Analysis of Single Buffer Random Polling System With State-Dependent Input Process and Server/Station Breakdowns

Thomas Y.S. Lee, Department of Information and Decision Sciences, University of Illinois, Chicago, IL, US

ABSTRACT

Models and analytical techniques are developed to evaluate the performance of two variations of single buffers (conventional and buffer relaxation system) multiple queues system. In the conventional system, each queue can have at most one customer at any time and newly arriving customers find the buffer full are lost. In the buffer relaxation system, the queue being served may have two customers, while each of the other queues may have at most one customer. Thomas Y.S. Lee developed a state-dependent non-linear model of uncertainty for analyzing a random polling system with server breakdown/repair, multi-phase service, correlated input processes, and single buffers. The state-dependent non-linear model of uncertainty introduced in this paper allows us to incorporate correlated arrival processes where the customer arrival rate depends on the location of the server and/or the server’s mode of operation into the polling model. The author allows the possibility that the server is unreliable. Specifically, when the server visits a queue, Lee assumes that the system is subject to two types of failures: queue-dependent, and general. General failures are observed upon server arrival at a queue. But there are two possibilities that a queue-dependent breakdown (if occurs) can be observed; (i) is observed immediately when it occurs and (ii) is observed only at the end of the current service. In both cases, a repair process is initiated immediately after the queue-dependent breakdown is observed. The author’s model allows the possibility of the server breakdowns/repair process to be non-stationary in the number of breakdowns/repairs to reflect that breakdowns/repairs or customer processing may be progressively easier or harder, or that they follow a more general learning curve. Thomas Y.S. Lee will show that his model encompasses a variety of examples. He was able to perform both transient and steady state analysis. The steady state analysis allows us to compute several performance measures including the average customer waiting time, loss probability, throughput and mean cycle time.

KEYWORDS


1. INTRODUCTION

A special class of single server queueing models, commonly known as polling systems, is a system of multiple queues attended by a single server in a predetermined cyclic order. Polling systems have been extensively studied for the last three decades because of the applicability to the performance
evaluation of computer, communication, and production systems. The surveys of Takagi (1990), Vishnevskii and Semenova (2006) provides a good overview of applications of polling models to communication and production systems. Takagi (1990) provides a survey of the existing results up to 1990. Most of the previous works uses the M/G/1 vacation model for performance evaluation on polling systems. Typically, the analysis utilizes the stochastic decomposition property of M/G/1 queue with vacation to decompose the system into a set of single server queues with vacations and applied an iterative procedure. Vishnevskii and Semenova (2006) provides an updated survey of the existing results up to 2006. It is worth noticing that almost all papers on polling systems assumes that the customer arrival rate stays constant throughout a cycle, although it may vary per queue. Recently, in response to the evolution of communication/production technology, some generalizations of polling systems have been considered. One of these generalizations of polling system allows the customer arrival rate depends on the location of the server (Boxma, 1994; Boon, van Wijk, Adan & Boxma, 2010) or the server’s mode of operation (Nakdimon & Yechiali, 2003). Another generalization of polling system allows the possibility of breakdowns/repairs (Ibe & Trvedi 1990; Boxma, Weststrate, & Yechiali 1993; Kofman & Yechiali 1996; Nakdimon & Yechiali, 2003).

The finite buffer variation of polling system is a loss system. It is usually harder to analyze because provision for overflows has to be taken into consideration. In order to compute the system performance measures, one typically needs to solve a huge system of linear equations. However, this computational problem seems to be inherent in the exact analysis of multiple-queue systems with finite buffers (Takagi 1991; Chung, Un, & Jung 1994; Lee & Sunjaya, 1996; Lee, 2015). There are four papers in the open literature that considers polling systems with finite buffers and nondeterministic server allocation policy. Chung et al. (1994) study a Markovian polling system with independent Poisson input process and single buffers. Lee et al. (1996) study a random polling system with correlated input process and single buffers. Lee (2013) analyzes a polling system with periodic nondeterministic server allocation policy, Bernoulli feedback of customers, server timeouts, randomly time varying connectivity, correlated input processes, and single buffers. Lee (2015) analyzes four different type of server allocation to queue policies; pre-emptive, non-preemptive, globally gated and state dependent random polling. The state dependent random polling system analyze by Lee (2015) has the property that the server would never visit an empty queue given that the system is nonempty. To the best of our knowledge no one has study polling models with finite buffers with customer arrival rate depends on the location of the server or the server’s mode of operation.

In this paper, we introduce a new approach to modeling and analyzing random polling systems with single buffers, multi-phase service, server breakdowns/repairs, and state-dependent correlated input process. We consider two variations of single buffers: conventional system and buffer relaxation system. In the conventional system, each queue can have at most one customer at any time and newly arriving customers find the buffer full are lost. In the buffer relaxation system, this constraint may be relaxed as follows: a new customer may join the queue as soon as the current customer in the queue is being served by the server (Lee & Sunjaya, 1996). However, the server delays the processing of this newly arrived customer until the next polling instant. Therefore, the queue being served may have two customers, while each of the other queues may have at most one customer. In this paper, we will show that the analysis of the conventional single buffer system is directly applicable to the buffer relaxation system with very minor modification. A significant difference between our method and the traditional approach is that no detailed model (e.g., Poisson arrival process) is assumed. The uncertainties incurred by the system are characterized by what we call a state-dependent non-linear model of uncertainty (Lee, 1996; 1998, for a linear-quadratic model of uncertainty; Lee & Sunjaya, 1996; Lee, 2013) for a non-linear model of uncertainty). The state-dependent non-linear model of uncertainty introduced in this paper allows us to incorporate correlated arrival processes where the customer arrival rate depends on the location of the server and/or the server’s mode of operation into the polling model. Specifically, we develop state-dependent non-linear model of uncertainty for analyzing a polling system with random server allocation policy, state-dependent correlated input.
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