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РАСПРЕДЕЛЕННЫЕ КОМПЬЮТЕРНЫЕ И ТЕЛЕКОММУНИКАЦИОННЫЕ СЕТИ: УПРАВЛЕНИЕ, ВЫЧИСЛЕНИЕ, СВЯЗЬ



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2021

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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. Вишневого, 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. – № государственной регистрации 0322103543. – Текст : электронный.

В научном электронном издании представлены материалы XXIV Международной научной конференции «Распределенные компьютерные и телекоммуникационные сети: управление, вычисление, связь» по следующим направлениям:

- Алгоритмы и протоколы телекоммуникационных сетей
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- Анализ производительности, оценка QoS / QoE и эффективность сетей
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- Интернет вещей и туманные вычисления
- Системы облачного вычисления, распределенные и параллельные системы
- Анализ больших данных
- Вероятностные и статистические модели в информационных системах
- Теория массового обслуживания, теория надежности и их приложения
- Высотные беспилотные платформы и летательные аппараты: управление, передача данных, приложения

В материалах научной конференции DCCN-2021, подготовленных к выпуску к.ф.-м.н. Козыревым Д.В., обсуждены перспективы развития и сотрудничества в этой сфере.

Сборник материалов конференции предназначен для научных работников и специалистов в области управления крупномасштабными системами.

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Modeling of non-reliable retrieval queueing systems with collisions and catastrophic breakdowns

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Abstract

The aim of the investigation is a closed retrieval queueing system with a finite source. The server is non-reliable, and collisions of customers are considered. The server can be reached from the source or the orbit. If an incoming job finds the server busy, the service of the job at the server is interrupted and both of them are transferred to the orbit (collision). The non-reliable server is subject to catastrophic breakdown. It means, that all of the customers at the server and in the orbit are sent back to the source. The novelty of this paper is to investigate the phenomenon of the catastrophic breakdown in a collision environment. Our goal is to calculate the steady-state probabilities and the performance characteristics (utilization, response time, etc.) of the system with the help of a software package. Figures illustrate the effect of the system parameters on the performance measures.

Keywords: retrieval queues, collision of customers, catastrophic breakdown

1. Introduction

There are several tools for modeling and studying working systems from different areas of the real world. One of the most effective tools is the retrieval queueing system (RQ-system). In RQ-systems the customers are not lost in case of a busy system. When an incoming job from the outside world (in the models from the sources or the queue of the system) finds the server busy, joins a virtual waiting room called orbit and after a random, usually exponentially distributed waiting time it retries to reach the server again. The most frequent application fields of an RQ-systems are the call centers, computer networks, telecommunication systems, etc. Infinite source models have been investigated and applied by many authors, very large number of results were published in the literature. But there exist cases, where the finite source models (finite number of customers in the source) are more adequate to describe the behavior of the considered system. The most characteristic examples are the mobile networks, sensor networks, some IoT systems, and cognitive radio systems.

The random and multiple access protocols for these types of systems have been investigated, for example, in [1], [2].

In the real-life situations, unfortunately, the systems are subject to breakdowns that is why this situation has to be investigated. In the modeling process of the system, random server failures and the corresponding repairs are included. The system characteristics and performance measures are highly dependent on the non-reliable operation of the systems. Finite-source RQ-systems with server breakdowns and repairs have been investigated in several recent papers, for example in [3], [4], [5].

A non-reliable $M/M/1//N$ retrial queueing system with collisions of customers is considered in the present paper. Collisions of requests (or conflict of customers) can be occurred frequently in unsynchronized communication systems with a limited number of resources, for example, communication channels. In this case, the transmission is lost and the interrupted requests need to be retransmitted, consequently, the performance of the system is sub-optimal. Developing methods and protocols which can prevent the system from the phenomenon of conflicts or at least try to minimize the damage has great importance. In this direction some recent results can be found in [6], [7], [8].

The focus of this paper is the catastrophic breakdown. Retrial queueing models in which customers are removed from the system due to catastrophic or disaster events have been studied extensively in the literature. Modeling special systems, e.g. automatic teller machines needs different types of breakdowns. A catastrophic event can be, for example, mechanical failures or power outages. Disaster events are known also as a negative arrival or a negative customer. When a negative customer arrives at the system, it immediately removes the positive customer in service if present. The case, when a negative customer removes all the positive customers from the system at once, is called a disaster. Disaster events not only break the service of the current customer but break down the server. The customers from the server and the orbit are sent back to the source. Detailed studies on negative customers can be found in [9], [10] [11], and reference therein.

In this paper, a software tool is used for calculating the steady-state probabilities of the system. Using these probabilities the most important performance measures can be computed. Several sample examples illustrate the effect of different parameters on the distribution of requests in the system.

2. Description of the system

A finite source closed retrial queueing system of type $M/M/1//N$ is considered. As the Kendall's notation says, this is a single server system with a number of sources N . Two scenarios of the system can be investigated and compared:

- The common break-down mode. The system is non-reliable, that is the server is subject to random breakdowns after an exponentially distributed time. In the case of an idle server, the breakdown parameter is γ_0 . When the server is busy, the breakdown parameter is γ_1 . Furthermore, it is assumed that the job under service is sent to the orbit. The repair starts immediately after the breakdown. The distribution of the repair time is also exponential with parameter γ_2 .
- The catastrophic break-down mode. This is the situation when a disaster event removes all of the customers from the system (from the orbit and from the server after interrupting the service). The repair of the system starts immediately. The same breakdown parameters are used as in the common breakdown mode, i.e. γ_0 and γ_1 for an idle server breakdown and a busy server breakdown, respectively, and γ_2 for the repair.

In both scenarios, the sources are blocked during the repair period of the server. No new request can enter into the system.

The dynamic behavior of the system is the following. The sources generate jobs (requests, customers) towards the server. The inter-request times of the job generation are exponentially distributed with parameter λ/N . After generating a request the source waits for a successful service. Until the end of service of the job, the source can not generate a new request. The generated customer reaches the server, which can be busy or idle state. When the server is empty (idle), the service of the job begins immediately, and the service times are assumed to be exponentially distributed with parameter μ . When the server is in a busy state and a new customer is arriving, a collision of the customers occurs. In this situation, the customer under service and the newly arrived customer are transferred into the orbit. From the orbit, the customers retry reaching the server again after an exponentially distributed time with parameter σ/N . See the model on Figure 1.

Let's denote $i(t)$ the state of the system, that is the number of customers in the service facility that is either in the orbit or under service, and let $k(t)$ denote the status of the server:

$$k(t) = \begin{cases} 0, & \text{if the server is up and idle,} \\ 1, & \text{if the server is up and busy,} \\ 2, & \text{if the server is down and under repair.} \end{cases}$$

Let $P(k(t) = k, i(t) = i) = P_k(i, t)$ the probability that at the time t there are i customers in the system and the server is in the state k . With the assumptions above the process $X(t) = \{k(t), i(t)\}$ is a 2-dimensional Markov-chain with a state space of $\{0, 1, 2\} \times \{0, 1, \dots, N\}$.

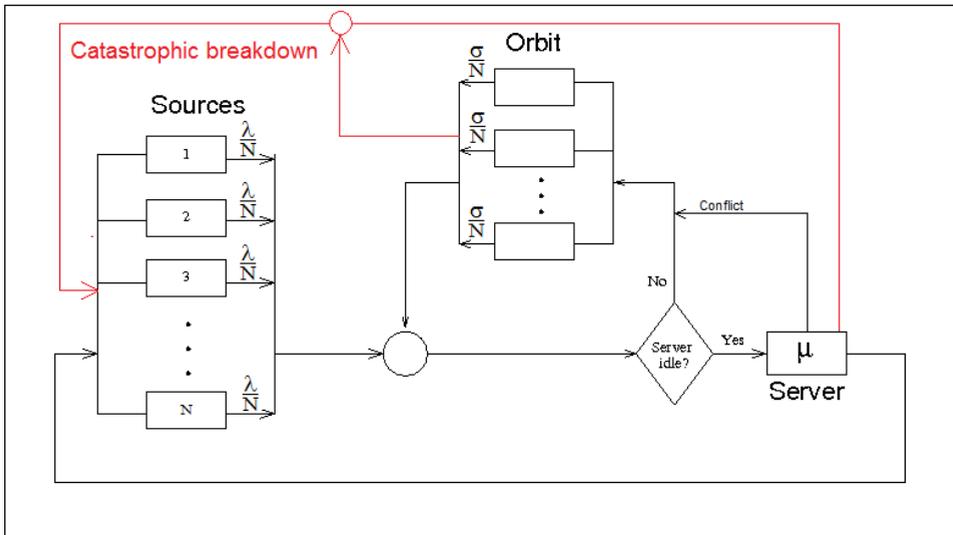


Fig. 1. System model

When the service of a request is successful, the request goes back to the source. All the random variables involved in the model construction are assumed to be totally independent from each other.

The $X(t) = \{k(t), i(t)\}$ process is a finite state Markov-chain, so the steady-state operation can be assumed: $P_k(i, t) = P_k(i)$.

The steady-state Kolmogorov balance equations for the normal breakdown case can be seen in [12]. The balance equations for the catastrophic breakdown case also can be formulated.

To demonstrate the effect of the input parameters on the operation of the system, different performance measures have to be calculated from the steady-state probabilities. These characteristics are the mean response time, mean waiting time, the utilization of the server, etc. For example, the mean number of customers in the system \bar{Q} and in the orbit \bar{O} can be obtained as

$$\bar{Q} = \sum_{i=0}^N iP(i), \quad \bar{O} = \bar{Q} - P_1.$$

3. Numerical results

There are methods for solving the steady-state equations. Here an analytical software tool, namely the MOSEL-2 was chosen. With the assumption of exponentiality of the system parameters, this tool is effective and quick for a reasonably

large number of sources. The MOSEL tool builds up the system equations. The steady-state probabilities of the system are calculated.

Figure	Model	λ	μ	σ	N	γ_0	γ_1	γ_2
2	Catastrophic	1	1	5	100	Legend	Legend	1

Table 1. Numerical values of model parameters

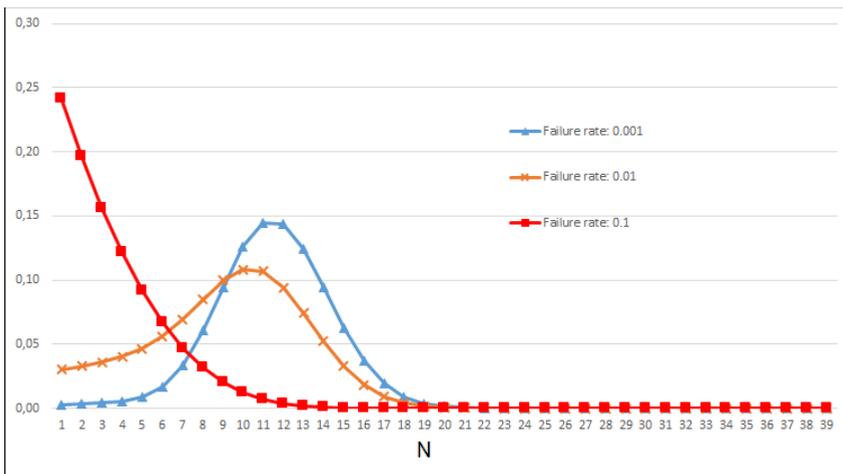


Fig. 2. The system probabilities with different failure rates

On Figure 2 the steady-state probabilities of the system can be seen. The parameters can be found in Table 1. Different failure rates were applied. The failure rates here for busy and idle states are the same. For a low failure rate, the usual normality of the probabilities can be observed [13]. For larger failure rates the property of the normal distribution of the system probabilities does not hold anymore. The reason for this is the frequent catastrophic breakdown, where the customers spend only a very short time in the system.

Based on the system probabilities further figures can be formed displaying the performance measures, e.g. Response times, waiting times, utilization, etc.

4. Conclusion

The paper compares the phenomena of common breakdown and the catastrophic breakdown in a non-reliable system. This comparison has great importance nowadays, because there are sensitive systems (e.g. automated teller machines), which have to face both types of failures. Equations, formulas, and further figures are not presented here due to the limitation of the available space.

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