Guest editorial

The papers in this issue of *Performance Evaluation* all deal with performability modelling of computer and communication systems. This was the topic of the *First International Workshop on Performability Modelling of Computer and Communication Systems* (PMCCS-1), held 7–8 February 1991, at the University of Twente, Enschede, the Netherlands.

Introduction

Over the last decade the use of fault-tolerant distributed computer and communication systems has steadily grown. With this increase in usage also the need for applicable quantitative evaluation techniques and tools came up. It is due to the efforts of many researchers from all over the world that over the last decade performability modelling and analysis has become a mature topic that deserves attention in its own.

In February 1990, at the IFIP WG 7.3 meeting in Lattrop, the idea of a workshop totally dedicated to performability was developed. As it was, and still is now, research contributions in the performability area are presented at a large variety of conferences, such as ACM Sigmetrics, IEEE Fault-Tolerant Computer Systems, IEEE Petri Nets and Performance Models, Performance etc., as well as in a broad range of related journals. By organizing a workshop especially dedicated to performability modelling and its applications, we hoped to bring together active researchers in the field, so as to maximize the information exchange among them.

In the early organization phase already, many people responded positively to the idea of a performability workshop. The initiative was also supported by the IFIP working group on performance analysis (IFIP WG 7.3). We were also encouraged by the quick and positive responses of leading scientists in the field, J.F. Meyer, K.S. Trivedi and E. de Souza e Silva to give an invited presentation. We are grateful to them for having

provided the workshop program with a very firm basis.

The organization and success of a workshop heavily rely upon support and positive input from both the participants, the authors and the local organizations involved. In these respects we are most grateful to all of the participants for enthusiasm, we like to thank the Tele-Informatics and Open Systems group of the University of Twente for providing the opportunity and accommodation for arranging the workshop, and we are most indebted to Ms. Ellen ter Brugge for handling the administrative overhead of the workshop.

The PMCCS1 workshop presentations

At the workshop, a total of 17 papers were presented. Here we wish to state that only a small number next to the three invited papers could be selected, taking into account the general scope of *Performance Evaluation*. The general opinion of all the participants was most positive. Let us briefly summarize all contributions.

R. Lepold presented the paper *PENPET: A New Approach to Performability Modelling using Stochastic Petri Nets*. In his presentation he discussed the conceptual modelling framework underlying the software tool PENPET (Petri Net Based Performability Evaluation Tool). The tool has been designed to automate the difficult and tedious process of constructing Markov reward performability models of large computer systems.

A. Tai, J.F. Meyer and H. Hecht presented a paper entitled *A Performability Model for Real-Time Software*, which deals with the performability analysis of software systems, operating in a particular environment. Both the system and the environment are modelled by stochastic activity networks. Given that there are still design faults left in the software, the overall system's ability to fulfill real-time constraints is evaluated.

The paper *Performability Analysis of the Integrated Software-Hardware Components of Real-Time Parallel and Distributed Systems* by S.M.R. Islam and H.H. Ammar dealt with the evaluation of the performability of interacting software components running on parallel machines. Due to the interdependencies between the software components running in different hardware models, the failure of one module may force another module to rollback. Based on stochastic Petri nets, large Markov models are generated which are then analyzed using Laguerre transforms.

In the paper *Fault Injection Simulation*, A.P.A. van Moorsel, B.R. Haverkort and I.G. Niemegeers discuss a new fast simulation technique that can be applied to derive performance metrics that are

highly influenced by very rarely occurring events such as failures. Prerequisite to the method is that the rare event occurrence probabilities are known in advance, which is, e.g., often the case when studying communication media. Simulation speed-up factors of order 100 are reported.

B.R. Haverkort and I.G. Niemegeers, in their paper *On the Mutual Performance-Dependability Influence in Dynamic Queueing Networks*, discuss how various influence relations between a system its performance and its dependability characteristics can be modelled conveniently by means of dynamic queueing networks.

In *Product Forms and Simple Bounds for Reliability Networks*, N.M. van Dijk outlined the following two results for reliability networks: (i) a

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His research interests involve exact product form expressions, simple performance estimates and analytic error bound results for queueing and communication networks and their application to telecommunications, computer networking and manufacturing.

Boudewijn R. Haverkort was born in Lichtenvoorde, the Netherlands in 1964. He received a M.Sc. and a Ph.D. degree computer science, both from the University of Twente, Enschede, the Netherlands, in 1986 and 1991, respectively.

In 1986 he stayed half a year at the University of Dortmund, West-Germany, where he worked on the performance modelling of local-area network interconnection structures. Since January 1990, Dr. Haverkort is an assistant professor in the Tele-Informatics and Open Systems group of the department of computer science at the University of Twente, where he teaches undergraduate courses on performance analysis of communication networks and computer systems.

His current research interests include performance, dependability and performability evaluation of fault-tolerant and distributed computer/communication systems, software tools for these evaluations, as well as formal specification techniques (Lotos) and their integration with performability analysis.

Dr. Haverkort, who is a member of the IEEE Computer Society and the ACM, received a Koninklijke/Shell research prize early 1991.

Ignas G. Niemegeers (S'70-M'78) was born in Gent, Belgium, in 1947. He received the M.Sc. degree in electrical engineering from the Rijksuniversiteit Gent in 1970. In 1972 he received the M.Sc. degree in computer engineering and in 1978 the Ph.D. degree from Purdue University, West Lafayette, IN.

From 1978 to 1981 he was a system design engineer at Bell Telephone Mfg. Co., Antwerp, Belgium, where he was involved in the design of the DPS 1500 system, a high capacity X.25 packet switching network. From 1981 to 1986 he was an associate professor in the Department of Electrical Engineering, at the University of Twente, Enschede, the Netherlands. Since 1986 he has been a full professor in the Tele-Informatics and Open Systems group in the Department of Computer Science of the University of Twente.

His present research interests are architectures for broadband integrated communication infrastructures, parallel processing in communication switches, performance analysis, and performability of fault tolerant systems.

condition and insight from which one can conclude steady-state product form expressions for the configuration of down components, and (ii) a methodology to use these insights to obtain simple and guaranteed bounds for both transient and steady state measures for reliability networks that fail this condition. Examples included a series-parallel system and a hierarchical database system.

P. Wartenhorst and F.A. van der Duyn Schouten in their presentation *Availability Analysis of a Two-Unit Standby System* showed how the embedding technique of Markov decision theory can be applied to obtain availability results for standby-repair systems with a control limit rule for repair. Their results extended existing results for the state independent and non-preemptive case to state-dependent and preemptive case, while further application of this technique seems promising.

In *Optimal Routing with Resequencing*, Z. Rosenberg and S. Ayoun studied an optimal routing problem of a single server queue from which jobs are dispatched to one of two heterogeneous parallel communication channels under the requirement of resequencing in arrival order upon completion. A holding time criterion is used. A threshold policy is proven to be optimal which shows that the routing decision is independent of the resequencing queue. In addition, explicit expressions are provided to determine the critical threshold values.

In the contribution *Numerical Studies of scheduled Maintenance* by R. Vallejos Campos, E. de Souza e Silva and H.R. Gail, the importance of preventive maintenance policies during operation is argued to improve the availability or performability of a system. Based on a recently proposed Markovian technique to evaluate scheduled maintenance policies, the impact of different parameters for performability measures of systems subject to periodically scheduled maintenance is addressed. Particularly, the importance of a detailed model and state description was made apparent.

O.J. Boxma, W.P. Groenendijk and J.A. Weststrate in their presentation *Optimal Scheduling of Preventive and Corrective Maintenance using Polling Systems*, propose a polling model to determine the optimal routing of a maintenance crew concerned with both preventive and corrective

maintenance. A polling table was provided that minimizes a particular performance measure for the system.

Selected papers

The three invited speakers were given *carte blanche* for their papers. In fact, they were encouraged to give survey like presentations and write their papers accordingly. Four other papers were chosen out of the regular presentations. We briefly mention the selected papers here.

The invited paper by J.F. Meyer, entitled *Performability: A Retrospective with Some Pointers to the Future*, surveys the historical development of the concept of performability as it grew out of the need to access the combined performance and dependability of fault-tolerant computer systems.

The invited paper by E. de Souza e Silva (co-authored by H.R. Gail), entitled *Peformability Analysis of Computer Systems: From Model Specification to Solution*, covers both specification techniques that have been developed for the construction of Markov reward models (thereby emphasizing on the object oriented approach followed in Tangram) as well as the randomization technique for the solution of these models.

The invited paper by K.S. Trivedi (co-authored by J.K. Muppala, S.P. Woolet, and B.R. Haverkort), entitled *Composite Performance and Dependability Analysis*, addresses the use of Markov reward models for performability modelling. Various performability measures and reward choices are surveyed and enlightened by many examples. The Markov reward models for performability are compared with completion time models and with models of queues with server breakdowns.

In the paper *A Combined Queueing Network and Stochastic Petri Net Approach for Evaluating the Performability of Fault-Tolerant Computer Systems*, H. Szczerbicka proposes a method to evaluate the performability of fault-tolerant computer systems by means of queueing networks. However, those systems aspects that can not be modelled adequately by these queueing networks are modelled separately by means of stochastic Petri nets. The results of these separate analyses are subsequently embedded in the overall queueing model, thereby preserving the first and second

moment of the throughput. In this way, dependability influenced performance metrics are obtained.

V. Grassi and L. Donatiello in their paper *Sensitivity Analysis of Performability* investigate the sensitivity of the expected cumulative reward over a finite time horizon with respect to system parameters such as the breakdown and repair rates. The results are based on differentiation of the uniformized expressions of the underlying Markov chain model which also lead to error bounds when numerically evaluating the sensitivity.

In *Distribution of the Minimal Completion Time of Parallel Tasks in Multi-Reward Semi-Markov Models*, A. Bobbio and L. Roberti model the completion time of parallel tasks in a randomly varying servicing system as the barrier hitting time in a multi-reward semi-Markov model. Different reward measures are dealt with such as maximum or specific job completion times. It is shown that whenever the barrier levels have phase type distributions that then also the distribution of the hitting times have phase type distributions. This result leads to recursive computational schemes.

G. Rubino and B. Sericola in their paper *Interval Availability Analysis using Operational Periods*

develop a computational method to evaluate the availability of semi-Markovian systems during a given time-interval. This method relies upon independence assumptions of successive operational and non-operational periods. Also the cumulative operational times up to the n -th operational period or failure are hereby analyzed.

Epilogue

By the responses in the planning phase of the workshop, by the various discussions during the workshop and by the presented papers, both the practical interests from different disciplines as well as the fundamental theoretical problems underlying the topic performability have only made more apparent that performability has grown into a mature topic which is more than open for fundamental research. By organizing this workshop and selecting papers for this special issue we primarily aimed to encourage further steps in this direction.

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