. EATCS Monographs. Springer (2006)

[6] Bottoni, P., Rosa, F., Hoffmann, K., Mecella, M.: Applying Algebraic Approaches for Modeling Workflows and their Transformations in Mobile Networks. Journal of Mobile Information Systems **2**(1) (2006) 51–76

[7] Agrawal, D., Zeng, Q.: Introduction to Wireless and Mobile Systems. Thomson Brooks/Cole (2003)
[8] Rosa, F., Martino, V., Paglione, L., Mecella, M.: Mobile Adaptive Information Systems on MANET: What We Need as Basic Layer? In: Proc. of MMIS 2003. (2003)
[9] Padberg, J., Ehrig, H., Hoffmann, K.: Formal Modeling and Analysis of Flexible Processes in Mobile Ad-Hoc Networks. Bulletin of the EATCS **91** (2007) 128–132