A Novel Approach for Analyzing Single Buffer Queueing Systems with State-Dependent Vacation and Correlated Input Process under Four Different Service Disciplines

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ABSTRACT

The author presents performance analysis of a single buffer multiple-queue system. Four different types of service disciplines (i.e., non-preemptive, pre-emptive repeat different, state dependent random polling and globally gated) are analyzed. His model includes correlated input process and three different types of non-productive time (i.e., switchover, vacation and idle time). Special cases of the model includes server with mixed multiple and single vacations, stopping server with delayed vacation and stopping server with alternating vacation and idle time. For each of the four service disciplines the key performance measures such as average customer waiting time, loss probability, and throughput are computed. The results permit a detailed discussion of how these performance measures depends on the customer arrival rate, the customer service time, the switchover time, the vacation time, and the idle time. Moreover, extensive numerical results are presented and the four service disciplines are compared with respect to the performance measure. Previous studies of the single buffer multiple-queue systems tend to provide separate analysis for the two cases of zero and nonzero switchover time. The author is able to provide a unified analysis for the two cases. His results generalize and improve a number of known results on single buffer multiple-queue systems. Furthermore, this method does not require differentiation while it is needed if one uses the probability generating function approach. Lastly, the author’s approach works for all single buffer multiple-queue systems in which the next queue to be served is determined solely on the basis of the occupancy states at the end of the cycle time.

Keywords: Correlated Input Process, Cycle Time, Globally Gated Service, Non-Preemptive Service, Preemptive Service, Single Buffer Multiple Queues System, State Dependent Random Polling System, Stopping Server

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1. INTRODUCTION

Polling system is a system of multiple queues attended by a single server in a predetermined cyclic order. Polling systems have been extensively studied during the last six decades because they provide a meaningful mathematical model for performance evaluation of computer, communication, transportation and manufacturing systems that operate under are source sharing mechanism. According to the survey by Vishnevskii, & Semenova (2006), there are over 700 papers on polling systems published by 1996. The standard reference for polling systems is Takagi (1986). Boon, van der Mei & Winands (2011) and Grillo (1990) provides surveys of applications of polling systems. Furthermore, Shiozawa, Takine, Takahashi, & Hasegawa (1990) used polling systems with correlated customer arrival process to analyze a token ring with correlated input process. In response to the evolution of communication technology, some generalizations of polling systems have been considered. These generalizations deal with non-cyclic server allocation to queue policies which includes priority, random, Markovian server allocation policy, or more generally, non-deterministic server allocation policy. With respect to the buffer size at each queue, these generalizations of polling systems can further be classified as finite buffer or infinite buffer systems. Before introducing our model, we group the related literature on polling system deals with non-cyclic server allocation policies under the buffer system classification. For the infinite buffer case, see Kleinrock, & Levy (1988), Lee (1997), Boxma, & Weststrate (1989), Lye, & Seah (1992), Srinivasan (1991), Fayolle, & Lagouttes (1995) and, Zorine (2014). For the finite buffer case, see Chung, Un, & Jung (1994), Lee (2013), Lee, & Sunjaya (1996) and Takine et al. (1988,1989,1990), Takagi (1985,1991). The finite buffer generalization of a polling system is a loss system. It is usually harder to analyze because provision for overflows have to be taken into consideration. In order to compute the system performance measures, one typically needs to solve a huge system of linear equations. Furthermore, previous studies of the single buffers multiple queues system tend to provide separate analysis depending on whether switchover time is needed when the server moves from one queue to another (i.e., zero or nonzero switchover times).

In this paper, we propose a simple approach to modeling and analyzing single buffer multiple queues system. By introducing a new definition for cycle time, we are able to provide a unified analysis for the two cases of model with zero and nonzero switchover times. It also allows us to model correlated input process, server’s idle time, and state dependent server’s vacation policy. Specifically, we assume that customers arriving according to a correlated Poisson input process and join a queue that is determined by the service they require. Three different types of nonproductive time: switchover, vacation and idle time are included in our model. No customers will be served if the server is engaged in one of these three types of non-productive times. Special cases of our model include server with mixed multiple and single vacations, stopping server with delayed vacation and stopping server with alternating vacation and idle time. The type of customers being served during one cycle is controlled by the server allocation or service disciplines. For four different disciplines, namely the non-preemptive, pre-emptive repeat different, state dependent random polling and globally gated disciplines we compute several performance measures which include the loss probability, throughput, mean cycle time, and the expected delay observed by a customer. In order to compute these performance measures our analysis requires the solution of a system of $2^m - 1$ linear equations where $m$ is the number of queues in the system. However, this computational problem seems to be inherent in the exact analysis of multiple queue systems with single buffers (e.g., Takagi (1991,1993), Takine et al., (1990), Kofman (1993), Chung et al., (1994), Lee (2013) and Lee, & Sunjaya (1996)).

It is well known that many problems in computer, communication and manufacturing systems (e.g., Takagi (1997), Boon et al., (2011))
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