

Book Reviews

N.M. van Dijk:
**Queueing Networks and Product
Forms**

John Wiley & Sons, Chichester-New York-Brisbane-Toronto-Singapore, 1993, pp. xx, 270, ISBN 0-471-92848-8. The book is published in "Wiley-Interscience Series in Systems and Optimization".

Queueing networks are used as a tool to evaluate the performance of stochastic service systems arising in different fields e.g. manufacturing, computer networks, telecommunication. This book is devoted to the single aspect of product forms which is generally perceived as narrow from a practical point of view. There is a natural question: why? The author's answer is the following: from one side one intends to indicate that this area is not so narrow from either theoretical or practical viewpoint. Furthermore, none of existing books is devoted only to product-form results for queueing networks. This book aims to provide simple, practical insights by which both researchers and practitioners are able to recognize when closed-form expressions can be expected for steady-state probabilities and it shows how these insights can be used to obtain simple bounds for non-solvable systems when such features as blocking, overflow and breakdowns are taken into account. The book contains eight chapters, a detailed notation list and literature background by chapters, the bibliography of the topic.

In the preliminary Chapter 0 some practical motivation is provided by a brief discussion of typical features that arise in manufacturing systems, computer networks, telecommunication

and broadcasting; they are considered in more detail in the course of the book. Chapter 1 contains an informal introduction and discussion of the use of balance equations describing the key concepts that are essential throughout the book to evaluate the performance of queueing networks by exact expressions: the steady-state or equilibrium distribution, a global balance equation which determines this distribution, a more detailed concept of partial as opposed to global balance. A cash-balance example illustrates the actual use and results of these concepts in terms of concrete system protocols, a hierarchy of partial balances is established. Chapter 2 presents basic properties of exponentiality that can be used to model the behaviour of queueing network by rates, the use of balance is formally justified by the presentation of different continuous-time Markov chains. A convenient discrete-time renewal result is given and a communication example illustrates how the combination of an appropriate concept of partial balance equations and the discrete renewal result may lead to a simple product-form expression also without exponentiality assumptions. There are introduced the mixtures of Erlang distributions and it is argued that the results obtained for them remain valid for arbitrary distributions.

Chapter 3 introduces and illustrates the properties of the concept of station balance by means of studying classical Erlang and Engset models, a two-station assembly-line example, closed and open Jackson networks with random routing. Unfortunately, as illustrated by a simple assembly-line example with finite capacity constraint at one of the stations which is common in practical situations, these insights may directly tell us that the station balance cannot hold. More generally, the

station balance property may typically be destroyed by blocking due to finite buffers, breakdowns and dynamic or state-dependent routing such as overflow control. Exact product-form expressions are not generally applicable in more realistic situations in which these features appear. However, insights into station balance may also be utilized on an intuitive basis to modify a system without product form into one with product form to obtain a quick approximation of orders of magnitude or simple secure lower and upper bounds. Such results can be of interest for engineering purposes: as the first indication of orders of magnitude, qualitative and quantitative insights, optimization and design purposes, sensitivity analysis. This approach is called practical and requires merely verification of the station balance equations either constructively solving these equations or by simply substituting a guessed product form. Here, by simple insights into the system behaviour, one can tell whether station balance can be expected or it is destroyed and why. Such method is strongly advocated as the first tool for practical application to obtain exact results as in Chapter 3 or simple bounds as in Chapter 4. But it is no longer applicable when more complex mechanisms are involved such as state-dependent service accelerations, job-interdependent delays or randomized blocking.

Chapter 5 studies the concept of station balance in a more formal way for arbitrary networks with load-dependent routing and servicing. A characterization of station balance is derived in terms of local solutions of state-dependent traffic equations. These local solutions can often be expressed in concrete system parameters. In case of communication and broadcasting the price of the high level of integration is a substantially increased complexity at design stages as well as a higher degree of interdependency between input and output nodes, switch transmission devices,

sources and end users. This usually leads to the following conflict. On one hand, at both the design and operational stages an evaluation of performance becomes very important as the implementation and operational costs are very high. On the other hand, performance evaluation becomes much more difficult, if not impossible, when the various interdependencies are to be taken into account. Chapter 6 shows that the station principle can also be operated on this more global level to obtain product-form results for queueing networks with finite capacity constraints of clusters of stations rather than on an individual station. Chapter 7 is the application chapter.

The presentation is both intuitively and formally illustrated by several examples from different application areas. The author wishes to apologize to mathematicians for heuristic steps without mentioning formal technicalities and to practitioners for not going into detailed technicalities that are certainly important for actual modelling and performance evaluation in practice. At the same time both theoreticians and practitioners can appreciate the primary interest of this book to provide a commonsense and unifying insight into the phenomenon of product forms and their potential. The book fully corresponds to its purpose, it answers two questions: 1. How to determine quickly whether one can expect a simple expression and which type of expression to look for; 2. How to realize which particular system protocol or characteristic will destroy the closed-form result and how possibly to obtain a reasonable approximation or a secure bound.

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