EDITORIAL

ANALYTICAL MODELS AND APPLICATIONS

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Performance modelling and evaluation has become an important part of the design, maintenance and development process of complex systems. There have been a huge amount of published performance studies applied for wide range of applications in computer, communications, manufacturing, transportation and many other areas. In these performance studies, wide range of methodologies have been used. However, most of these published studies are based on simulation modelling and/or the numerical solution of Markov models. Analytical models based on queueing network or matrix geometric solutions have also been used for different systems and scenarios but in much smaller volume.

Simulation is an efficient tool for studying detailed system behaviour but it becomes costly in manpower needed to develop the software and/or in computing time if high accuracy results are required. This is typical for systems with events happening at different time scales. Markov models on the other hand provide more flexibility in producing numerical results for many interesting performance measures. Nevertheless, the numerical solution of Markov models may suffer from several drawbacks, such as state space explosion limiting the analysis to only small systems and restrictive assumptions of independent Poisson arrival processes for all types of homogeneous and uniformly distributed traffic types with exponentially distributed service times.

Analytical models, if they exist, provide a powerful tool for performance evaluation. Their power stems from their capability to provide fast and accurate solutions given that a set of appropriate assumptions are made. As the range and the complexity of investigated systems increases, new advances on these methodologies become imminent. These advances cover all aspects of analytical and stochastic methodologies including the exact or approximate, transient or steady state, but also the analytical or numerical solutions.

This special issue is a second of series of special issues [1] of the International Journal on Simulation; Science, Systems, and Technology devoted to present novel articles on advances in many of the above listed directions. The papers in this issue are organised into two parts. The first part presents novel results in queueing theory. Exact and approximate results are presented for three very important queueing systems and networks with a relevant potential of application in modern computer and communications systems. These are queueing systems in random enviroment, fluid queues, and G-networks. The second part presents novel applications of queueing and analytical models to modern computer and communication areas including Wormwhole interconnection networks, the Internet, the Third Generation (3G) mobile networks and the priority queues.

All the papers in this issue are extended versions of a set of selected papers presented either within the special analytical track of the UK Simulation Workshop held in Cambridge, UK in April 2003 or at the 10th International Conference on Analytical and Stochastic Modelling Techniques and Applications (ASMTA'03) that took place in Nottingham, UK in June 2003 as part of the European Simulation Multiconference. The ASMTA conference has attracted a large number of high quality papers in all areas of analytical, numerical and stochatic modelling. Another group of selected high quality papers from the conference will be considered for publication in a future issue of this series.

In the first paper by **Economou**, the author presents a general model for continuous-time Markov chains representing queueing systems in random environment. First, he studies the relationship between its equilibrium distribution and the Palm (or embedded) distributions at certain environmental change epochs. The achieved results enable him to obtain the equilibrium distribution of the continuous-time model in terms of the equilibrium distribution of a discrete-time process. This is useful in simulation studies where one can extract information for the continuous-time model by recording the state of the system only in environmental change epochs. Then,he obtains necessary and sufficient conditions that ensure a product-form stationary distribution for the model. As an illustration, the results are applied to study the stationary distributions of Jackson networks in random environment. The author extends his study for models that do not satisfy the product-form conditions. Here, he develops a product-form approximation, which is proved to be very good for models evolving in a slowly changing random environment.

Barbot and Sericola in their paper consider a fluid system composed of multiple buffers in series. The first buffer receives fluid from a finite superposition of independent identical on-off sources. The active and silent periods of sources are exponentially distributed. The ith buffer releases fluid in the $(i+1)$th buffer. Assuming that the input rate of one source is greater than the service rate of the first buffer, the output process of each buffer can be modeled by an on-off source with the active period distributed as the busy period of an M/M/1 queue. For $i \geq 2$, the stationary content distribution of the ith buffer is obtained by the use of generating functions which are explicitly inverted.

The third paper of the special issue considers the newly introduced G-Networks [2] which became the subject of intensive research. **Bocharov and D'Apice** present some results on an exponential queuing network with signals and impatient service. Positive customers and signals arrive to each node according to a Poisson process. When the service is finished in a node, a positive customer moves to another node with fixed probabilities either as a positive customer or as a signal, or quits the network. Every signal is activated during a random exponentially distributed amount of time. Activated signals with fixed probabilities either move a customer from the node they arrive to another node or kill a positive customer. Each customer can be served in a node at most a random time ("patient" time) distributed exponentially. When the patient service is finished, the customer with fixed probabilities either goes to another node or quits the network. Product form solution has been obtained for stationary state probabilities of such G-network in the case of positive customers processed by a single server in each node as well as in the case of an analogous symmetrical G-network in which service rate of a positive customer in a node depends on its state.

The second part, although presents theoretical results, is more devoted towards the application of analytical models in computer and communications networks. The paper by **Shahrabi and Ould-Khaoua** deals with the latency in Wormhole routed interconnection networks. Several analytical models have been proposed in the literature for wormhole-routed multicomputers. However, all these models have been discussed in the context of unicast communication and there has been comparatively little activity in the area of analytical modelling of collective communication algorithms like broadcast. According to the authors, this paper presents the first analytical model to predict latency of unicast and broadcast messages in wormhole-routed hypercubes with deterministic routing. Results obtained through simulation experiments show that the model exhibits a good degree of accuracy in predicting message latency under different working conditions.

Providing quality of service in the Internet has always been an important issue. It is anticipated that congestion may still be an occasional matter of fact under the Differentiated Services Framework. Based upon this observation, **De Meer and Retzekes** propose a Quality of Service architecture that uses segmented adaptation mechanisms on whole traffic aggregates, in order to allow for the co-operation between network operators in case of congestion. Service curves are introduced as a tool for defining Quality of Service levels internally in each Service Level Agreement. Edge routers are responsible for the smooth movement between the predefined service curves in case of congestion. Moreover, a domain administrative entity (Service Level Agreement Broker) is used in order to monitor the adaptation/recovery procedures and the processes associated with resource trading and billing. They examine the structure and operation of the Service Level Agreement Broker and some signalling issues related to the proposed architecture. The simulations show the existence of congestion effects under certain conditions in DiffServ domains, as well as the impact of aggregated congestion control architectures to congested domains.

One of the main features of the third Generation (3G) mobile networks is their capability to provide different classes of services; especially multimedia and real-time services in addition to the traditional telephony and data services. These new services, however, will require higher Quality of Service (QoS) constraints on the network mainly regarding delay, delay variation and packet loss. Additionally, the overall traffic profile in both the air interface and inside the network will be rather different than used to be in today's mobile networks. Therefore, providing QoS for the new services will require more than what a call admission control algorithm can achieve at the border of the network, but also continuous buffer control in both the wireless and the fixed part of the network to ensure that higher priority traffic is treated in proper way. This paper by **Awan and Al-Begain** proposes and analytically evaluates a buffer management scheme that is based on multi-level priority and Complete Buffer Sharing (CBS) policy for all buffers at the border and inside the wireless network. The analytical model is based on the G/G/1/N censored queue with single server and R ($R \geq 2$) priority classes under the Head of Line (HOL) service rule for the CBS scheme. The traffic is modelled using the Generalised Exponential distribution. The paper presents an analytical solution based on the approximation using the Maximum Entropy (ME) principle.

Biographies

Irfan Awan received his PhD from the Department of Computing, Bradford University, UK (1997). During his PhD studies, he developed cost effective approximate analytical tools for the performance evaluation of complex queueing networks. His research mainly focused on service and space priorities in order to provide quality of service and to control the congestion in high speed networks. After completing his PhD he joined GIK Institute of Engineering Sciences and Technology, Pakistan as an assistant professor and has been teaching various subjects related to network communications for two years. In 1998 and 1999, he spent summer terms with the Performance Modelling Group, University of Bradford. In 1999 he joined the Department of Computing, University of Bradford as a Lecturer and is a module coordinator for "Concurrent and Distributed Systems" and "Intelligent Network Agents". His recent research lies in developing analytical tools for the performance of mobile and high speed networks.

Khalid Al-Begain is Professor of Mobile Networking and Head of the Mobile Computing and Networking Research Centre at the School of Computing of the University of Glamorgan in Cardiff/Wales/UK. He received his High Diploma (1986), the Specialisation Diploma of Communication Engineering (1988) and his Ph.D. degree in Communication Engineering (1989) from the Technical University of Budapest in Hungary. From 1990 to 1996 he held the position of a Assistant Professor at the Department of Computer Science of the Mu'tah University in Jordan. Then he became an Associate Professor at the same university. In 1997 he moved to the Department of Computer Science at the University of Erlangen-Nuremberg in Germany as Alexander von Humboldt research fellow. Later, he spent one year as Guest Professor at the Chair of Telecommunications, Dresden University of Technology, Germany. From 2000-2003, he has been Senior Lecturer and Director of Postgraduate Research in the Department of Computing of the University of Bradford, UK before moving to Glamorgan. He co-authored the book "Practical Performance Modelling" published by Kluwer Academic Publishers in Boston and more than 100 journal and conferences papers. He is senior member of the IEEE and many other scientific organisations. He also served as Guest Editor for a previous special issue of this Journal on Analytical and Stochastic Modelling Techniques. Since 2003, he became the Conference Chair for the annual ASMTA (Analytical and Stochastic Modelling Techniques and Applications) Conference (ASMTA'03 in Nottingham,UK and ASMTA'04 in Magdeburg, Germany). He also manages several research projects funded by the EPSRC and EU. His research interests are performance modelling and analysis of computer and communication systems, analytical modelling and design of wireless mobile networks and multicast routing in mobile IP networks. He is also interested in Mobile Computing research.

The last paper of this issue by **Goh and Thng** presents a new priority queue implementation for the pending event set. This article describes a novel and innovative approach using traditional linked lists with a multi-tier structure to develop an efficient priority queue that offers near O(1) performance by uniquely eliminating the resize operation. This new implementation, named Multi-tier Linked List (MList), is shown experimentally to be, on average, at least 100% faster than all the current priority queues.

References

[1] K. Al-Begain (Editor): Analytical and Stochastic Modelling Techniques; A Special Issue of the *International Journal on Simulation: Science, Systems and Technology*, Vol. 3, No. 3-4, Dec. 2002.

[2] E. Gelenbe: Product Form Queueing Networks with Positive and Negative Customers, *Journal of Applied Probability*, Vol. 28, pp. 656-663.