

FINITE-SOURCE QUEUEING SYSTEMS AND THEIR APPLICATIONS

A Bibliography

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Abstract

The aim of the present paper is to give a collection of some important results of finite-source queueing systems and their applications in solving several practical problems. Its main contribution is the bibliography of recent papers and books collected from different databases and private sources. It concentrates on both theoretical and practical developments and tries to supplement of several review papers devoted mainly to cyclic queues or manufacturing system modeling.

Keywords: machine interference, machine-repairman problem, finite-source, finite population, quasi-random input, state-dependent arrivals, multi-terminal systems, multiprogrammed systems, multiprocessor systems, renewable systems, multiple access protocols, reliability.

As it is well-known, there are many practical situations when the request's arrivals do not form a renewal process, that is, the arrivals may depend on the number of customers, request, jobs e.t.c staying at the service facility. This happens in the case of **finite-source queueing systems**.

Let us consider some specific examples in order of their appearance in practice.

Example 1 *Consider a set of N machines that operate independently of each other. After a random time they may break down and need repair by one or several operatives (repairmen) for a random time. The repair is carried out by a specific discipline and after having been served each machine renew his operation. It is assumed that the server can handle only one machine at a time. Besides the usual main characteristics in reliability theory we would like to know the **distribution of the failure-free operation time** of the whole system.*

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Example 2 Suppose a single unloader system at which trains arrive which bring coal from various mines. There are N trains involved in the coal transport. The coal unloader can handle only one train at a time and the unloading time per train is a random variable. The unloader is subject to random breakdowns when it is in operation. The operating time and the time to repair a broken unloader are also random variables. The unloading of the train is resumed as soon as the repair of the unloader is completed. An unloaded train returns to the mines for another load of coal. The time for a train to complete a trip from the unloader to the mines and back is assumed to be a random variable, too.

Example 3 N terminals request to use of a computer (server) to process transactions. The length of time that the terminal takes to generate a request for the computer is called "think" time. The length of time from the instant a terminal generates a transaction until the computer completes the transaction (and instantaneously responds by communicating this fact to the user at the terminal) is called "response time". We would like to know, for example, the rate at which transactions are processed (which in steady-state equals the rate at which they are generated) is called "throughput", which is one the most important performance measures showing the system's processing power.

Example 4 Let us consider a memory system where N disk units share a disk controller (server) and transmit information when they find the controller idle. Unsatisfied requests are repeated after a disk's rotation which can be modelled as a constant repetition interval.

Example 5 In trunk mobile systems, telephone lines are interfaced with the radio system at the repeaters which serve dispatch type mobile subscribers and telephone line users. Let us consider a system which serves two different types of communication traffic (i) dispatch traffic has short average service time and (ii) interconnect traffic of telephone line users. Both types of users are assumed to arrive from a finite population. The dispatch users are allowed to access all repeaters while interconnect users can occupy only a fixed number of repeaters. A sharing service algorithm to derive blocking probabilities of dispatch and interconnect users and average dispatch delay is to be find.

Example 6 Let us examine the dynamic behavior of a local area network based on the non-persistent Carrier Sense Multiple Access with Collision Detection (CSMA/CD) protocol. In such a network a finite number, say N , of users (or active terminals) are connected by a single channel (bus). Under the specific protocol, if a terminal has a message ready for transmission, the terminal immediately senses the channel to see whether it is idle or busy. If the channel is sensed busy, it re-senses the channel after a random amount of time. On the other hand, if the channel sensed is idle, it starts transmitting the message immediately. Due to non-zero propagation delay, within a certain time interval after the terminal starts transmitting the message, other terminals (if any) with messages ready for transmission may also sense the channel idle and transmit their messages. This phenomenon is referred to as a collision. Each terminal

involved in a collision abandons its transmission and re-sense the channel at a later time as if it had sensed a busy channel. A collision usually lasts for a certain amount of time during which no terminals are allowed to transmit, that is, a recovery time is needed by the channel to be free again. This kind of system can be modeled as retrial queueing system with server's vacation.

As we could see all the above mentioned examples have a common characteristic: We have a queueing system in which requests for service are generated by a finite number N of identical or heterogeneous sources and the requests are handled by a single or multiple server(s). The service times of the requests generated by the sources are random variables. It is assumed that the server can handle only one request at a time and uses specified service discipline. New requests for service can be generated only by idle sources, which are sources having no previous request waiting or being served at the server. A source idle at the present time will generate a request independently of the states of the other sources after a random time with given distribution.

It is easy to see, that in homogeneous case this system can be considered as a closed queueing network with two nodes one with an infinite server (source) and another one with a single or multiple servers (service facility). Similarly, in heterogeneous case it can be viewed as a closed network consisting of $N + 1$ nodes where each request has it own node where to it returns after having been serviced at the " central " node representing the service facility, see for example [47].

Depending on the assumptions on source, service times of the requests and the service disciplines applied at the service facility, there is a great number of queueing models at different level to get the main steady-state performance measures of the system. It is also easy to see, that depending on the application we can use the terms *request, customer, machine, message, job* equivalently. The above mentioned models (problems) are referred to as *machine repair, machine repairmen, machine interference, machine service, unloader problem, terminal model, quasi-random input processes, finite-source or population models* , respectively.

The aim of the present paper is to give a collection of some important results of finite-source queueing systems and their applications in solving several practical problems. The main contribution is the bibliography of recent papers and books collected from different databases and private sources. It concentrates on both theoretical and practical developments and tries to supplement of earlier review papers by Koenigsberg [53], Stecke [75], Stecke and Aronson [76] devoted mainly to cyclic queues and manufacturing system modeling, respectively. Some recent comprehensive bibliography of books and survey papers on queueing systems should also be mentioned, for example, Dshalalow [22], Gertsbakh [32], Kovalenko [62], Papadopoulos and Heavey [68], Prabhu [71], Syski [79], Takagi and Boguslavsky [86].

It should also be mentioned that well-known book of Takagi [84] provides an organized and unified presentation of the analysis techniques for $M/G/1//N$ systems without and with vacations. The $M/G/1K/N$ and $M/G/m/m/N$ models are also treated. In Takagi [85] discrete-time $Geo/G/1/K/N$ systems are analyzed. To the best knowledge of the author these books are the most comprehensive ones on this special topic in the existing literature.

Despite of the effort to compile an exhaustive bibliography of the literature in this area, there is a little doubt that a number of related papers may have unintentionally been omitted. It is hoped that these represent a small percentage of all the relevant papers.

The organization of the paper is as follows. 10 bibliographies are available concerning their contents where the selection criteria was their subject not the solution method used by in deriving the results.

In *General References* we list books and papers that are concerned with basic queueing systems including finite-source models or their applications. As a consequence, several works are devoted to manufacturing systems, computer and telecommunication performance evaluation, reliability theory, construction and mining, retrial queues, algorithms and approximation for queueing systems.

Machine interference problem, Machine service and repair model, Machine-repairman problem list papers with these classical applications. Analytical, numerical, different approximation and simulation techniques are used to obtain the particular characteristics.

The bibliography of *Finite-source or state-dependent arrival systems* deals with more comprehensive situations and with more general applicability of the models.

Multiprogrammed or multiprogramming systems, Multiprocessor systems collect papers with these special problem formulation and solution techniques.

A separate bibliography is devoted to *Multiple access protocols* where mainly retrial queueing models with or without vacations are used to investigate very recent telecommunication systems.

In *Terminal and multiterminal systems* queueing models with these applications are listed.

Finally, *Repairable and renewable systems* provides an extensive bibliography of reliability analysis systems with finite number of units with different setups. Here the main goal of investigations of the distribution of the failure-free operation time of the system.

This kind of classification and listing cannot be complete. Nevertheless, it is believed that the present lists are more comprehensive and reliable than any other existing bibliographies.

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