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Modelling and Performance Evaluation With TimeNET 4.4

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Abstract. The paper presents the current status of the software tool TimeNET. It supports modeling and performance evaluation of stochastic models, including extended deterministic and stochastic Petri nets, colored stochastic Petri nets, and Markov chains as well as UML extensions. Among its main characteristics are simulation and analysis modules for stationary and transient evaluation of Petri nets including non-exponentially distributed delays, as well as a simulation module for complex colored models. Recent enhancements include algorithms for the efficient rare-event simulation of Petri nets, a new multi-trajectory hybrid simulation/analysis algorithm, and a net class for Markov chains.

Keywords: Modeling tool, TimeNET, stochastic Petri nets, colored Petri nets, performance evaluation

1 Introduction

TimeNET is a software tool for the modeling and performability evaluation with several variants of stochastic Petri nets including GSPNs, eDSPNs, and colored SCPNs (for definitions see e.g. [8]). In comparison to other related tools such as GreatSPN [1], SPNP [4], Möbius [3] and CPN Tools [5], it supports evaluation of models combining exponential and deterministic as well as more general non-exponentially distributed firing delays. Numerical analysis and simulation methods both for transient and steady-state solution have been implemented as well as structural analysis modules. Moreover, TimeNET supports colored stochastic Petri nets as well as rare-event simulation algorithms for these model classes. The token game can be run interactively or automatically to validate and test eDSPN and SCPN models.

The software architecture contains a Java graphical user interface, shell scripts controlling analysis processes, and evaluation algorithms implemented mainly in C++ running as background processes. The tool runs in 32 and 64 Bit Linux and Windows environments. It is available free of charge for non-commercial use from http://timenet.tu-ilmenau.de/. Successful applications reported in the literature include communication systems, reliability evaluation, manufacturing and transportation, and business as well as logistics processes. Numerous papers including application examples are listed in the tool's web page.

2 New Features in TimeNET 4.4

This paper presents changes in TimeNET since the previous tool description [9], which covered version 4.1 in 2012. More in-depth coverage of history and tool architecture can be found in [9, 8].

Among the various changes in the tool since 2012, the scientifically most relevant extensions cover rare-event simulation methods motivated by reliability applications. Such examples will otherwise lead to unacceptably long run times because of the number of events to be simulated until enough samples of interest are generated.

An example application model is shown in Figure 1, describing a sample network architecture of the Avionic Full-Duplex Ethernet used in modern aircraft [11]. Reliability of such systems is a major concern, and a model-based analysis can show that the required end-to-end message delays are achievable for a certain setup. This is a typical example of industrial systems in which numerical analysis is impossible because of the large state space and concurrent non-Markovian activities, while standard simulation would need exceedingly high run times to compute the results with acceptable statistical accuracy.

While rare-event simulation is a well-known technique for the efficient evaluation of highly reliable systems, the available algorithms require significant background knowledge or apply to quite restricted model classes only. Our goal is to make such methods available for tool users, aiming at semi-automatic algorithm configuration using the available model information.

TimeNET implements a variant of the splitting technique RESTART, which is now extended by automatically deriving an estimation of the result via perfor-

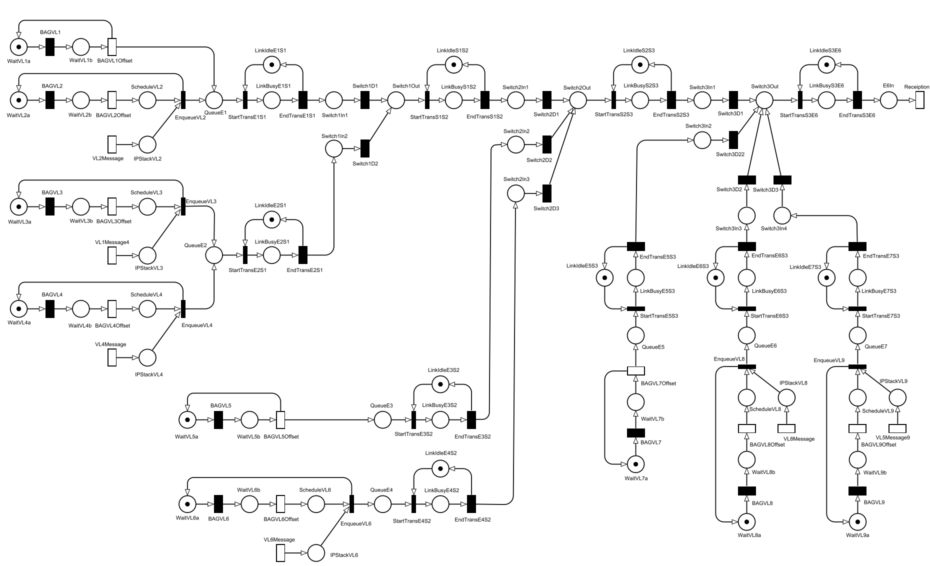

Fig. 1. AFDX network model

mance bounds to calculate splitting factors, and an online distance estimation using structural properties analyzed via a linear programming problem [12]. This avoids the user-defined importance function otherwise necessary. In addition to that, an automated importance sampling method for rare-event SPN simulation proposed by Daniël Reijsbergen [6] is currently being integrated in the tool.

A new multi-trajectory simulation algorithm for eDSPNs [10] has been implemented recently. It combines elements of simulation and numerical analysis for the first time such that the behavior of the performance evaluation method follows either method just depending on the amount of trajectories (state particles) being stored and followed. This allows a mixed approach, avoiding the pitfalls of simulation (rare events) and numerical analysis (large state spaces).

Another addition is a simulation method for eDSPN models with incompletely known initial state. Automated and distributed optimization of eDSPN and SCPN models [2] have been implemented as a separate add-on. The initial transient phase of steady-state SCPN simulations is now detected and deleted. Modern random number generators for simulations (Mersenne twister) are used instead of standard library implementations now.

Model extensions include a new model class stochastic automata that allows to specify discrete-time and continuous-time Markov chains for teaching purposes. A standard stationary solution has been implemented. UML state charts extended with stochastic elements based on the MARTE profile and energy usage stereotypes have been added as another model class [7]. Such models can be edited and translated into eDSPNs models for the analysis of embedded systems. Model parameters (or definitions) are now unified without a numeric type and may depend on each other in most model classes. Reward definitions for performance measures have been unified for eDSPNs and SCPNS, and extended by transition throughputs (impulse rewards). Color-dependent SCPN model parts were extended and streamlined, including performance measures, arc expressions, and firing delays.

GUI and user interaction have been improved with several details, including a graphical visualization of the reachability graph, and adaptive mouse pointer appearance when adding objects.

User support outside the tool itself is undergoing a major update in 2017: A new integrated support web page will be made available until summer 2017. It contains installation and background information, example models, FAQs, daily and by-version downloads, and user feedback for bug reports etc.

Efficiency and quality of the internal **software development** process are now supported by a build and test server that automatically and regularly checks out the complete source code on different supported systems, compiles the tool, tests it, and makes new builds available for download. The tool is now available as a native 64 Bit application.

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References

1. Bernardi, S., Bertoncello, C., Donatelli, S., Franceschinis, G., Gaeta, G., Gribaudo, M., Horvàth, A.: GreatSPN in the new millenium. Research Report 760/2001, Universität Dortmund (Germany) (Sep 2001), tools of Aachen 2001, Int. Multiconf. on Measurement, Modelling and Evaluation of Computer-Communication Systems, pages 17–23.
2. Bodenstein, C., Zimmermann, A.: TimeNET optimization environment - batch simulation and heuristic optimization of SCPNs with TimeNET 4.2. In: 8th Int. Conf. on Performance Evaluation Methodologies and Tools (VALUETOOLS 2014). Bratislava, Slovakia (Dec 2014)
3. Courtney, T., Gaonkar, S., Keefe, K., Rozier, E., Sanders, W.: Möbius 2.3: An extensible tool for dependability, security, and performance evaluation of large and complex system models. In: IEEE/IFIP Int. Conf. on Dependable Systems Networks. pp. 353–358 (2009)
4. Hirel, C., Tuffin, B., Trivedi, K.S.: SPNP: Stochastic Petri nets. Version 6.0. In: Computer Performance Evaluation, Modelling Techniques and Tools — 11th Int. Conf., TOOLS 2000. Lecture Notes in Computer Science, vol. 1786, pp. 354–357. Springer Verlag, Schaumburg, IL, USA (2000)
5. Jensen, K., Kristensen, K.L., Wells, L.: Coloured Petri nets and CPN tools for modelling and validation of concurrent systems. Int. Journal on Software Tools for Technology Transfer (STTT) 9(3–4), 213–254 (2007)
6. Reijsbergen, D., Boer, P.T., Scheinhardt, W., Haverkort, B.: Automated rare event simulation for stochastic Petri nets. In: Joshi, K., Siegle, M., Stoelinga, M., D'Argenio, P.R. (eds.) Quantitative Evaluation of Systems, Lecture Notes in Computer Science, vol. 8054, pp. 372–388. Springer Berlin Heidelberg (2013)
7. Shorin, D., Zimmermann, A.: Extending the software tool TimeNET by power consumption estimation of UML MARTE models. In: Proc. 4th Int. Conf. on Simulation and Modeling Methodologies, Technologies and Applications (SIMULTECH 2014). pp. 83–91. Vienna, Austria (Aug 2014)
8. Zimmermann, A.: Stochastic Discrete Event Systems. Springer, Berlin Heidelberg New York (2007)
9. Zimmermann, A.: Modeling and evaluation of stochastic Petri nets with TimeNET 4.1. In: Proc. 6th Int. Conf on Performance Evaluation Methodologies and Tools (VALUETOOLS). pp. 54–63. Corse, France (2012)
10. Zimmermann, A., Hotz, T., Canabal Lavista, A.: A hybrid multi-trajectory simulation algorithm for the performance evaluation of stochastic Petri nets. In: Quantitative Evaluation of Systems (QEST 2017) (2017), (accepted for publication)
11. Zimmermann, A., Jäger, S., Geyer, F.: Towards reliability evaluation of AFDX avionic communication systems with rare-event simulation. In: Proc. Probabilistic Safety Assessment & Management Conference 2014 (PSAM 12). pp. 1–12. Honolulu, Hawaii, USA (Jun 2014)
12. Zimmermann, A., Maciel, P.: Importance function derivation for RESTART simulations of Petri nets. In: 9th Int. Workshop on Rare Event Simulation (RESIM 2012). pp. 8–15. Trondheim, Norway (Jun 2012)