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Сборник содержит избранные материалы XVIII Международной конференции имени А.Ф. Терпугова по следующим направлениям: теория массового обслуживания и телетрафика, графы и их применение в задачах анализа дискретных автоматов, прикладной вероятностный анализ.

Для специалистов в области информационных технологий и математического моделирования.

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Reliability Analysis of Cognitive Radio Networks

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In the current paper we investigate the queuing model in order to evaluate the performance of a cognitive radio network and its reliability. We are taking into consideration two subsystems in this queuing system. The first subsystem is built for the primary users (PU) requests. The number of sources is finite, moreover, each exponentially distributed interval of time the source generates a primary request for the PU, these tasks should be sent with a preemptive discipline to a single server which is called the Primary Channel Service (PCS), to get served based on an exponentially distributed time as well. The second part of the model is dedicated to the secondary unit requests, which is finite also, supposing that the service and the inter-request times of the secondary server are exponentially distributed. Every generated primary request is headed to the primary server in order to check its accessibility, in case that the service unit is free, the service starts instantly. However, If the primary unit is already busy with another primary request, the packet joins a FIFO queue. However, if the primary unit is busy by treating a service for a secondary user, this latter service disconnects right away and should be sent back to the Secondary Channel Service (SCS), based on the availability of the secondary server this postponed task either starts the service again, or joins the orbit.

In the other hand, the secondary requests are sent to the secondary server to verify its availability, if the aimed server is available, the request starts instantly, otherwise these unlicensed requests need to give a try in order to join the Primary Service Unit (PSU) if it is free the low priority tasks begin. If not, they must join the orbit automatically. Canceled requests in the orbit retry to be served after a random interval of time exponentially distributed, more details can be found in [1–3].

In this investigation we assumed that both service units are subject to some random breakdowns, in such case the suspended requests are respectively sent to the queue or to the orbit.

It is assumed that the server failure and repair times are generally distributed (Hypo-Exponential, Hyper-Exponential, Gamma, Pareto and Lognormal). All the random times concerned in this model are supposed to be independent of each other. [4] considered that the network has a single server however, the only server is subject to breakdown and repair. This type of network suffers from difficulty with processing the requests, as the breakdown of the only server of the network effects the whole system, if the server is down then the whole network is down. Some other papers investigated further the retrial queuing model, by modeling a cognitive radio network using two service channels (Primary and Secondary) both are subject to breakdowns and repair. For example, the authors of [8] assumed that both servers are unreliable and used different distributions for the inter-event times. Hypo and Hyper Exponential for the failure and repair times, however, Exponential distributed was used for the rest of the inter-event times (arrival, service and retrial).

In brief, the main aim of this work is to add Lognormal, Pareto and Gamma distributions to Hypo-Exponential, Hyper-Exponential, which were studied in mentioned above work, in order to investigate the effect of the mean and variance of these several distributions on the server breakdown and repair times. It allows us as well, to visualize the behavior of the whole system while using different distributions and parameters by the help of a simulation program.

Simulation Results

The values of the input parameters for the distributions are given in Table 1. In this Section we are showing two figures which are in connection with the effect of the distribution's parameters on the operating time of the primary server. We have chosen the means and the variances for all the distributions following two scenarios. Since the squared coefficient of Hypo-Exponential distribution should be less than 1, as a first scenario we ran our simulation program respecting this condition to generate Fig. 1, where the Means and the Variances of the other distributions (Gamma, Pareto and lognormal) were equals to Hypo's as well. Similar to Hypo-Exponential, in Fig. 2, we followed the condition that the squared coefficient of variation of Hyper-Exponential should be greater than 1, furthermore, all the Means and Variances of the rest of the distributions were the same as the mean and the variance of Hyper-Exponential. In such a way we will be able to see the effect of the variance of each distribution on the primary operating time.

The following set of parameters explained the paramaters used in the simulation program: Number of primary sources: N1, Nnumber of secondary sources: N2, Primary arrival rate: λ1, Secondary arrival rate: λ2, Primary service rate: μ1, Secondary service rate: μ2 Primary failure rate: γ1, Secondary failure rate: γ2, Repair rate of the primary server: σ1, Repair rate of the secondary server: σ2 (Table 2).

Table 1

Values of the distribution's parameters

Distribution		Hyper	Hypo	Gamma	Pareto	Lognormal
Fig. 1	Mean	N/A	0.2	0.2	0.2	0.2
	Variance	N/A	0.03	0.03	0.03	0.03
	Parameters	N/A	$\lambda1 = 0.0292$ $\lambda2 = 0.1707$	$\alpha = 1.333$ $\beta = 6667$	$\alpha = 2.5275$ $k = 0.6043$	$m = -1.889$ $\sigma = 0.74807$
Fig. 2	Mean	0.2	N/A	0.2	0.2	0.2
	Variance	0.4	N/A	0.4	0.4	0.4
	Parameters	$\lambda1 = 0.2$ $\lambda2 = 0.632$	N/A	$\alpha = 0.1$ $\beta = 0.5$	$\alpha = 2.04880$ $k = 0.51191$	$m = -1.657$ $\sigma = 1.5485$

Table 2

Numerical values of model parameters

No.	N1	N2	λ1	λ2	μ1	μ2	σ 1	σ 2	γ1	γ2
Fig. 1	6	10	0.6	0.1	1.5	1	x–axis	0.5	5	4
Fig. 2	6	10	0.6	0.1	1.5	1	x–axis	0.5	5	4

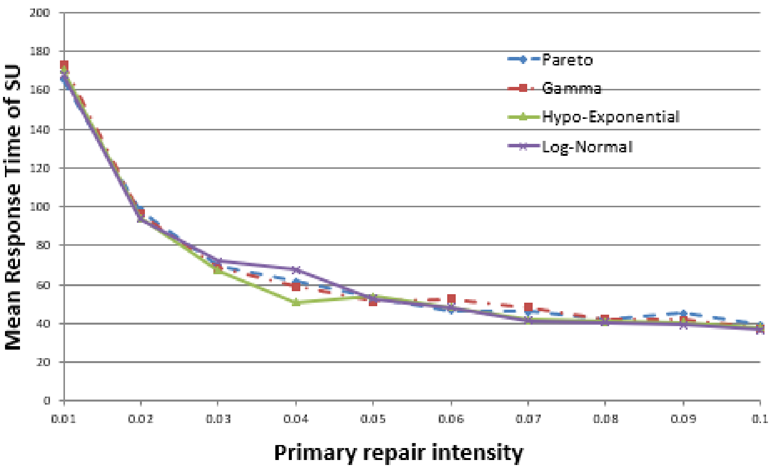

Fig. 1. The effect of the primary repair intensity on the mean response time of the Secondary Users

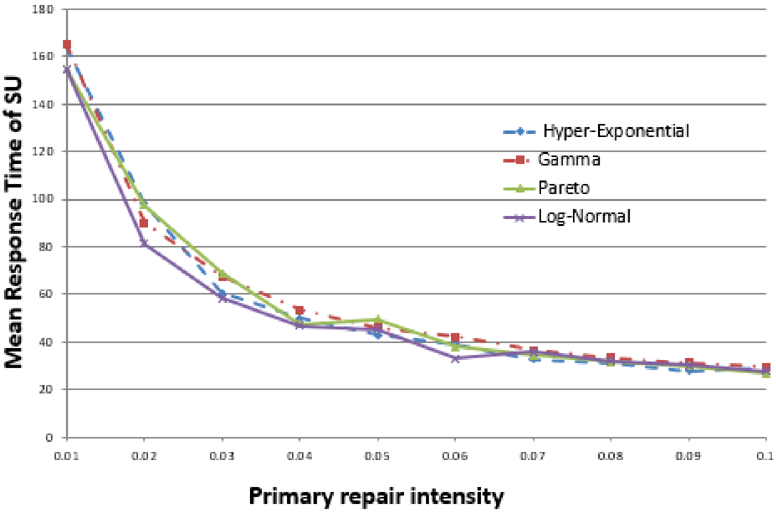

Fig. 2. The effect of the primary repair intensity on the mean response time of the Secondary Users

Both Figs. 1 and 2 show the mean response time of secondary users in function of the primary repair intensity using different distributions (Hypo, Hyper, Gamma, Pareto and Lognormal) for the primary operating time, knowing that the Exponential distribution was used for the rest of the inter-event times (arrival, service, retrial and failure).

As expected, the mean response time of the users decreases with the increment of the repair intensity. In Fig. 1 the highest values can be found at gamma distribution during the growing of the repair rate expect two values (0.04 and 0.09), however, the differences of the distributions are not significant as much as in Fig. 2, where the squared coefficient of variation is greater than one, more differences between the distributions can be observed.

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