Optimal Thresholds of an Infinite Buffer Discrete-Time Two-Server System with Triadic Policy

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ABSTRACT

This paper analyzes a discrete-time infinite-buffer Geo/Geo/2 queue, in which the number of servers can be adjusted depending on the number of customers in the system one at a time at arrival or at service completion epoch. Analytical closed-form solutions of the infinite-buffer Geo/Geo/2 queueing system operating under the triadic (0, Q, N, M) policy are derived. The total expected cost function is developed to obtain the optimal operating (0, Q, N, M) policy and the optimal service rate at minimum cost using direct search method. Some performance measures and sensitivity analysis have been presented.

Keywords: Cost, Direct Search, Discrete-Time, Queue, Triadic Policy

INTRODUCTION

Discrete-time queuing models have received considerable growing interest during the last few decades due to their potential applications to a variety of slotted digital computer, communication systems. These queuing models are more accurate and efficient than their continuous-time counterparts to analyze and design digital transmitting systems. Extensive analysis of a wide variety of discrete-time queuing models have been reported in Bruneel and Kim (1993), Chaudhry (2000), Gravey and Hbuterne (1992), Hunter (1983), Takagi (1993), and Woodward (1994).

The queuing systems with control (threshold) policy in which the number of working servers can be adjusted one at a time at any arrival epoch or at any service completion epoch depending on the number of customers have been discussed by many researchers. Surveys of single-threshold continuous-time queues have been reported in Tadj and Choudhury (2005). The batch arrival M/G/1 queueing system with Bernoulli vacation schedule and two phases of service under an N policy have been discussed in Choudhury and Madan (2005). Choudhury and Paul (2006) studied an N policy of model with second optional channel for the batch arrival queue. An M/G/1 queueing system with server breakdowns and startup under NT policy was investigated by Ke (2006). Ke (2008)

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examined system characteristics and optimal two-threshold policy of a batch arrival $M/G/1$ queueing system with a modified $T$ policy. Ke and Chu (2008) derived the explicit distributions of the randomized $T$ and $N$ policies for the $M/G/1$ queueing system. Brouns and Van Der Wal (2006) have analyzed optimal threshold policies in a two-class preemptive priority queue. Choudhury and Dekker (2008) discussed an $M/G/1$ retrial queueing system with two phases of service subject to the server breakdown and repair. An $M/G/1$ queue with two phases of service subject to the server breakdown and delayed repair has been reported in Choudhury and Tadj (2009). Some related works have been reported in Wang (1995, 2003), Wang et al. (2004), Efrosinin (2008), and Tadj and Choudhury (2009). Cost framework for evaluation of information technology has been discussed in Pathak and Vidyarthi (2011).

Lin and Ke (2009) discussed the optimal operating policy for a controllable queuing model in which cost elements, arrival rate and service rate are all fuzzy numbers. Yang et al. (2008) analyzed an analytical optimization analysis of a randomized $T$ policy for an unreliable server $M/G/1$ queueing system with second optional service. The busy period distribution of an infinite capacity $M/M/2$ queueing system operating under triadic $(0, Q, N, M)$ policy has been discussed in Rhee and Sivazlian (1990). Wang and Wang (2002) studied the optimization of finite capacity $M/M/2$ queueing system under triadic $(0, Q, N, M)$ policy.

It has important applications in the design of control policies for high-performance computer and telecommunication systems, as well as manufacturing systems. With these two service rate control, the service resources or servers’ times can be better allocated to both primary and secondary uses to improve the operational economy of a multiserver queueing system. Fast food restaurant or supermarket cashiers, bank tellers, and telephone service operators are usually multi-task employees. Some of them might perform other secondary jobs when they are not busy and come back to serve waiting customers again when the queue becomes long again. This study is motivated by the popularity of these practical multi-task-server systems and the scarcity of the research work in this area.

The analysis of optimal thresholds of an infinite capacity two servers system with triadic policy in continuous-time has been carried out by Lin and Ke (2010). Discrete-time queueing systems are better suited than their continuous-time counterparts to evaluate system performance measures in computer and digital telecommunication networks, because of the clock-driven operation of those systems. Furthermore, the modeling of discrete-time queues is more involved and quite different from the analysis used for the corresponding continuous-time queueing models. The advantage of analyzing a discrete-time queue is that one can obtain the continuous-time results from it as a limiting case but the converse is not true.

This paper focuses on optimal thresholds of an infinite buffer discrete-time $Geo/Geo/2$ queueing system with triadic $(0, Q, N, M)$ policy. The inter-arrival and service times of customers are assumed to be independent and geometrically distributed. In the triadic policy, whenever there are no customers in the system, both servers are temporarily inactive until certain specified conditions arise. By using the recursive method the steady-state probabilities and some performance measures such as the average number of customers in the system and expected busy period with computational experiences have been presented. The results obtained in this paper are simple enough to be suitable for implementation in software packages developed for different management control systems where an automatic threshold control limits alert can be used as a warning mechanism.

The rest of the paper is organized as follows. First we devote to the description of the queuing model and its analysis for the steady-state probabilities at arbitrary epoch. System characteristics are discussed next. The cost analysis and optimization investigation is carried out, followed by the conclusion.
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