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Распределенные компьютерные и телекоммуникационные сети: управление, вычисление, связь (DCCN-2021) = Distributed computer and communication networks: control, computation, communications (DCCN-2021) **:** материалы XXIV Междунар. научн. конфер, 20–24 сент. 2021 г., Москва / под общ. ред. В.М. Вишневского, К.Е. Самуйлова; Ин-т проблем упр. им. В.А. Трапезникова Рос. акад. наук Минобрнауки РФ – Электрон. текстовые дан. (1 файл: 24,9 Мб). – М.: ИПУ РАН, 2021. – 1 электрон. опт. диск (CD-R). – Систем. требования: Pentium 4; 1,3 ГГц и выше; Acrobat Reader 4.0 или выше. – Загл. с экрана. – ISBN 978-5-91450-258-1. – № госрегистрации 0322103543. – Текст : электронный.

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Simulation of Two-Way Communication Retrial Queuing Systems With Non-reliable Server, Impatient Customers to the Orbit and Blocking

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Abstract

The goal of this paper is to carry out a sensitivity analysis to examine the effect of different distributions of service time when blocking is applied with the help of retrial queueing systems having the property of two-way communication. This eventuates in outgoing calls (secondary customers) which are performed by the service unit after a random time in its idle state. Primary customers arrive from the finite-source according to an exponential distribution. This model does not contain queues so the service of an incoming request starts immediately if the server is functional and in an idle state. Impatience of the customers and server failures are characterized by this system which also follows an exponential distribution. The novelty of the investigation is to illustrate the effect of blocking with several figures obtained by simulation using various distributions of service time on the desired performance measures.

Keywords: Simulation, blocking, sensitivity analysis, finite-source queueing system, unreliable server, retrial queue, impatient customers.

1. Introduction

The explosive growth of network traffic in recent years evokes the necessity of investigating communication networks to understand the behaviour of different systems. More and more communication sessions evolve partly almost every device becomes "smart" leading to higher bandwidth requirements not just in multinational companies but in our homes as well. So many unknown quantities may modify the performance of networking systems making them very complex and difficult

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to realize every aspect of their operation. Consequently, researchers dedicate their time to develop mathematical models describing telecommunication systems. With the help of retrial queueing systems arising real-life problems can be modelled in main telecommunication systems like telephone switching systems, call centers, or computer systems. These systems possess a virtual waiting room the so-called orbit where customers get into when the service unit is unavailable. Some examples are listed where queueing models are utilized: [1],[2].

In this paper, the customer owns the impatience feature meaning that customers are able to decide to leave the system earlier without obtaining its service requisition. This is a natural occurrence of human behaviour and can be experienced in many fields of life like in healthcare applications, call centers, telecommunication networks so various works examine the effect of this phenomenon like in [3], [4], [5]. In these articles impatient request is portrayed: if the queue is sufficiently long balking customers choose to avoid entering the system, jockeying customers can alter queues if they encounter them may get served faster, and reneging customers leave the queue if they have waited a definite time for service.

Examining the available literature the considered models include service units that are assumed to be accessible all the time. This hypothesis does not reflect the reality as unexpected errors can take place like power outages, human negligence, or other sudden actions. Although devices are developing and become more reliable, unfortunate failures have a massive effect on the operation of the system modifying the performance measures significantly hence retrial queuing systems have been investigated in several papers recently for example in [6],[7],[8],[9].

Two-way communication scheme gains ground ultimately due to its usefulness in many application fields modelling arising actual problems. One prime example is call-center where service units in an idle state may perform other activities besides satisfying the needs of incoming calls including selling, advertising, and promoting products. In other words, whenever the server is idle it may call for customers outside of the system after a random time. Utilization of such systems is always a key issue in that way many scientists are trying to optimize the service of different requests see for example [10],[11],[12],[13].

The main focus of this paper is to carry out a sensitivity analysis inspecting the various distributions of service time of primary customers when blocking is applied on the main performance measures for instance the mean waiting time and variance of an arbitrary, successfully served and impatient customer, the total utilization of

the service unit, the probability of abandonment. Because giving exact formulas are difficult especially when one of the variables does not follow exponential distribution, the obtained results are gathered by stochastic simulation based on SimPack [14] which contains the basic building blocks of the code. One of the main motivation is to develop simulation models in this way because it gives us the freedom to calculate any performance measure which we desire using various values of input parameters. The achieved results indicate the relevance of the used distributions using various parameter settings and the effect of blocking illustrated by numerous figures concentrated on the interesting phenomena of these systems.

2. System model

The regarded system is a retrial queueing system of type $M/G/1//N$ with impatient customers and an unreliable server that is capable of producing outgoing calls. N denotes the number of sources where each individual generates requests according to an exponential distribution with rate λ/N so the distribution of inter-request time is exponential with parameter λ/N. There are no queues in our model in this way whenever an incoming customer finds the server in a busy state, it will be forwarded to the orbit. Otherwise, the service of an incoming customer starts instantly that follows gamma, hypo-exponential, hyper-exponential, Pareto, and lognormal distribution with different parameters but with the same mean value. During its residence in the orbit a customer may launch an attempt to reach the service unit after an exponentially distributed time with parameter σ/N. Call generation can not occur until the end of the successful service of the individual in the source. We suppose that the service unit breaks down after an exponentially distributed time interval with parameter γ_0 when it is busy and with parameter γ_1 when idle. The repair time is also an exponentially distributed random variable with parameter γ_2 which starts instantly after a failure takes place. During faulty period requests can not enter the system because of blocking. Customers have impatient characteristics therefore they may decide to leave the system after waiting a random exponential time in the orbit with rate τ. As mentioned earlier an idle server may perform an outgoing call towards the customers (secondary) from an infinite source after an exponentially distributed time with parameter γ. The service of secondary customers is a gamma distributed random variable with parameters α_2 and β_2. At the time the secondary request is arriving, if the server is busy or non-operational then it will be cancelled and returns without entering the system. In the case of breakdown:

- The service of a primary request is interrupted and it is forwarded immediately towards the orbit.
- The service of a secondary request is also interrupted but it departs the system.

3. Simulation

As mentioned earlier results are obtained by a self-developed simulation program and a statistical package [15] was integrated into our code to determine the performance measures. The method of batch means is used where the useful run is divided into N batches thus $n = M - K/N$ observations are carried out in every batch. K represents the warm-up period observations at the beginning of the simulation which is rejected. M represents the length of simulation. We just simply calculate the sample average of the whole run after the warm-up period. To have a valid estimation batches should be long enough and the sample averages of the batches should be approximately independent. In the following articles you can find more information about this process [16], [17]. The simulations are performed with a confidence level of 99.9%. The relative half-width of the confidence interval required to stop the simulation run is 0.00001. The size of a batch used to detect the initial transient duration is 1000.

Table 1 display the used values of input parameters in our scenarios.

N	γ_0	γ_1	σ/N	γ	α_2	β_2	τ
100	0.05	0.5	0.01	0.8	1	1	0.001

Table 1. Numerical values of model parameters

Table 2. Parameters of service time of primary customers

Distribution	**Gamma**	**Hyper-exponential**	**Pareto**	**Lognormal**
Parameters	$\alpha = 0.037$ $\beta = 0.015$	$p = 0.482$ $\lambda_1 = 0.385$ $\lambda_2 = 0.416$	$\alpha = 2.018$ $k = 1.261$	$m = -0.751$ $\sigma = 1.826$
Mean	2.5			
Variance	169			
Squared coefficient of variation	27.04			

3.1. Simulation results. We distinguished different scenarios where the values of service times of incoming customers are different to check how the various distribution modify the operation of the system. First, the squared coefficient of variation is greater than one, and to have a valid comparison we chose the parameters that the mean and variance would be the same in every case. For this, a fitting process was performed and [18] contains detailed info about these mechanisms.

Figure 1 demonstrates the mean waiting time of an arbitrary customer in the function of arrival intensity when the service time of the customer follows a gamma distribution. The results prove what we expected aforehand when blocking is applied, lower mean waiting time is obtained especially besides higher arrival intensity. That ratio is true for the other used distributions as well. Although having the same first

two moments maximum property characteristic of a finite-source retrial queueing system arises even with the appearance of blocking.

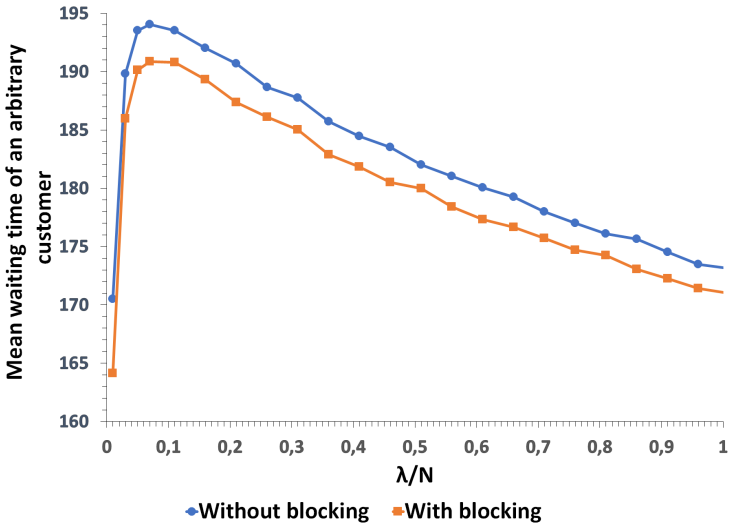

Fig. 1. The effect of blocking on the mean waiting of an arbitrary customer besides service time of gamma distribution

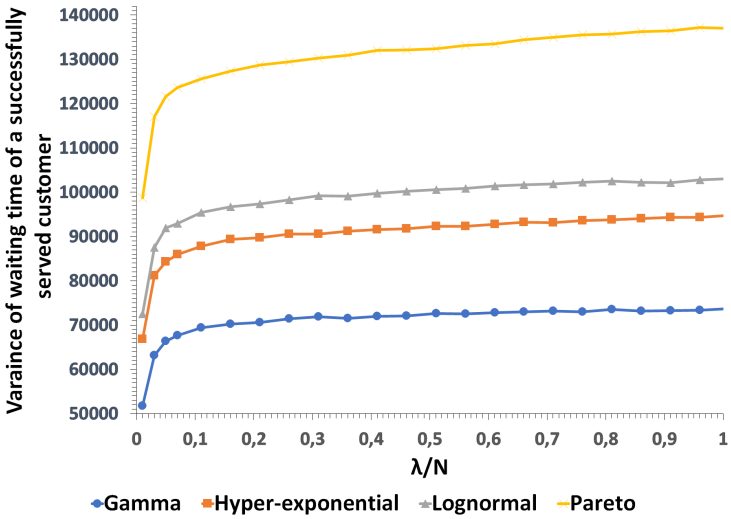

Fig. 2. The variance of waiting time of a successfully served customer

The variance of waiting time of a successfully served customer is depicted in Figure 2 versus arrival intensity. Interestingly the differences are significant among the used distributions in spite of the selected parameters having the same first two moments. This is especially remarkable if we compare the values at gamma distribution with the values at Pareto distribution. This performance measure starts to escalate rapidly and after λ/N reaches 0.1 variance stagnates around a certain value. Due to the page limitation results in connection with the squared coefficient of variation are less than one will be published in the extended version of the paper.

4. Conclusion

We introduced a retrial queueing system of type $M/G/1//N$ with impatient customers in the orbit and with an unreliable server having a two-way communication feature from an infinite source when blocking is implemented. Results are obtained by stochastic simulation and it is shown that the stationary probability distribution of the number of customers in the orbit tends to correspond to the Gaussian distribution despite the used distribution of service time of the primary customers. We investigated different scenarios for example when the squared coefficient of variation is greater than one the obtained values of mean waiting time of an arbitrary, successfully served customer significantly differ from each other even though the parameters are chosen that the mean and variance would be equal in case of every distribution. Results also revealed the effect of blocking which lowers the value of mean waiting time and the number of customers in the system. In our second scenario when the squared coefficient of variation is less than one interestingly the curves almost overlap each other minor disparity turns up examining all the desired performance measures. In the future the authors intend to continue their research work, analyzing other features of the system like collisions, outgoing calls toward the customers from the orbit, or carrying out sensitivity analysis on other random variables.

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