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Book Review

Reliability and Availability Engineering: Modeling, Analysis, and Applications

Kishor S. Trivedi and Andrea Bobbio. 2017, 726 pages, ISBN 9781107099500

Reviewers: Xiwei Qiu and Yuanshun Dai

School of Computer Science and Engineering, University of Electronic Science and Technology of China, Chengdu, 610054, China

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This book provides systemic and comprehensive treatment of reliability and availability (i.e., dependability) models of complex computing, communication, and network systems. It will be known as not only a classic textbook for any scholar who studies dependability modeling and analysis but also a technical reference for any engineer who develops dependability assurance techniques. This book is divided into six parts: 'Part I. Introduction', 'Part II. Non-state-space models (combinatorial models)', 'Part III. State-space models with exponential distributions', 'Part IV. State-space models with non-exponential distributions', 'Part V. Multi-level models', and 'Part VI. Case studies'. Some parts are further sub-divided into chapters. Thus, the book is well-organized so that readers can easily and explicitly find pertinent approaches and methods and understand how to solve a concrete problem of dependability modeling, evaluation, and analysis. We believe this book makes significant contributions to dependability engineering, as detailed below:

1. A Comprehensive Guide to Notations, Definitions, and Measures

This book collects and describes consistent notation, rigorous definitions, and attributes or measures used in dependability engineering in Part I. This ensures that the reader can have a clear understanding of this subject to avoid confusion in later chapters. Part I is sub-divided into three chapters. Chapter 1 introduces several examples of dependability evaluation and clearly defines various aspects of dependability. Chapter 2 gives a comprehensive review of dependability evaluation from two important approaches, that is, modeling and measurement. Chapter 3 presents several metrics for quantifying dependability and basics of probability relevant to dependability modeling.

2. Comprehensive Guide to Models and Algorithms for Analyzing Reliability and Availability

In Parts II, III, and IV, the authors introduce all commonly used model types and algorithms that can be employed in analyzing reliability and availability. All the mathematical models are explained in great detail, and all the algorithms are elaborated on thoroughly. Therefore, you can always find feasible and appropriate modeling methods and relevant algorithms to efficiently solve various reliability and availability problems that arise in different real-world environments. All these models and algorithms have rigorous formulation derivation for verification and validation. Part II (Chapters 4-8) is dedicated to the non-state-space models. Part III (Chapters 9-12) and IV (Chapters 13-15) are devoted to the state-space models with exponential distributions and non-exponential distributions, respectively.

In Part II, the authors discuss non-state-space models that can be solved using independence assumption without generating the underlying state space. These model types are often known as combinatorial models. Each model type is illustrated with copious examples. Chapter 4 considers the application of the reliability block diagrams in series-parallel systems and k-out-of-n systems. Chapter 5 discusses binary probabilistic networks, binary probabilistic weighted networks, and multi-state networks that can be used to analyze network reliability. Powerful static analysis methods including fault tree analysis and state enumeration are also studied in Chapters 6 and 7, respectively. Meanwhile, an important redundancy technique for real-life systems, i.e., dynamic redundancy with cold standby, warm standby, and hot standby, is discussed in Chapter 8. This is done without explicitly considering the underlying state space. Such dynamic redundancy is widely

adopted by modern computing systems, such as grid computing and cloud computing systems. Chapters 7 and 8 can be considered bridge chapters between non-state-space (Part II) and state space models (Part III).

In real system reliability and availability models, independence does not often hold. State space models are capable of dealing with such dependence. Random failure times and repair times are often approximated to have the exponential distribution. To deal with such cases, Part III discusses the state-space models represented by homogeneous continuous-time Markov chains (CTMC). Chapter 9 focuses on steady-state analysis of CTMC for availability evaluation, while Chapter 10 emphasizes transient-state analysis for reliability evaluation. In Chapter 11, performance analysis via CTMC is studied. Chapter 12 considers an important high-level specification paradigm for CTMC – stochastic Petri nets and stochastic reward nets.

Part IV deals with more complex situations where the exponential assumption needs to be relaxed. Chapter 13 presents non-homogeneous CTMC and efficient numerical solution methods. Chapter 14 studies transient and stationary solutions of Semi-Markov and Markov regenerative processes. States of such stochastic processes have non-exponentially distributed sojourn times. Chapter 15 is dedicated to the phase-type distributions, which is an important class of random distributions that can accurately approximate any general distribution while maintaining analytical tractability.

3. Flexible Sub-Modeling and Integrating Approach to Deal with Complex Situations

Parts II, III, and IV cover not only classical models and algorithms but also timely topics and analytical techniques contributing to dependability engineering. However, in realistic environments, modern computing systems, such as hybrid cloud systems, Internet of Things (IoT) systems, and large-scale network systems, are very complex. Therefore, it is hard to build a monolithic model for such a complex system, since then both the generation and the solution of the state space become impossible. Fortunately, Part V provides flexible sub-modeling and integrating approaches to deal with such complex situations. Chapter 16 explores how to integrate different sub-models in a hierarchical manner, that is, a flexible multi-level modeling approach that can efficiently avoid the complexity of generating and solving an overall monolithic model. It combines the efficiency of no-state-space models with the capability of state space models to provide an efficient approach to complex system models. Interdependence among sub-models often requires a more sophisticated approach beyond just the use of hierarchy. Chapter 17 develops a fixed-point iteration method to derive the reliability and availability of systems with cyclic dependence among sub-models.

4. Numerous Examples and Real-life System Models

This book provides not only numerous solved examples but also real-life problems for the reader to further practice on their own. Across the book, all mathematical concepts, theoretical models, and solution algorithms are illustrated through numerous examples. Some of the examples run over multiple chapters. This can efficiently help the reader grasp the combined application of multiple techniques provided by this book. The book also discusses many real-life problems in detail. For example, the network reliability of the real current return network subsystem of Boeing 787 is analyzed using a new bounding algorithm. This bounding algorithm and its implementation in the SHARPE software package is now routinely used by Boeing for the current return network subsystem of all airplanes. Hardware/software co-design models are also illustrated to analyze the dependability of IBM's SIP service system. Meanwhile, Part VI further gives comprehensive case studies of more real-life systems. The book also exposes the important topic of combining reliability and performance models, i.e., performability modeling and analysis. This provides a meaningful and useful instruction of multi-criteria modeling, which is increasingly important for modern systems since multiple metrics (e.g., reliability, availability, performance, survivability, and security) may need to be considered together.

Our overall impression is that *Reliability and Availability Engineering* is an excellent book that puts all the aspects of the dependability engineering, particularly, *theoretical models, analysis methods, and practical applications*, in one place. It is bound to become an indispensable guide and reference for a broad range of students, researchers, and practicing engineers interested in scientific studies and the practice of dependability engineering. We are told that the authors have nearly completed a solution manual for the unsolved problems in the book and that they will soon complete a set of power point slides of each chapter. We believe that the software package SHARPE could be very useful to help solve problems and examples in the book. We are also aware that a Chinese translation of the book is underway.