НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ
ТОМСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ

РОССИЙСКИЙ УНИВЕРСИТЕТ ДРУЖБЫ НАРОДОВ

ИНСТИТУТ ПРОБЛЕМ УПРАВЛЕНИЯ
им. В.А. ТРАПЕЗНИКОВА РАН

ИНФОРМАЦИОННЫЕ ТЕХНОЛОГИИ И МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ (ИТММ-2021)

МАТЕРИАЛЫ
XX Международной конференции имени А. Ф. Терпугова
1–5 декабря 2021 г.

ТОМСК
Издательство Томского
государственного университета
2022

УДК 519
ББК 22.17
И74
Информационные технологии и математическое моделирование (ИТММ-2021): Материалы XX Международной конференции имени А. Ф. Терпугова (1–5 декабря 2021 г.). — Томск: Издательство Томского государственного университета, 2022. — 391 с.

ISBN 978–5–907572–20–1

Сборник содержит избранные материалы XX Международной конференции имени А.Ф. Терпугова по следующим направлениям: теория массового обслуживания и ее приложения, интеллектуальный анализ данных и визуализация, информационные технологии и программная инженерия, математическое и компьютерное моделирование технологических процессов.

Для специалистов в области информационных технологий и математического моделирования.

УДК 519
ББК 22.17

Конференция проведена при поддержке международного научно-методического центра Томского государственного университета по математике, информатике и цифровым технологиям в рамках федерального проекта «Кадры для цифровой экономики» национальной программы «Цифровая экономика в Российской Федерации»

ISBN 978–5–907572–20–1

NATIONAL RESEARCH TOMSK STATE UNIVERSITY

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V.A. TRAPEZNIKOV INSTITUTE OF CONTROL SCIENCES OF RUSSIAN ACADEMY OF SCIENCES

INFORMATIONAL TECHNOLOGIES AND MATHEMATICAL MODELLING (ITMM-2021)

PROCEEDINGS
of the 20th International Conference
named after A. F. Terpugov
2021 December, 1–5

TOMSK
Tomsk State
University Publishing
2022

UDC 519
LBC 22.17
I60
Informational technologies and mathematical modelling (ITMM-2021): Proceedings of the 20th International Conference named after A. F. Terpugov (2021 December, 1–5). — Tomsk: Tomsk State University Publishing, 2021. — 391 p.

ISBN 978–5–907572–20–1

This volume presents selected papers from the XIX International Conference named after A.F. Terpugov. The papers are devoted to new results in the following areas: queuing theory and its applications, data mining and visualization, information technology and software engineering, mathematical and computer modeling of technological processes.

UDC 519
LBC 22.17

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The conference was supported by
International Computer Science
Continues Professional Development Center
of the Federal project “Human Resources for the Digital Economy”
of the National program
“Digital Economy of the Russian Federation”

ISBN 978–5–907572–20–1

PERFORMANCE INVESTIGATION OF REVERSE BALKING IN COGNITIVE RADIO NETWORKS USING SIMULATION

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In this article, the concept of reverse balking is developed and integrated into a Cognitive Radio Network. Reverse balking is a customers pattern in which an arriving user is more likely to join a system if it is more occupied, and vice versa. This type of customer's attitude can be seen in a variety of industries, especially finance. The key performance measures are obtained with the help of simulation.

Keywords: *Finite source queuing systems, Simulation, Cognitive radio networks, Performance measures, Reverse balking.*

Introduction

Our Cognitive Radio Network (CRN) model's principal aim is to enhance the use of the free spaces in the primary frequency band to benefit the secondary. More details can be found in [1, 2, 3, 4, 5, 6]. Our queuing system considers two parts. The first part is developed for Primary Users (PUs) with a finite number of sources who generate primary calls after an exponentially distributed time. All the generated calls are placed in a FIFO queue for service. The second subsystem is dedicated to secondary users (SUs) jobs which are created following exponential distribution and routed to the secondary channel service (SCS) to obtain service. The service time of PUs and SUs is exponentially distributed as well. The generated licensed calls will verify the status of the PCS; if it is available, the service may begin immediately; if it is already in use by a primary call, the latter call will be placed in the FIFO queue. If a secondary customer is occupying the PCS, its service will be interrupted immediately and diverted back to the SCS. The aborted call will be resumed from the beginning of its service or added to the retrial queue (orbit) depending on its present state.

SCS, on the other hand, handles unlicensed queries. If the targeted server is idle, the SU is permitted to start the service; if it is occupied, they

The research work of János Sztrik is supported by the EFOP-3.6.1-16-2016-00022 project. The project is co-financed by the European Union and the European Social Fund. Mohamed Hedi Zaghouani is supported by the Stipendium Hungaricum Scholarship.

may attempt to start opportunistically their service in the PCS. If the last service channel is free, the low priority call may be able to begin the service; otherwise, if it is occupied, the call will be automatically added to the orbit, from where it will retry to be served after an exponentially distributed time.

Several investigations have dealt with CRN in different scenarios. The effect of server unreliability on the CRN, for example, was studied by the authors of [3]. Abandonment was employed in [6], wherein SUs were forced to leave the system if their total waiting time exceeded a random maximum waiting duration. Balking has been investigated in a variety of queuing systems, including [7, 8, 9, 10]. However, after a thorough search of numerous similar topics and reports, we were unable to find any studies that addressed this model in the scenario of revers balking, which is the novelty of our research.

1. System model

The queuing cognitive radio system shown in Fig. 1 is based on the following assumptions. Consider two interconnected subsystems in which primary requests are generated by a finite number of sources N_1 and submitted to the first server using an exponentially dispersed time with an average value of $1/\lambda_1$. If the unit is available, the service may begin; otherwise, the call will be placed in the preemptive priority queue. The principal users' service time is a random variable with an exponential distribution and a parameter μ_1.

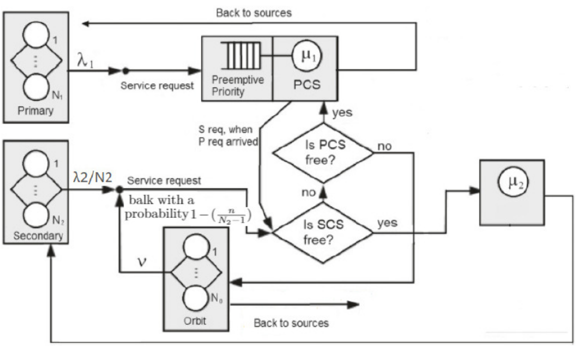

Figure 1. Finite-source retrial queuing system: Modeling the Cognitive Radio Network with reverse balking

Table 1

Simulation input parameters

N_1	N_2	λ_1	λ_2/N_2	μ_1	μ_2	ν	p
20	50	0.03	x-axis	1	1	20	0.5

N_2 denotes the number of sources in the secondary subsystem. Each source produces low priority call according to an exponentially distributed time with parameter λ_2/N_2. SUs service time is generally distributed using hypo-exponential, hyper-exponential, and gamma distributions with the same mean and different variances with a rate μ_2. The retrial time of the secondary customers is supposed to be an exponentially distributed random variable with a parameter ν.

When the system is empty (at the start of the simulation) first customers might balk (do not enter the system) with probability p or join it with $1 - p$. However, when there is at least one customer in the system, new arriving ones balk with a probability 1-q and enter the system with probability q=($\frac{n}{N_2-1}$), while n is the number of SU in the system at a time t. Reverse balking is the term for this type of balking.

2. Simulation results

Assuming that all random variables included in the system are exponentially distributed except the secondary service, we created a stochastic simulation program written in C coding language with SimPack to generate the results of this section. All the numerical results were collected by the validation of the simulation outputs. Table 1 shows the numerical values of the simulation main class input parameters while.

Figure 2 illustrates the influence of secondary service time distribution on the mean residence time of SUs versus secondary request time generation. A high distributions sensitivity can be observed when service times are gamma distributed with a squared coefficient of variation greater than one, especially, in the beginning of the simulation. Furthermore, increasing the arrival intensity of SUs, did not involve a greater mean response time for SUs until value 2.8, where the mean response time was noticeably increased. This was the effect of the reverse balking, as new coming customers are getting more encouraged to enter the system through the time.

The impact of the service time distribution for the secondary subsystem on the mean balking rate versus λ_2 can be observed in Figure 3. Increasing the secondary arrival rate involves a higher discouragement for new arriving secondary customers, this can be seen clearly in the case of Gamma distribution.

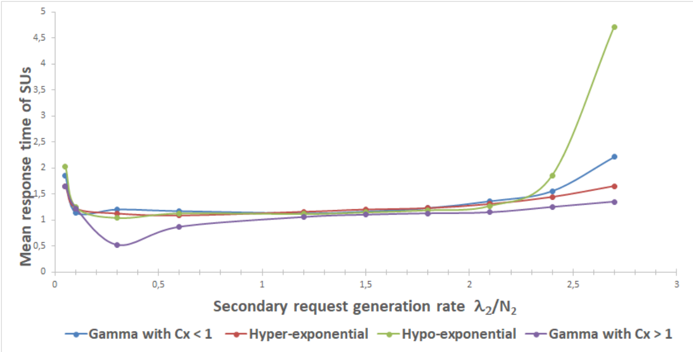

Figure 2. The impact of secondary service time distribution on the mean residence time of SUs vs secondary request time generation

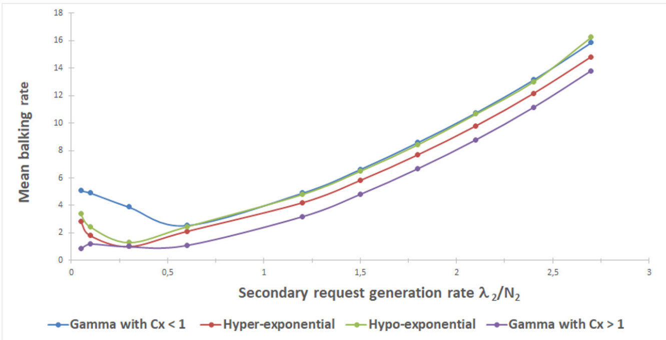

Figure 3. The impact of secondary service time distribution on the mean balking rate of SUs vs secondary request time generation

It is well known according Gamma distribution function that when $c_x^2 > 1$ the generated random service time is great which leads to an overloading of the system.

3. Conclusion

This paper introduces a finite-source retrial queueing system with two non-independent components. Our system was designed to model a cognitive radio network with primary and secondary service units, as well as reverse balking. A thorough review was conducted using simulation to investigate the impact of service time distributions and cognitive technology on the system's key performance measures.

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