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Simulation analysis in cognitive radio networks with unreliability and abandonment*

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The current paper presents a Cognitive Radio Network with impatient customers and unreliable servers by the help of a finite-source retrial queueing system. Our queuing system consists of two not independent, interconnected sub-systems. The first part is allocated to primary requests, with N_1 the number of sources. These sources will be responsible for generating a high priority requests with an inter-request and service times exponentially distributed, using parameters λ_1 and μ_1, respectively. All the produced requests are directed to a single server unit (PCS) with a FIFO queue.

The second subsystem is devoted to the low-priority requests with number of sources denoted by N_2, the inter-arrival times and service times in this subsystem are assumed to be exponentially distributed as well, with parameter λ_2 and μ_2, respectively. Based on the state of both server (idle or busy), the generated primary packet goes to the primary server (if the server is idle) or joins the FIFO queue (if it is busy with a PU). However, if an unlicensed user occupies the PCS, its service is instantly stopped, and will be sent back to the Secondary unit.

Depending on the secondary unit's availability, the aborted task is addressed either to the server or the retrial queue from which reties to get served from the beginning after an exponentially distributed time with parameter ν.

On the other hand, requests from SUs are directed to SCS. If it is idle, the service begins. If not, this unlicensed task will sens the PCS. In case of an idle status for PCS, this service may opportunistically join the high priority channel. If the PCS is engaged, the request goes to orbit. More details can be found in [1–3].

It should be noted that Secondary Users in orbit are obliged to leave the system once their total waiting time exceeds a random abandonment time

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generally distributed (Hyper, Hypo, Gamma, Lognormal and Pareto) using τ as a parameter. A random breakdowns and repairs will occur on the secondary server using the mentioned-above distributions with parameters γ_2 and σ_2, respectively.

Several studies have examined the Abandonment and/or Unreliability on the basis of different scenarios and systems.

At [6] as an example, the authors have presented a retrial queueing system with a single server which is subject to random breakdowns and assuming that collisions may occur when a customer arrives at a busy server which forces both jobs to join the orbit.

However, to get closer to real-life situations and involving more servers to the system, the authors of [7] examined the abandonment concept on a Cognitive Radio Network by setting a constant value for the maximum waiting time (abandonment time) of secondary users. In an extended work [8], the same authors of the above-mentioned paper assumed that the abandonment time is random, using various distributions to investigate their influence on the main performance measures of such a system.

Other probes analysed the abandonment in other types of networks and showed that customers can leave systems from queues, server units while receiving services and while waiting; more details are given in [4, 5]. However, in the current paper, we assume that impatient users (secondary) are forced to leave the system only from the orbit while waiting.

Unreliability of servers was investigated in [9, 10], without taking in consideration that customers have the opportunity to leave the system.

Several figures will show the effects of the abondenment and unlicensed server unreliabilty on the performance measures of the system using simulation.

Simulation examples

The batch mean value method was used in the simulation to estimate the average response times of the requests. This method is a common confidence interval technique used for the analysis of the steady-state simulation output. See for more details [1–3].

We have treated several scenarios in order to investigate the possible effect of the maximum waiting time of secondary customers (impatience) on the average and variance estimations of the performance measures when it is exponentially distributed, furthermore, the impact of the distribution of the involved random variables (impatience time) when it is generally distributed in case their squared coefficient of variation is less and greater than one.

These investigations are dealt when primary server is reliable and secondary one is non-reliable (Scenario 1) and when both servers are non-reliable (Scenario 2).

Due to of the limitation of pages, in this short paper we present two figures from scenario 1 that illustrate the impact of general distribution while their C_x^2 >1 on the average arbitrary time of secondary customers.

Table 1

Numerical values of model parameters

Fig No.	N_1	N_2	λ_1	λ_2	μ_1	μ_2	ν	τ	γ_2	σ_2
Fig. 1	100	100	1.5	x-axis	1	1	0.1	0.002	0.1	0.1
Fig. 2	100	100	x-axis	1.5	1	1	0.1	0.002	0.1	0.1

Table 2

Numerical values of distributions parameters, C_x^2 >1

Distribution	Hyper	Gamma	Lognormal	Pareto
Mean	500	500	500	500
Variance	640000	640000	640000	640000
Parameters	$P = 0.078$ $\gamma_1, \theta_1 = 0.078$ $\gamma_2, \theta_2 = 0.09219$	$\alpha = 0.9756$ $\beta = 0.048$	$\sigma = 0.8399$ $m = 0.3527$	$\alpha = 1.4055$ $k = 5.7708$

Table 1 shows the value of input parameters for the simulation program, while Table 2 defines the numerical values of the parameters for the distributions illustrated in Fig. 1 and Fig. 2. They have the same mean and variance knowing that the squared coefficient of variation is greater than one.

Let us put some comments on the obtained results. The average sojourn time of different types of customers depending on the arrival intensity is shown in Fig. 1, which illustrates how the mean response time of an arbitrary customer. This mean value can be determined using the law of total expectation. Differences can be observed, the results clearly illustrate the effect of different distributions. Highest values have experience with Pareto distribution in this case. Despite the increasing arrival intensity, the maximum characteristic of the maximum value of the mean value can be shown.

Figure 2 illustrates the effect of different distributions on the mean response time of secondary arbitrary customers in the function of the primary generation rate λ_1. The mean sojourn time of arbitrary users depends on the average of impatience, probability of abandonment, and success. Despite the highest value of the mean that is obtained when the secondary waiting time is

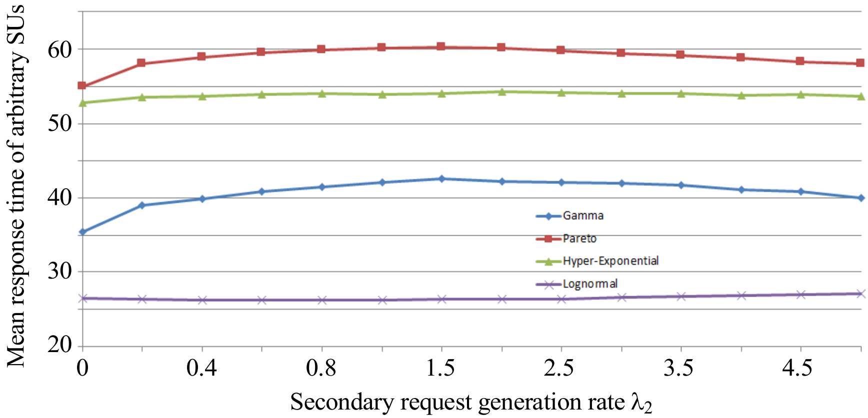

Fig. 1. The effect of the impatience distribution on the mean response time of an arbitrary customer vs secondary request generation rate

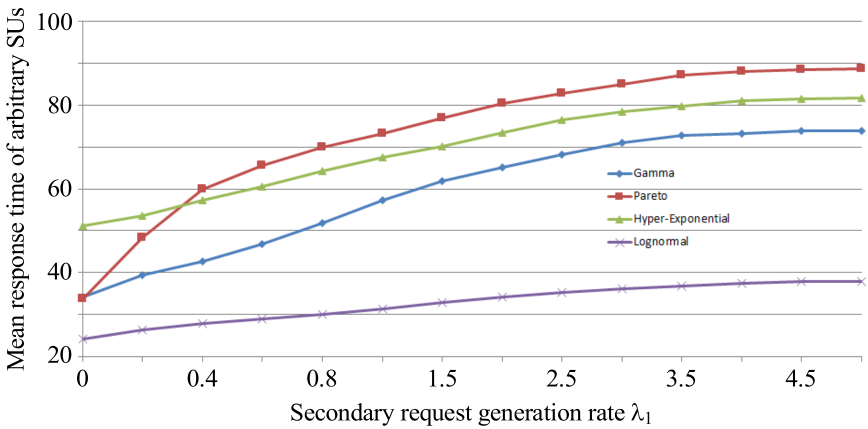

Fig. 2. The effect of the impatience distribution on the mean response time of an arbitrary customer vs primary request generation rate

Pareto distributed, it is clearly seen that when the primary arrival rate is very small (very large inter-arrival time, λ_1 less than 0.4), the distributions have a different impact where we obtain the highest value of the mean when the secondary waiting time is hyper-exponentially distributed. Our Explanation for both figures is the following when the squared coefficient of variation is greater than one, the lognormal distribution gives big values where the gamma distribution gives small values comparing to Pareto and hyper-exponential. So in the case of gamma distribution customers leave the system more often and stay in the system in the case of the lognormal distribution. Furthermore, when λ_1 is less than one, Fig. 2 shows the characteristic of cognitive technology as more secondary customers access the licensed channel and getting served rather than leave the system.

Conclusions

In this short paper a finite-source retrial queueing system is used to model a cognitive radio network with non-reliable servers and impatient customers. The results obtained have demonstrated the importance of the distribution of the maximum waiting time of a customer (impatient) as it has a big impact on the system performance measures of a such complex system, although the mean and variance of the distributions are the same depending on their squared coefficient of variation.

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