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MODELING TWO-WAY COMMUNICATION SYSTEMS WITH CATASTROPHIC BREAKDOWNS

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A two-way communication system is modeled in this paper. A retrial queueing system with a finite and an infinite sources is used in the model. Requests from the finite source are the first order or regular customers, while the requests from the infinite source are the second order or the invited customers. In case of an idle server, the second order customers are called for service. The non-reliable server is subject to random breakdowns, and even to catastrophic breakdown, i.e all of the requests at the server, in the buffer, and in the orbit are sent back to the sources. The novelty of this paper is to investigate the effect of catastrophic breakdown in a two-way communication environment. The goal is to determine the steady-state probabilities and the system characteristics with the help of a software package. Figures illustrate the effect of the system parameters on the performance measures.

Keywords: *Two-way communication, catastrophic breakdown.*

Introduction

For modeling various fields of infocommunication and computer sciences, the retrial queueing systems are one of the well-known and widely spread models. Results can be found in works of Falin, Templeton, and more authors [5, 9]. Several models assume, that the customers generate their request from a finite number of population. In some cases, these finite source models are more realistic and give a better description of the considered application [1, 4]. In addition, the considered real-life systems are unfortunately non-reliable, that is the server can lose its efficiency or may break down. These type of a non-reliable systems were investigated e.g. in [10].

Furthermore, a new general model was developed not to lose the requests, who are not able to wait for the server in the queue or in the orbit. They can register for the service and later the idle system can call (outgoing call) for these customers (two-way communication systems). The first and later results can be found e.g. in [2, 3, 7].

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In this paper a special two-way communication system is considered. It is called searching for customers. Two types of customers are considered. The organization has a finite number of regular or goodwill customers. They are the first order customers, making primary calls towards the organization, i.e. the server. These clients are served according to the retrial queueing model. During the busy period of the server, the incoming customers are sent back to the orbit, where they can retry their requests. These customers are represented with a finite number of the source. During the idle periods of the server, outgoing calls are performed towards the customers in the second, infinite source. The clients in this infinite source (second order customers) will contact the organization with some special interest. In case of a busy server (meanwhile another regular customer might be arrived), this special second order customer is treated as a non-preemptive priority client. They are sent into a priority buffer.

The non-reliable server is subject to random breakdowns. The focus of this paper is a special type of breakdowns, 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 an arrival of a negative customer. When a negative customer arrives at the system, it immediately removes the positive customer from service. 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, the orbit, and the priority buffer are sent back to the source. Detailed studies on negative customers can be found in [6, 8], and reference therein.

The remaining parts of this work contain the following. In Section 1 the model definition, the underlying Markovian process with 2 dimensions, and the applied parameters are described. In Section 2 the steady-state probabilities are considered, and some performance measures (utilization, response times, etc.) are provided with the help of MOSEL-2 tool. At the end of the paper, the results are summarized in a Conclusion.

1. Description of the model

The system is modelled by a single-server retrial queueing system with a finite and an infinite sources. The functionality of the model is displayed in Figure 1.

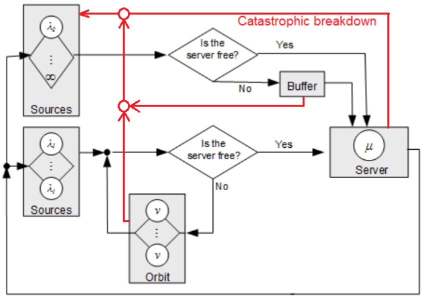

Figure 1. The system model

The system has two sources. The first one is finite with the first order customers, the number of customers is N. These customers generate a job towards the server using the exponential law with parameter λ_1. For the first order customers there is no queue at the server. After the service, the job goes back to the source can generate a new request again. The service time is also exponential distributed with parameter μ_1. When the server is busy, the incoming job is transferred to the orbit. The size of the orbit is N. From the orbit the jobs after an exponential random time interval with parameter ν retry their request to the server until they are served. The model has second order customers in an infinite number of sources. These customers generate triggered requests only. The idle server makes outgoing calls towards this infinite source, and the second order customers generate a request to be served. The generation is also exponential with parameter λ_2. The distribution of service times is also exponential with parameter μ_2. When a second order customer finds the server busy, the job is transferred to a priority buffer. In case of an idle server, a second order customer is called from this buffer. The size of the buffer is one, because in case of an idle server, there is no outgoing call when a customer is in the buffer.

In this model the single server is unreliable, it may subject to breakdown. Here the catastrophic break-down is considered. This is the situation when a disaster event removes all of the customers from the system (from the orbit, from the buffer, and from the server after interrupting the service). The repair of the system starts immediately. The breakdown parameter is γ_0 and γ_1 for idle and busy servers, respectively. γ_2 is the parameter of the repair. The considered times are exponentially distributed. During the breakdown period, the sources are blocked, they are not able to generate requests.

Let us denote $O(t)$ and $S(t)$ the number of requests in the orbit and the state of the server at a given time point of t:

$$S(t) = \begin{cases} 0, & \text{when the server is idle,} \\ 1, & \text{when the server is busy} \\ & \text{with a first order customer,} \\ 2, & \text{when the server is busy} \\ & \text{with a second order customer,} \\ 3, & \text{when the server is down.} \end{cases}$$

The state-space of the underlying Markovian-process $(S(t), O(t))$ can be described as a set of $\{0, 1, 2, 3\} \times \{0, 1, 2, ..., N\}$ elements. Although the system has an infinite source, the maximum number of the customers in the system is $(N + 1)$ (N in the orbit and one second order customer under service), there is no stability problems regarding the system. The state space is finite.

For buffered and non-buffered models the system balance equations can be formulated. The steady-state system probabilities are:

$$p_{i,j} = \lim_{t \to \infty} P(S(t) = i, O(t) = j), i = 0, 1, 2, 3 \text{ and } j = 0, 1, ..N$$

Solving manually these balance equations is rather difficult. There exist several effective tools for performing the background calculations. In this paper, the MOSEL-2 tool was used. When the steady-state probabilities are calculated, this tool provides the well-known performance characteristics. These measures are obtained using the following formulas, e.g. average number of jobs in the orbit

$$\overline{O} = \sum_{s=0}^{3} \sum_{o=0}^{N} oP(s, o).$$

2. Numerical results

The most important goal of these types of stochastic systems is to obtain the performance measures and system characteristics. Usually the throughput, utilization, response times, waiting times, queue length are considered. Here the utilization and response time are focused.

There exist several methods to calculate the system measures. Solving directly the balance equations is rather difficult in most cases. Effective software tools can be used to get the steady-state system probabilities. From these probabilities the performance measures can be computed directly or by the help of the considered tool. Because solving directly the balance equations is rather difficult, the MOSEL-2 tool is used. The system equations are solved by the SPNP (Stochastic Petri Net Program). The following figures illustrate the most interesting numerical results.

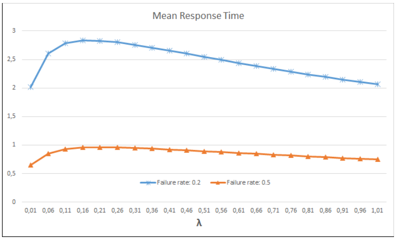

Figure 2. Mean Response Time vs. λ_1

In Figure 2 and 3 the running parameter is $\lambda = \lambda_1$, the first order generation rate. In Figure 2 the mean response time can be seen for two different failure rates ($\gamma_0 = \gamma_1$ in this figure). The catastrophic breakdown is applied. For a higher failure rate lower response time can be observed because the jobs are more often kicked off to the source.

Figure 3 displays the server utilization. $\mu_1 = 4$ and $\mu_2 = 2$. This is the reason, that the utilization is higher in the catastrophic case than in the normal breakdown case.

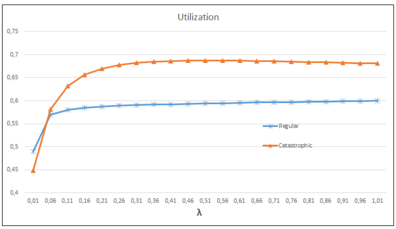

Figure 3. Server utilization vs. λ_1

3. Conclusion

A special two-way communication system was investigated here. First order customers come from a finite source, while in the case of an idle server, second order customers can reach the system via a direct call. Different cases can be considered. Failure rates are set to be equal for idle server, for server with first order customer, and for server with second order customer. Two different cases were considered. The system subject to general breakdown and catastrophic breakdown. In this short abstract only two measures, the mean response time and the server utilization were investigated. Of course, more characteristics with more parameters can also be considered.

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