UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electronics and Computer Engineering

QUEUING SYSTEM 'EXCEPTIONS', THEIR AFFECTS AND NON-QUEUE STATE: A NEW STOCHASTIC APPROACH

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Master of Science in Electronic Engineering

2014

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A thesis submitted

in fulfillment of the requirement for the degree of Master of Science

in Electronic Engineering

Faculty of Electronics and Computer Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electronic Engineering.

Signature:

Supervisor Name: Professor Dr. Muhammad Ghazie Ismail

Date: 15 May 2014

DECLARATION

I declare that this thesis entitle "Queuing System 'Exceptions', Their Affects and Non-Queue State: A New Stochastic Approach" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Most queuing models are based on organized behavior of customers served by a server or multiple servers. However, there are many instances that the queuing model does not stand by real world queue ethics. The consequences can go towards non-queue state caused by overcrowding and cultural background of the customers. This research portrays the successive outcomes that sourced non-queue state due to customer ignored behaviors as well as the unsystematic policy of a single serving system which becomes the main research problem. Such activities are termed as 'exceptions' and their disturbances in queuing system. The main objective of this research is to present 'exceptions', their affects and to resolve the non-queue state. It is important so that the waiting time distribution, behaviour of the system during 'exceptions' and queuing system can be evaluated, demonstrated and reinstated to a single server queuing state, respectively. A non-queue is a state addressed when system utilization goes beyond 100 percent. Furthermore, this would indicate no formal queue at all as customers could be assumed at random locations. This research will explain the state of the system during 'exception' and non-queue transformation largely with the support of probability theory in time index values. Various 'exceptions' categories with constructed waiting time probability models and their results have proven that the customers large waiting do actually overcrowd the queuing system. This thesis discusses 'exceptions' affects through the Markov chain, random walk and birth-death process. The above concepts illustrate system behaviour, as 'exception' that disrupts services. In exceptional case, stochastic matrix considered two types such as actual job and 'exception' to occur during state transition. Their limitation is further simplified by random walk in convolution idea. The system parameters such as late departures, queue loss and others are affirmed in continuous-time by birth-death process. Simulation of change of discrete-event of queuing system such as service times shows, in long-run on averages service time fluctuates, utilization gets large, service finishing late and customers get increased in the system causing non-queue state. A platform of dissimilar manners used by stochastic process in non-queue transformation analysis. One of the manner employed are Markov conditional selection procedure is presented to recover queuing system through selecting and ordering random states. In other manner, random state(s) proceeds to get in order are expanded by proceeding walk and multinomial-pure death view. The interrelation of such models is grounded through the random states and distance decays by an interval. All such manners in stochastic process have likely to bring into being a queuing model after non-queue transformation. This research finds that the stochastic process has tremendous potential to model 'exception' outcomes and to restore the 'exception' eventual affects.

ABSTRAK

Kebanyakan model baris-gilir adalah berdasarkan kepada tingkah laku terancang para pelanggan yang dilayan oleh satu pelayan atau pelayan berganda. Sungguhpun begitu, terdapat banyak contoh di mana model baris-gilir tidak berdiri dengan etika giliran dunia yang sebenar. Kesannya boleh sampai kepada keadaan bukan baris-gilir yang disebabkan oleh kesesakan dan latar belakang budaya para pelanggan. Kajian ini menggambarkan hasil berturut-turut yang bersumberkan keadaan bukan-bergilir kerana pengabaian perlakuan pelanggan serta dasar tidak sistematik sistem layanan tunggal yang menjadi masalah utama penyelidikan. Aktiviti sedemikian disebut sebagai 'pengecualian' dan gangguannya dalam sistem baris-gilir. Objektif utama penyelidikan ini adalah untuk membentangkan 'pengecualian-pengecualian', kesannya dan penyelesaian kepada keadaan tidak berbaris-gilir. Ia adalah penting agar taburan masa menunggu, tingkah laku sistem semasa 'pengecualian-pengecualian' dan sistem baris-gilir masing-masing boleh dinilai, ditunjukkan dan dinyatakan kembali kepada keadaan bergilir layanan tunggal. Bukan-bergilir adalah keadaan yang dinyatakan apabila penggunaan sistem melampaui 100 peratus. Tambahan pula, ini boleh menunjukkan tiada baris-gilir formal langsung kerana para pelanggan boleh diandaikan berada di lokasi-lokasi rawak. Kajian ini akan menjelaskan keadaan sistem semasa 'pengecualian'dan transformasi bukan-bergilir dengan sokongan besar oleh teori kebarangkalian dalam nilai indeks masa. Pelbagai kategori 'pengecualian-pengecualian' dengan pembentukan model-model kebarangkalian masa menunggu dan keputusannya telah membuktikan bahawa penantian besar para pelanggan sebenarnya menyesakkan sistem baris-gilir. Tesis ini membincangkan kesan 'pengecualian-pengecualian' menerusi rantaian Markov, perjalanan rawak dan proses kelahiran-kematian. Konsep-konsep di atas menggambarkan sistem tingkah laku sebagai 'pengecualian' yang mengganggu perkhidmatan. Dalam kes yang istimewa, matrik stokastik mengambil kira dua jenis keadaan yakni kerja sebenar dan 'pengecualian' untuk berlaku semasa peralihan tahap. Limitasi mereka kemudiannya dipermudahkan dengan perjalanan rawak dalam idea kekusutan. Parameter-parameter sistem seperti keberangkatan lewat, kehilangan giliran dan lain-lain adalah ditegaskan dalam masa-berterusan oleh proses kelahiran-kematian. Simulasi perubahan acara-diskret sistem baris-gilir seperti pertunjukan masa perkhidmatan, purata masa perkhidmatan yang turun-naik dalam jangka panjang, penggunaan semakin meningkat, perkhidmatan tamat lewat dan para pelanggan semakin meningkat dalam sistem menyebabkan keadaan tidak-berbaris. Satu platform adab yang berbeza digunakan oleh proses stokastik dalam analisis transformasi tidak-berbaris. Salah satu cara yang digunakan adalah prosedur pemilihan bersyarat Markov yang dibentangkan untuk mendapatkan semula sistem beratur melalui pemilihan dan mengarah keadaan rawak. Dalam cara lain, keadaan rawak diteruskan untuk mendapatkan aturan yang diperkembangkan oleh perjalanan berterusan dan pandangan kematian tulen-multinomial. Hubungkait model-model tersebut adalah berasaskan kepada keadaan rawak dan pereputan jarak menerusi hentian sementara. Semua kaedah ini dalam proses stokastik mempunyai kemungkinan membawa kepada penciptaan model baris-gilir selepas transformasi bukan-bergilir. Kajian ini mendapati bahawa proses stokastik mempunyai potensi besar untuk membentuk hasil model 'pengecualian' dan akhirnya untuk memulihkan kesan 'pengecualian'.

ACKNOWLEDGEMENTS

As it pleases You, You assign tasks to one and all.
All things are Your Doing; we can do nothing ourselves.
(*Guru Granth Sahib*: 103)

I would like to express my sincerest gratitude to my supervisor, Professor Dr. Muhammad Ghazie Ismail for introducing me to the queuing theory, giving parallel coordination on thesis contents and inspired me to publish articles in international journals. Likewise, the most important is the arriving at the rest of thesis through his 'higher degree of independence' morals. I am grateful for the constructive comments and suggestions given by the external examiner, Professor Dr. Kamaruzzaman Seman for the advancement of this thesis.

I must also appreciate the current existence of electronic media that had helped me in understanding the conceptual framework of the queuing theory. Especially the e-learning video tutorials, which was uploaded by the volunteers/universities. I sincerely thanks to Dr. Charanjit Kaur for supporting my research finances, providing required literatures, translating thesis abstract in Bahasa Melayu, editing assistance, dealings with university administrating staff and outside the university in local language throughout my research duration. I attribute the level of my Masters degree to their encouragements and efforts. Without them, this thesis would not have been integrated, improved and completed.

I would like to thanks my parents Sardar Bhagat Singh Azad and Sardarni Balbir Kaur, my wife Dr. Charanjit Kaur, my siblings Satbir Kaur, Rupinder Singh and rest of other family members for their endless love and spiritual support during the course of my studies. Last but not least, a very acknowledgment to the new-born daughter Eykam Parteet Kaur during my study period. Her cheerful presence boosts the enthusiasm of our everyday life.

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LIST OF SYMBOLS

Symbol	Characteristics	Explanation
ρ	Rho	Mean service time of a single customer over mean interval between arrivals of successive individual customers.
$1/\mu$	Reciprocal service rate	Mean service time.
$1/\lambda$	Reciprocal arrival rate	Mean interval between arrivals.
$\{X_n\}$	Markov chain process	Set of random variable at step n.
x_{n+1}	Next state random variable	Variable that will take some state value at $n+1$ step.
S_{R_n}	Random variables set	Set of series of n random variable R_n.
$\cdot \leftrightarrow *$ $* \leftrightsquigarrow \cdot$	Implies	It implies that both $(*)$ and $(.)$ have same meaning.
Y_e	Random variable	Random variable for exponential distribution that exceed define time.
$\mathcal{T}_{b(*)}$	Before waiting time	Waiting time before the outlet opens for customer to arrive at T_i.
$X \sim \text{Exp}(\lambda)$	Distribution function parameters	It is a short hand notation which implies X is an exponential random variable with parameter λ.
$\mathcal{T}_{a(*)}$	After waiting time	Waiting time set after the queuing system begins.
$F(\tau)$ $F(\tau)_*$	Distribution function	Cumulative distribution function at time τ. Cumulative distribution function at time τ of $(*)$ form.
$R(\tau)$ $R(\tau)_*$	Survivor function	Survivor function of exponential distribution or probability of waiting more than τ. Survivor function of $(*)$ form.
k_{T_i}	Arrival time of k	k number of customer arrived at time T_i.
$\dot{\text{M}}(*)$	Median	The median is used to determine the location of the reasonable time when the distribution is skewed.
$\text{S}(T_n)$	System opening time	Time T_n, at which the queuing system will open.
$\tilde{*}$	Long-run average of	The accent mark on any character is used to symbolize the average or expectation, whichever related to relative section.
$P_{T_{b(i)}}$	Customer's waiting time	Long-run stationary value in discrete time.

$F_{Z_N}(T)$	Distribution function	Cumulative distribution for sum of N random variable Z_N.
X_i^{th}	Customer number	Random variable for i^{th} affected customer due do displacement act.
$R(T)_{state *}$	Survivor function	Survivor function of state $*$.
$R(T)_{\bullet}$		Survivor function of any state.
μ_a	Service rate	Service rate before i^{th} customer.
μ_b		Service rate after i^{th} customer.
$\rho_*^{\cdot}$	Traffic intensity during service variations	where $(.)$ represents the state of the system and $(*)$ for before or after service rate.
p_0	State probability	Probability that the queuing system is empty.
l_i	Time length	Length of interval i.
l_j		Length of interval j.
$(i,j)_v$,	State transitions pair	State transition from i to j at interval label v.
A_j	Actual job	The actual job stand for the service supposed to perform for a customer in queue in a specified interval.
$\mathcal{E}_x$	'Exception'	Behaviour that can brings the queuing system to non-queue state.
$p(*)_v$	Probability at interval	Probability of type $(*)$ at interval label v.
P_S	Survival probability	The probability of actual job done so far.
$k_{\neq 0}^{\in \mathbb{N}}$	Dual classification of a variable	It defines k is an element of natural number and also not equals to zero.
$\{S_N\}_{N=1}^{\infty}$	Sequence of random variable	Sequence of N random variable from 1 to ∞.
S_{N_i}		Sequence of i steps random variables.
x_k	Long run random variable	Long-run random variable of being in state k.
$x_k^{(i)}$	Long run random variable	Random variable at i^{th} step of being in state k.
D	Discrete-time	Discrete-time used during Markov chain.
C	Continuous-time	Continuous-time used during birth and death process.
$P_{k>\delta}(t+\Delta t)$	State probability	Probability of being in state of $k>\delta$ at $(t+\Delta t)$, where δ is default queue size and k is total of default number of customers and overcrowded customers.
λ^k	Arrival rate	Arithmetic collection of back to back occurrences of arrival rates.

P_{0,E_k}	State probability	Probability of accumulated states from 0 until E_K.
$P_{1\|N}$	Conditional probability	Probability that single event will occur given N births.
$E_*[f(\tilde{\cdot})]$	Expected value	Expected value of long-run function of (.).
${}_{\cdot}C_{*}$	Combination	It signifies (.) choose (*), as same as n choose r.
$(x_i, y_j)_P$	Coordinate pair	The location of dissipated customer with its previous value P, prior to non-queue state.
GLB	Greatest lower bound	Greatest lower bound will be the next nearest value.
LUB	Least upper bound	Least upper bound will be the rarest customer.
${}^{u}_{f}p$	Proceeding walk with up and flat proceeds	p with u and f only indicates the to proceed up and flat.
$P(u^p)$	Probability of up step	Probability of steps during up proceeding.
$P(f_p)$	Probability of flat step	Probability of steps during flat proceeding.
${}^{+1}_{+0}p$	Proceeding walk with random digits	It screens out the directions of proceedings in up and flat, positively.
$(x_p, -y_q)$	Coordinate pair	Position of dissipated customer in 4^{th} quadrant
$\mathbb{E}_{p_n}$	Effective position	n^{th} effective position from $(x_p, -y_q)$.
$<r>$	Ranged	Ranged of effective positions at the end-queue.
$\|-y\|$	Absolute distance	Distance from $(x_p, -y_q)$ to first effective position.
$x_{+x\ axis}$	Location at abscissa	Location at x of $+x$ axis.
$x_{-y\ axis}$		Location at x of $-y$ axis.
$0_{+x\ axis}$		Location at 0 of $+x$ axis.
$y_{-y\ axis}$	Location at ordinate	Location at y of $-y$ axis.
$\pm\infty_*$	Infinity of	Positive infinity of $\{x, y\}$ or negative infinity of $\{x, y\}$.
l_{+*}	Level proceeding	Random digit sign (0 or 1) added up to l.
N_j	Number of steps	Number of j steps that lead to effective positions.
$X_l(w)$	Random variable	The process that performs counting number of ways collected by random variable, which is used to reach the destination, where l represent ordinate level.
$P(\mathbb{E}_{p_k})_s$	Probability of effective position at s	Probability of k^{th} effective position is s distance far from $(x_p, -y_q)$.

$W_x(x,-y)$	Probability function	Probability function when $(x_p,-y_q)$ is x proceeding far.
$(s-1)\times(s)$ $(s-2)\times(s)$ $(s+1)\times(s-2)$ $(1)\times(s-2)$	Mutually overlapping cells	Numbers of column and row arrangement during overlapping of ranged of two different locations when effective position is s distance far.
$D(t)$ $D(t_i)$	Random process	Counting process of decreasing distance in time period t or t_i.
$d_{\{\alpha,\beta,\gamma\}}$	Distance through modes	d distance covered or declined through α,β and γ modes.
$i_{\alpha+\beta+\gamma}$	i^{th} distance	Covered i^{th} distance through the combination of α,β and γ.

LIST OF PUBLICATIONS

Singh, Harpreet and Ismail, M. Ghazie, 2014. 'Exceptions' in Queuing Theory. International Journal of Computer and Information Technology, 3 (1), pp. 110-119.

Singh, Harpreet and Ismail, M. Ghazie, 2014. 'Exception' in Queuing Theory through Markov Chain. International Journal of Electrical and Electronics Engineering, 1 (1), pp. 14-29.

CHAPTER 1

INTRODUCTION

1.1 Background

In a system of line up there are various factors that can develop the chain of complications before breaking the queuing system into unlike situation. Any system that constitutes individual giving services to seekers either mechanically or electronically or manually or else and a seeker that gets services from either authorized or experienced individual is known as serving system. In the queuing literatures, it is recognized as queuing system. Generally the host(s) provides services to the chronological arrivals of seeker that waits for their turn patiently. The study that mathematically analyzes the number of customers in the system, queue length, system size, arrival discipline, service time, service discipline, expected number of waiting, time in queue, load in the system and many other interested terms, can know from the queuing theory (Hlynka, 2007). Danish engineer, Agner Krarup Erlang considered as a discoverer of such theory when he published first paper in 1909 on queuing theory in telephonic networks at Copenhagen.

The theory results in the form of queuing models with many applications in different fields of study. This theory extensively used in telecommunications, hospitals, traffic, computers, retails, airports, banks and many others. The arrival and service can be individual or group, completely random or constant. A server can be single or multiple. Queue size can be both finite and infinite. The queue controlling can be chronological, random, or unordered. Customers permitted in the system are finite or infinite. The make-up of all these choices can collectively define in Kendall notation given as (P/Q/R):(X/Y/Z), where P/Q is the arrival and a server probabilistic approach, R is server quantity, X is queuing controlling, Y is number of customers permitted and Z is size of customer population.

It is routinely believed that the mutual contribution of socially acceptable behaviour by the seekers and the host(s) supports queuing system performances. This can only be possible if they are following ethics that are organized. If the queuing system considers human involvements then most probably the only term relevant is the waiting. Waiting requires patience and patience requires practice. Besides this, due to their achievement rate the system in services does not desirable to keep customers in the waiting. However, the reason that put into concern that why the waiting begins and gets large. The reason is simple, when the undesirable exception comes in during the current task and its regularity cause the beginning of waiting more than expected.

Large waiting completely influenced by the large accumulation of small-scale of hindrances. It possibly will be an unnecessary exception that caused either the service provider gets undesirably slow or service seekers are undesirably arriving faster than normal. If there were no hindrances then the servicing rate is infinite and queue size is zero, i.e., *sojourn* time in such state is nothing. Otherwise, it causes growing of queue besides overcrowding prior to the queue less state. For e.g., in a queue network, service rate variation within a larger time frame gives sudden input to subsequent server or specific time of arrival of requests in a system in a short period of time.

The services of the customer may be either constant or stochastic, and the organization of queuing system varies globally. However, in some area of the world the queue routines are not following properly. From place to place the cultural practice of queuing includes awful customers, dishonor and for few the existence of a queue is almost alien to them. Such practices cause pressure on the serving system. However, the proper restricted policy can control customer behavior inside the serving system to avoid from delay in services. Gross et al. (2008) suggested that if such behaviours are not controlled in time the chances are that the queues get bigger and bigger unless at some point the customers are not allowed to enter the system.

Ever since Erlang, most of the researches have been focused on designing well-organized system by assuming static conditions to perform without any disruptions. In general, queue analysis is based on the stationary assumption in customer's variability, but in reality there are other variables that can direct to a different state of the system. Many literatures analyzed the results using a queuing model on the basic assumption that $\rho < 1$, otherwise later $\rho \geq 1$, the queuing system goes imbalance or unimagined situation. But the series of outcomes with an undesired event and the queuing system later $\rho > 1$ exclusively not at all exhibited. As Gross et al. (2008) highlighted, in queuing theory the queuing models that predict the performance of serving system with the assumption that demands arising randomly, but not unnaturally, which can be either service or arrival.

Such unnatural randomness may perhaps be due to undesired behaviour occurrences of customers and server. Cohen (1982) describes the behavior of customers with two characteristic features, viz. The arrival process and the waiting process, and thus the continuation of unnoticeable behaviour may challenge the service seekers patience. Cox and Smith (1961) and Conolly (1975) mentioned that congestion in queuing system occurs due to an abnormality, i.e., the sudden changes in behaviours of either customer(s) or server will result in an unbalanced system. Wang et al. (2010) highlighted that numerous queuing literatures discuss two types of behaviours concerned with customer and servers which are *impatience* and *vacation* period, respectively. In customer behaviours case reneging, preemptive, baking and jockeying is covered largely by other researchers. Kok and Tijms (1984), Shin, Choo and Chakravarthy (2009), Sudesh, Perel and Yechiali (2010)