Book Reviews

Queueing Systems, Vol. I: Theory and **Vol. II: Computer Applications**—L. Kleinrock (New York: Wiley 1976, 417 pp. and 549 pp., $19.95 and $24.95, respectively)

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This two-volume set will make an excellent text on queueing theory and its engineering applications, suitable for graduate courses in such departments as electrical engineering, computer (or information) science, and operations research. Included at the end of each chapter are a number of exercise problems. Both volumes will also be valuable reference books to system analysts engaged in modeling computer systems and computer communication networks, as well as to those who conduct research in queueing theory.

To follow the material, the reader must have a working knowledge of probability and random processes at the first year graduate level. This prerequisite is reviewed in Appendix II of Vol. I. Although the reader deficient in knowledge of computer systems may not be handicapped in digesting the material presented in Vol. II, there is a potential danger, however, that such readers may develop a biased view concerning the subject matter of computer system modeling. The material treated in Vol. II, Chapter 4, "Computer time-sharing and multiaccess systems," covers only that portion of computer performance modeling that allows elegant solutions by queueing theory. A large number of modeling and performance issues for computer systems are too complex to be handled by existing queueing theory. More frequently than not, a realistic simulation and/or measurements of a real system will be the only viable approach to real performance issues. In this respect, Chapters 5 and 6 of Vol. II on computer-communication networks provide a more balanced treatment of its application field.

With these cautions in mind, the reader will find in these books a wealth of information on queueing theory and its applications. They include a number of exciting and new results, and there are motivating examples and illustrating figures which make them more readable than most of the existing books on queueing theory.

VOLUME I

Chapter 1, "Queueing systems," is an introductory chapter. Chapter 2, "Some important random processes," reviews those random processes pertinent to queueing systems, e.g., Markov chains, Markov processes, and birth-death processes. Chapter 3, "Birth-death queueing systems in equilibrium," deals with a class of queueing systems with Poisson arrivals (possibly with queue-dependent rate) and exponential service times. In Chapter 4, "Markovian queues in equilibrium," the author discusses queueing systems with Erlangian service time or interarrival time, bulk arrival systems, and the like. Networks of queues with exponential servers are discussed in the last section. Chapter 5, "The queues $M/G/1$," and Chapter 6, "The queue $G/M/m$," are treated using the imbedded Markov chain technique. Most of the material presented in Chapters 2 through 6 are found in many previously published books, but Kleinrock's treatment is perhaps the most comprehensive.

Chapter 7, "The method of collective marks," is a unique chapter. The z-transform and Laplace-transform, originally introduced in Chapter 2 as formal solution techniques, are now given a physical and probabilistic interpretation. The last chapter of Vol. I is Chapter 8, "The queue $G/G/1$," which deals with Lindley's theory for solving the waiting time distribution in the $G/G/1$ queue. The mathematical problem is reduced to an integral equation of Wiener–Hopf type and its corresponding spectral factorization problem. The reader of this TRANSACTIONS will recognize an analogy between Lindley's theory and Wiener's filtering theory.

VOLUME II

This volume contains advanced materials of queueing theory plus three application chapters. Chapter 1, "A queueing theory primer," is a 22-page summary of Volume I. Chapter 2, "Bounds, inequalities and approximations," is perhaps the most novel and worthwhile chapter in this two-volume series. Exponentially tight bounds on the tail of the waiting time distribution are discussed with much the same spirit as the bounding arguments that the information theorist applies to the probability of decoding errors: the Chernoff bound finds a beautiful application in queueing theory also! The author also gives a comprehensive account of the diffusion process approximation and heavy traffic theory as applied to queueing systems. Chapter 3, "Priority queue," is also a unique and valuable chapter. Much of the material is based on the author's earlier work: conservation laws, time-dependent priorities, and optimal bribing for queue position. Chapter 4, "Computer time-sharing and multiaccess systems," is a collection of analytic models as applied to computer system modeling. Sections 4.1–4.10 deal with various CPU scheduling disciplines: RR (round-robin), FB (foreground/background), PS (Processor-sharing), and their combinations. These models are solved by assuming a single resource (i.e., the CPU) with Poisson arrivals, namely, in the $M/G/1$ queue setting. Extensions of these results in the framework of multiple resource models (i.e., queueing network models) are among the most important unsolved research problems. Sections 4.11–4.13 discuss recent advances in queueing network models and applications to computer performance models, in particular to models of interactive and time shared systems and models of multiprogramming systems.

The remaining two chapters, Chapters 5 and 6, are entitled "Computer-communication networks," with the subtitles "Analysis and design," and "Measurement, flow control and ARPANET traps," respectively. These chapters serve as an excellent introduction as well as providing a major reference source to those who work in this field. The first five sections of Chapter 5 describe what a packet-switching network is and what the performance issues are. An overview of the ARPANET is given as a case example. Section 5.6, "Delay analysis," is a simple application of the exponential queueing network discussed in earlier chapters. Section 5.7, "The capacity assignment (CA) problem," and Section 5.8, "The traffic flow assignment (FA) problem," are both concerned with optimization problems. A number of simplifying assumptions and heuristics are introduced to obtain practical solutions. The CA and FA problems and their joint optimization are topical research issues and should arouse the interest of readers of this TRANSACTIONS. Section 5.11, "Satellite packet switching," discusses primarily the ALOHA random-access and multiplexing technique. The chapter ends with a section of "Ground-radio packet switching," which is the author's current research effort at UCLA.

Chapter 6 is essentially a case-study report on the measurement of the ARPANET in which the author was involved for the past several years. It gives a vivid description of how measurements of the ARPANET led to the identification of various performance problems, and how various control procedures and related protocol evolved.

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Quantum Detection and Estimation Theory—Carl W. Helstrom (New York: Academic Press, 1976, ix + 309 pp., $24.50)

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This lucid account of quantum detection and estimation theory is the first book on the ten-year old subject, statistical theory of quantum signal detection, written by its pioneer, Professor Helstrom. The book "... addresses two groups of readers. The first includes communications engineers and scientists and students of communication theory who need to cope with basic problems arising in communication with optical signals. The second group of readers comprises physicists interested in the foundations and applications of quantum mechanics ..." Since the readers of this TRANSACTIONS usually fall in the first group and since the foundation questions of quantum theory are still controversial, this review is written primarily for the first group of readers.

At optical frequencies, quantum effects play a significant role in determining the performance of communication and detection systems. On the one hand, an otherwise deterministic signal at a receiver has to be replaced by a statistical quantum description. On the other hand, the qualitative and quantitative nature of the quantum noise that a receiver suffers is strongly dependent on the quantum measurement that the receiver performs on the received optical signal. In designing a receiver, one has to make a choice between the various possible but mutually exclusive quantum measurements, such as measurement of phase versus measurement of amplitude, to extract efficiently the relevant information. In a quantum detection theory, one therefore needs to develop quantum mechanical receiver models and to consider the measurement optimization problems that are additional to the conventional classical (nonquantum) theories. Helstrom's book shows how such a revision of classical detection and esti-