Hindawi Publishing Corporation
ISRN Probability and Statistics
Volume 2013, Article ID 508045, 6 pages
http://dx.doi.org/10.1155/2013/508045

Research Article

Note on a Binomial Schedule for an $M^X/G/1$ Queueing System with an Unreliable Server

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Received 26 May 2013; Accepted 7 July 2013

Academic Editors: M. Galea and J. López-Fidalgo

We consider in this paper a batch arrival queueing system with an unreliable server. If the queue is empty at a service completion, then the server becomes inactive and begins an idle period. However, if the queue is not empty, then the server will take at most K vacation before serving the next customer. A linear cost structure is developed for the system and the optimal value of K is obtained.

1. Introduction

As mentioned by Hlynka [1], "the use of queueing theory in the analysis and management of computer and telecommunication systems has by now a lengthy history, with many important contributions in the design and analysis of such systems. There appear to be no signs of this letting up opportunities abound for queueing to aid in developments in wireless networking, cloud computing, social networking, and many other modern application areas." The part of queueing theory concerned with the optimization of a queueing system is called the *optimal design and control of queues*. For a comprehensive survey of the research on this topic, see the book by Stidham [2] and the survey by Tadj and Choudhury [3].

The current paper presents yet another model that combines many known features to accommodate the increasingly complex computer networks and telecommunication systems. Meaningful and systematic scheduling requires sophisticated models to allocate the sometimes scarce available resources. Since most of these traits are standard and can be found in many papers, our review of the literature will make do with citations of surveys where the reader can find the relevant references.

The first feature of our model is the batch arrival process. Batch arrival models have been extensively used in an uncountable number of papers. A topical textbook is that of Chaudhry and Templeton [4].

The second feature of the model considered in this paper is that of an unreliable server. Indeed, a server, such as a machine, may break down while providing service. The service of the customer being served is then interrupted and cannot resume until the server is repaired. This is a very realistic assumption that models real-life situations. For a review of the research on this topic, the reader is referred to the broad survey of Tadj et al. [5].

Finally, the last characteristic of the model under consideration is that of a binomial vacation schedule. For a review of vacation queueing systems, see the comprehensive surveys of Doshi [6, 7]. In this class of queueing models, we find the models with Bernoulli vacation schedule where if the queue is empty at a service completion, then the server becomes inactive and begins an idle period. However, if the queue is not empty, the server will choose randomly to either take a vacation or process the next customer. If a vacation is chosen, it is followed by the service of the customer at the head of the queue. Various aspects of Bernoulli vacation models have been discussed by a number of authors; see the survey of

Ke et al. [8]. In real life, the vacation period may be used by the server to perform some other activities such as a maintenance operation or a quality control or even attend another queue of customers.

However, since there are different activities, we may have the server take more than one vacation, for a maximum number of, say, K vacations, instead of just one. Thus, we use in this paper the notion of a *binomial vacation schedule*. Under this policy, at a service completion and before serving the next customer, the server takes a series of vacations. The number of vacations is a binomial random variable. Each vacation has a random duration and corresponds to some auxiliary activity.

Having in mind the optimization of the queueing system, the decision variable will be the maximum number of vacations (auxiliary works) that the server should take before processing the next customer. That is, since we allow the server to take many vacations, what would the ideal number of vacations that will optimize the operations of the system be?

The rest of the paper proceeds as follows. The next section reviews some relevant results from a well-studied queueing system, the $M^X/G/1$. Section 3 shows how to extend the results of Section 2 to our model. Section 4 is concerned with the design of the optimization of the system. Finally, Section 5 concludes the paper.

2. Review of $M^X/G/1$ Queueing Model

The $M^X/G/1$ is a well-studied queueing system and its analysis is available in classical queueing textbooks; see for example Medhi [9]. We just recall here some of the results relevant to our study. Let λ denote the arrival rate. Customers arrive to the system in batches of random size X. The batches are independent and identically distributed (iid) random variables with probability mass function $a_k = P(X = k)$, $k \geq 1$, probability generating function (pgf) $a(z) = E[z^X]$, and moments $a_{(k)} = E(X^k)$, $k \geq 1$. The service times σ are iid random variables with common cumulative distribution function (CDF) $B(t) = P(\sigma \leq t)$, $t \geq 0$ ($B(0) = 0$), Laplace-Stieltjes Transform (LST) $B^*(\theta) = E[e^{-\theta\sigma}]$, $\mathrm{Re}(\theta) \geq 0$, and moments $b_{(k)} = E(\sigma^k)$, $k \geq 1$. We are assuming that the service process is independent of the arrival process. We use the following notation:

$Q(t)$: total number of customers in the system at any instance of time $t \geq 0$,

$T_0 = 0, T_1, T_2, \ldots$: sequence of the successive departure times of individual units,

$Q_n = Q(T_n^+)$, $n = 1, 2, \ldots$: total number of customers in the system at a customer departure time.

The imbedded process $\{Q_n; n = 0, 1, \ldots\}$ is a homogeneous Markov chain. Its transition probability matrix $P = (p_{ij})$ is a Δ_2 matrix; see Abolnikov and Dukhovny [10]. This fact can be used to derive the steady-state condition mentioned next. The process $\{Q(t); t \geq 0\}$ is a semiregenerative process relative to the sequence $\{T_n; n = 0, 1, \ldots\}$ of stopping times, and $\{(Q_n, T_n)\}$ is the corresponding imbedded Markov renewal process; see Çinlar [11]. The necessary and sufficient ergodicity condition is given by

$$\rho := \lambda a_{(1)} b_{(1)} < 1. \tag{1}$$

Let the equilibrium probabilities be $p_i = \lim_{n\to\infty} P(Q_n = i)$ and $\pi_i = \lim_{t\to\infty} P(Q(t) = i)$. We are interested in the PGFs $P(z) = \sum_{i=0}^{\infty} p_i z^i$ and $\pi(z) = \sum_{i=0}^{\infty} \pi_i z^i$. In the $M^X/G/1$ queueing system, Kendall's formula, most often referred to as *Pollaczek-Khinchin formula*, is

$$P(z) = \frac{B^*(\lambda - \lambda a(z))[a(z) - 1]\, p_0}{z - B^*(\lambda - \lambda a(z))}, \tag{2}$$

with

$$p_0 = \frac{1-\rho}{a_{(1)}}. \tag{3}$$

Also,

$$\pi(z) = a_{(1)} \frac{1-z}{1-a(z)} P(z), \tag{4}$$

which yields

$$\pi_0 = a_{(1)} p_0 = 1 - \rho. \tag{5}$$

For this queueing system, some performance measures are as follows.

(a) The expected number of customers in the system at an arbitrary instance of time:

$$L_{(1)} = \frac{2\lambda a_1^2 b_{(1)} + a_{(2)} - a_{(1)}}{2a_{(1)}} + \frac{\lambda}{2(1-\rho)}\left[\left(a_{(2)} - a_{(1)}\right) b_{(1)} + \lambda a_1^2 b_{(2)}\right]. \tag{6}$$

(b) The expected length of an idle period of the server in the equilibrium:

$$I_{(1)} = \frac{1}{\lambda}. \tag{7}$$

(c) The expected length of the busy in the equilibrium:

$$B_{(1)} = \frac{\rho}{\lambda(1-\rho)}. \tag{8}$$

(d) The expected length of the busy cycle:

$$C_{(1)} = \frac{1}{\lambda(1-\rho)}. \tag{9}$$

3. Extension to $M^X/G/1$ Queueing System with an Unreliable Server and Binomial Vacation Schedule

It is interesting to note that, using a modified service time distribution, it is possible to obtain all the results of the $M^X/G/1$ queue with unreliable server and binomial vacation schedule (that we will call the new system) from the results of the classical $M^X/G/1$ queueing system. Similar change of variable is common and was recently used by Blanc [12].

Let us first describe the new system and define the notation used. While providing service, the server may break down and it is assumed that breakdowns occur according to a Poisson process with positive rate α. When service interruption occurs, repair is provided with a random time, and as soon as the server is repaired, it immediately returns to provide this service until the queue is empty again. Service time is cumulative. This means that, on repair after an interruption, the service of the customer which was interrupted earlier is resumed from where it got interrupted and is not repeated from the very beginning. Let R denote the duration of the repair time. Then, R is distributed according to the CDF $R(t)$ with LST $R^*(\theta) = E[e^{-\theta R}]$ and finite moments $r_{(j)}$, $j \geq 1$.

To analyze this model, we introduce the *modified service time* H, which includes the actual service time and possible repairs. Then, H is distributed according to the CDF $H(t)$ with LST $H^*(\theta) = E[e^{-\theta H}]$ and finite moments $h_{(j)}$, $j \geq 1$. The modified service times, actual service times, and repair times are related through the following formula:

$$\begin{aligned} H^*(\theta) &= \sum_{n=0}^{\infty} \int_0^{\infty} e^{-\theta x} e^{-\alpha x} \frac{(\alpha x)^n}{n!} [R^*(\theta)]^n dB(x) \\ &= B^*(\theta + \alpha(1 - R^*(\theta))). \end{aligned} \tag{10}$$

We also assume that the server implements the binomial vacation schedule, so that, at the end of a service, the server has the option to take k ($k = 0, \dots, K$) vacations of random length V_k with probability

$$y_k = \binom{K}{k} p^k (1-p)^{K-k}, \quad k = 0, \dots, K. \tag{11}$$

Vacation times V are distributed according to the CDF $V(t)$ with LST $V^*(\theta) = E[e^{-\theta V}]$ and finite moments $v_{(j)}$, $j \geq 1$. Let G denote the duration of the *generalized service time* of a customer. Then, G is distributed according to the CDF $G(t)$ with LST $G^*(\theta) = E[e^{-\theta G}]$ and finite moments $g_{(j)}$, $j \geq 1$. Now, since with probability y_k the service required for a customer is

$$G = B + V_0 + \cdots + V_k, \tag{12}$$

then, we have

$$G^*(\theta) = H^*(\theta) \sum_{k=0}^{K} y_k [V^*(\theta)]^k, \tag{13}$$

where $H^*(\theta)$ is given by (10). We are assuming that the input process and service and repair times random variables are mutually independent of each other.

We now want to generalize the results (1)–(5) to the new system. Let $\rho_G = \lambda a_{(1)} g_{(1)}$. Using (13), we find

$$g_{(1)} = h_{(1)} + Kpv_{(1)}. \tag{14}$$

Now, using (10), we have

$$h_{(1)} = b_{(1)}(1 + \alpha r_{(1)}), \tag{15}$$

so that $\rho_G = \lambda a_{(1)}[b_{(1)}(1+\alpha r_{(1)}) + Kpv_{(1)}]$. Then, the necessary and sufficient ergodicity condition for the new system is given by

$$\rho_G := \rho(1 + \alpha r_{(1)}) + \lambda Kpa_{(1)}v_{(1)} < 1. \tag{16}$$

Let the equilibrium probabilities be $p_i = \lim_{n\to\infty} P(Q_n = i)$ and $\pi_i = \lim_{t\to\infty} P(Q(t) = i)$ and let the PGFs be $P(z) = \sum_{i=0}^{\infty} p_i z^i$ and $\pi(z) = \sum_{i=0}^{\infty} \pi_i z^i$. The results (2)–(5) are generalized to the new system as follows:

$$P(z) = \frac{G^*(\lambda - \lambda a(z))[a(z) - 1]p_0}{z - G^*(\lambda - \lambda a(z))}, \tag{17}$$

with

$$p_0 = \frac{1 - \rho_G}{a_{(1)}}. \tag{18}$$

Also,

$$\pi(z) = a_{(1)} \frac{1 - z}{1 - a(z)} P(z), \tag{19}$$

which yields

$$\pi_0 = a_{(1)} p_0 = 1 - \rho_G. \tag{20}$$

4. Optimal Management Policy

In order to design an optimal management policy for the service system, we first derive the relevant system characteristics.

4.1. System Characteristics. Using the results (6)–(9), we obtain the following performance measures.

(a) The expected number of customers in the system at an arbitrary instance of time is given by

$$\begin{aligned} L_{(1)} = &\frac{2\lambda a_1^2 g_{(1)} + a_{(2)} - a_{(1)}}{2a_{(1)}} \\ &+ \frac{\lambda}{2(1 - \lambda a_{(1)} g_{(1)})} \\ &\times \left[(a_{(2)} - a_{(1)}) g_{(1)} + \lambda a_1^2 g_{(2)} \right], \end{aligned} \tag{21}$$

where $g_{(1)}$ is found in (14), while $g_{(2)}$ is found from (13) as

$$g_{(2)} = h_{(2)} + 2Kph_{(1)} + K(K-1)p^2, \tag{22}$$

where $h_{(1)}$ is given by (15), while $h_{(2)}$ is derived from (10) as

$$h_{(2)} = b_{(2)}(1 + \alpha r_{(1)})^2 + \alpha b_{(1)} r_{(2)}. \tag{23}$$

(b) The expected length of an idle period of the server in the equilibrium is given by

$$I_{(1)} = \frac{1}{\lambda}. \tag{24}$$

(c) The expected length of the busy in the equilibrium is given by

$$B_{(1)} = \frac{\rho_G}{\lambda(1-\rho_G)}. \tag{25}$$

(d) The expected length of the busy cycle is given by

$$C_{(1)} = \frac{1}{\lambda(1-\rho_G)}. \tag{26}$$

Using (24)–(26), one can derive the following probabilities.

(e) The probability that the server is idle, as expected:

$$P_I = \frac{I_{(1)}}{C_{(1)}} = 1-\rho_G. \tag{27}$$

(f) The probability that the server is busy, as expected:

$$P_B = \frac{B_{(1)}}{C_{(1)}} = \rho_G. \tag{28}$$

Once all the performance measures of the system are available, it is possible to use them in order to design an optimal management policy. The goal is to derive the threshold level that yields the minimum system cost. We derive next an expression for the cost function, and then illustrate on a numerical example how the management policy is designed.

4.2. Total Expected Cost per Unit of Time. In order to develop an optimal management policy for the system, it is customary to write an expression for the total expected cost per unit of time incurred by the system and then obtain the optimal value of the threshold parameter. In our case, the decision variable sought to minimize the cost function is K, the maximum number of the server vacations. The total expected cost function per unit time is given by

$$\mathrm{TC}(K) = c_h L_{(1)} + c_o\frac{B_{(1)}}{C_{(1)}} + c_a\frac{I_{(1)}}{C_{(1)}} + c_s\frac{1}{C_{(1)}}, \tag{29}$$

where c_h is the holding cost per unit for each customer present in the system, c_o is the cost per unit time for keeping the server on and in operation, c_a is the startup cost per unit time for the preparatory work of the server before starting, and c_s is the setup cost per busy cycle. Upon substitution using (21) and (24)–(26), we get

$$\begin{aligned}\mathrm{TC}(K) &= c_h\left[\frac{2\lambda a_1^2 g_{(1)} + a_{(2)} - a_{(1)}}{2a_{(1)}} + \frac{\lambda}{2(1-\lambda a_{(1)}g_{(1)})}\right.\\ &\qquad\left.\times\left[\left(a_{(2)}-a_{(1)}\right)g_{(1)} + \lambda a_1^2 g_{(2)}\right]\right]\\ &\quad + (c_o - c_a - \lambda c_s)\lambda a_{(1)}g_{(1)}\\ &\quad + (c_a + \lambda c_s),\end{aligned} \tag{30}$$

where $g_{(1)}$ and $g_{(2)}$ are given by (14) and (22), respectively, and are functions of the decision variable K. Let $A_1 = (\lambda p a_{(1)})^2 c_h(1-v_{(1)}^2)$, $B_1 = \lambda p c_h[(a_{(1)}+a_{(2)})v_{(1)} + \lambda a_{(1)}^2(2h_{(1)} - 4h_{(1)}v_{(1)} - p)]$, $B_2 = 2\lambda p a_{(1)}v_{(1)}$, $B_3 = \lambda p a_{(1)}v_{(1)}(c_o - c_a - \lambda c_s)$, $C_1 = \lambda c_h[(a_{(1)}+a_{(2)})h_{(1)} + \lambda a_{(1)}^2(h_{(2)} - 2h_{(1)}^2)]$, $C_2 = 2(1-\lambda a_{(1)}h_{(1)})$, and $C_3 = \lambda a_{(1)}h_{(1)}(c_o - c_a - \lambda c_s) + (c_h/2)(a_{(2)}/a_{(1)} - 1) + c_a + \lambda c_s$. Then, (30) is rewritten as

$$\mathrm{TC}(K) = \frac{A_1K^2 + B_1K + C_1}{C_2 - B_2K} + B_3K + C_3. \tag{31}$$

4.3. Optimal Threshold Level K^*. The first-order optimality condition yields the critical value. Taking K as a continuous variable and calculating the first derivative of the expected cost per unit of time with respect to K, we find

$$\begin{aligned}\frac{d\mathrm{TC}(K)}{dK} &= \left(B_2\left(B_2B_3 - A_1\right)K^2\right.\\ &\qquad + 2C_2\left(A_1 - B_2B_3\right)K\\ &\qquad \left.+B_1C_2 + B_2C_1 + B_3C_2^2\right)\\ &\quad\times\left(\left(C_2 - B_2K\right)^2\right)^{-1}.\end{aligned} \tag{32}$$

Setting this expression to zero and solving for K yields the two roots

$$\begin{aligned}K_1 &= \frac{C_2}{B_2} + \frac{\sqrt{A_1C_2^2 + B_1B_2C_2 + B_2^2C_1}}{B_2\sqrt{B_2B_3 - A_1}},\\ K_2 &= \frac{C_2}{B_2} - \frac{\sqrt{A_1C_2^2 + B_1B_2C_2 + B_2^2C_1}}{B_2\sqrt{B_2B_3 - A_1}}.\end{aligned} \tag{33}$$

The second optimality condition allows deciding which value should be chosen. The second derivative of the expected cost per unit of time with respect to K is given by

$$\frac{d^2\mathrm{TC}(K)}{dK^2} = \frac{2\left(A_1C_2^2 + B_1B_2C_2 + C_1B_2^2\right)}{\left(C_2 - B_2K\right)^3}. \tag{34}$$

Note that the sign of the second derivative is the same as the sign of $C_2 - B_2K$. Direct substitution shows that

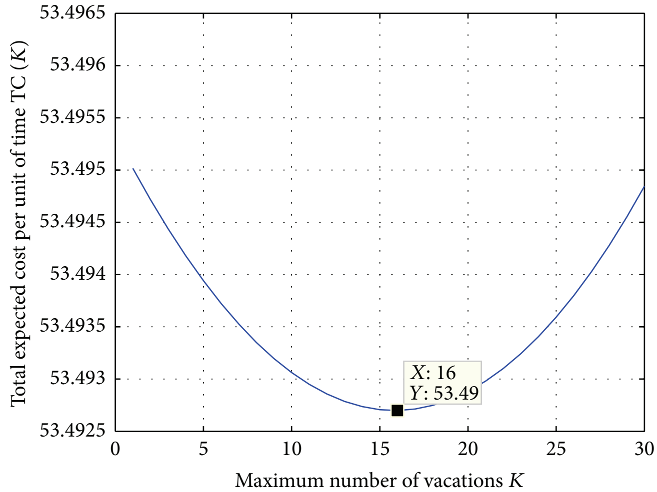

Figure 1: Plot of the total expected cost per unit of time as a function of the threshold level K.

Table 1: System parameters.

Parameter description	Values			
Customers arrival rate	$\lambda = 0.01$			
Batch arrival size parameter	$\varepsilon = 0.2$			
Server Bernoulli vacation probability	$p = 0.25$			
Server breakdown rate	$\alpha = 0.25$			
Server mean service time	$b_{(1)} = 0.7$			
Server mean repair time	$r_{(1)} = 0.5$			
Server mean vacation time	$v_{(1)} = 0.25$			
System unit costs	$c_h = 2$	$c_o = 50$	$c_a = 50$	$c_s = 300$

$C_2 - B_2K_1 < 0$ yielding the maximum cost value, while $C_2 - B_2K_2 > 0$ yielding the minimum cost value. Therefore, the optimal threshold level is the integer closest to

$$K^* = \frac{C_2}{B_2} - \frac{\sqrt{A_1C_2^2 + B_1B_2C_2 + B_2^2C_1}}{B_2\sqrt{B_2B_3 - A_1}}. \tag{35}$$

4.4. Numerical Illustration. We present numerical computations to illustrate the analytical results obtained. We also perform some sensitivity analyses to assess the effect of some system parameters on the optimal values of the threshold and cost function. Let us assume that the distributions involved are exponential. We recall that, in this case, the second moment is equal to twice the square of the first moment. For the size of the batch arrival, let us assume that it follows the shifted geometric distribution $a_k = P(X = k) = (1 - \varepsilon)\varepsilon^{n-1}$, $n \geq 1$. Then, $a(z) = E[z^X] = (1-\varepsilon)z/(1-\varepsilon z)$, $a_{(1)} = 1/(1-\varepsilon)$, and $a_{(2)} = (1+\varepsilon)/(1-\varepsilon)^2$. The illustrative system parameters chosen are listed in Table 1.

The variations of the total cost per unit of time as K changes are decpited in Figure 1. The curve is perfectly convex. The optimal value of K is $K^* = 16$ and the optimal value of the total expected cost per unit of time is $\mathrm{TC}(K^*) = 53.49$.

Table 2: Effect of the batch arrival size parameter ε on the optimal threshold level K^* and the optimal expected cost $\mathrm{TC}(K^*)$.

	ε								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
K^*	30	16	2	1	1	1	1	1	1
$\mathrm{TC}(K^*)$	53.21	53.49	53.86	54.34	55.02	56.05	57.78	61.32	72.61

Table 3: Effect of the arrival rate λ on the optimal threshold level K^* and the optimal expected cost $\mathrm{TC}(K^*)$.

	λ								
	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
K^*	16	30	30	30	30	30	30	30	30
$\mathrm{TC}(K^*)$	53.49	56.31	58.96	61.44	63.75	66.90	67.90	69.74	71.45

Therefore, in order to optimize the system operations, for this specific set of values of the system parameters, the server should take at most 16 vacations to perform different auxiliary works before serving the next available customer.

The expressions of the optimal threshold level and the total expected cost per unit of time are quite complex, and it is difficult to assess analytically the effect of the system parameter on these quantities. However, sensitivity analysis can be performed for a specific set of values of the system parameters. For example, suppose that we are interested in the effect of the arrival process on the optimal management policy. This can be done numerically by changing the values of the arrival process parameter and keeping all other parameters at the base values listed in Table 1. Tables 2 and 3 show that the optimal expected cost increases as the batch arrival size parameter ε or the arrival rate λ increases; however, the optimal number of vacations K^* decreases when ε increases and increases when λ increases.

5. Conclusion

We have considered in this paper a variant of the $M^X/G/1$ queueing system where the server may break down while providing service. Also, the server implements a binomial vacation policy. Using a suitable change of variable, we obtain from the $M^X/G/1$ performance measures for our queueing system. We then developed a linear cost structure and derived an expression for the optimal value of the maximum number of vacations the server should take at a service completion epoch before processing the next customer in line.

References

[1] M. Hlynka, "Myron Hlynka's Queueing Theory Page," 2013, http://web2.uwindsor.ca/math/hlynka/queue.html.

[2] S. Stidham, Jr., *Optimal Design of Queueing Systems*, CRC Press, Boca Raton, Fla, USA, 2009.

[3] L. Tadj and G. Choudhury, "Optimal design and control of queues," *Top*, vol. 13, no. 2, pp. 359–412, 2005.

[4] M. L. Chaudhry and J. G. C. Templeton, *A First Course in Bulk Queues*, A Wiley-Interscience Publication, John Wiley & Sons, New York, NY, USA, 1983.

[5] L. Tadj, G. Choudhury, and K. Rekab, "A two-phase quorum queueing system with Bernoulli vacation schedule, setup, and N-policy for an unreliable server with delaying repair," *International Journal of Services and Operations Management*, vol. 12, no. 2, pp. 139–164, 2012.

[6] B. T. Doshi, "Single server queues with vacations," in *Stochastic Analysis of Computer and Communication Systems*, H. Takagi, Ed., pp. 217–265, North-Holland, Amsterdam, The Netherlands, 1990.

[7] B. T. Doshi, "Queueing systems with vacations—a survey," *Queueing Systems: Theory and Applications*, vol. 1, no. 1, pp. 29–66, 1986.

[8] J. C. Ke, C. H. Wu, and Z. G. Zhang, "Recent developments in vacation queueing models: a short survey," *International Journal of Operations Research*, vol. 7, no. 4, pp. 3–8, 2010.

[9] J. Medhi, *Stochastic Models in Queueing Theory*, Academic Press, Boston, Mass, USA, 1991.

[10] L. Abolnikov and A. Dukhovny, "Markov chains with transition delta-matrix: ergodicity conditions, invariant probability measures and applications," *Journal of Applied Mathematics and Stochastic Analysis*, vol. 4, no. 4, pp. 333–355, 1991.

[11] E. Çinlar, *Introduction to Stochastic Processes*, Prentice-Hall, Englewood Cliffs, NJ, USA, 1975.

[12] H. J. P. Blanc C, "M/G/1 Queues with postponed interruptions," *ISRN Probability and Statistics*, vol. 2012, Article ID 653167, 12 pages, 2012.