International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume –06, Issue – 11, November 2021, PP – 17-28

# Average Delay with Different Priorities for SecondaryUser in Cognitive Radio Networks

Suad O. Merad[1], Asma M. Eshahiry[2], Mohamed A. Elalem[3]

[1,2,3](Electrical and Computer Department, Elmergib University, Libya)

**Abstract:** In this paper, we investigate the mean delay of packets with different priorities in cognitive radionetworks (CRN) using queueing models in studying the performance of the secondary users underthe pre-emptive resume and pre-emptive repeat priority scheduling systems under severaloperating conditions. It is found that the pre-emptive resume priority gives better performanceunder all the conditions. Specifically, we consider four scenarios for CRN. Results revealed thataverage delay of SUs in the queue and SU packet loss probability is worst when the arrival rate ofPU is greater than SUs, and a better performance when the arrival rate of both users are the same. Furthermore, the model gives the best performance when the arrival rate of SUs is greater than PUs.

**Keywords:** Cognitive radio, Secondary user, Primary user, Priority Queueing, Pre-emptive.

## 1. INTRODUCTION

Since radio spectrum is now very congested due to the increasing demand and explosion growth in wireless services over the past several years. Fast data transfer rate becomes a challenging task especially in the bands below 3GHz. Extensive measurements taken reveal a typical utilization of 0.5%in the 3-4 GHz band which drops more in higher bands [1]. Recent survey has proved that most of the radio frequency spectrum is vastly under-utilization.

The FCC reported vast temporal and geographic variations in the use of the allocated spectrum with utilization ranging from 15% to 85%. In order to utilize this spectrum holes, the FCC announced Cognitive Radio (CR) technology as a candidate to implement negotiated or opportunistic spectrum sharing [1]. Cognitive radio is an intelligent device that is aware of its surrounding environment and uses the methodology of understanding-by-building to learn from the environment and adapts its internal states to make corresponding changes in certain operating parameters [2].

Traditionally, a large amount of spectrum bands have already been assigned to different users who are often referred to as Primary Users (PUs). They have the exclusive right to use these bands. This inflexible policy has already been a huge waste of spectrum resources. While cognitive radio allows the SecondaryUsers (SUs) to use the licensed bands when such bands are vacant by PUs. By detecting particular spectrum holes and jumping into them rapidly, cognitive radio improves the utilization of the spectrum significantly.

The fundamental requirements for SUs are to control the interference to the potential PUs in their vicinity. To guarantee a high spectrum efficiency while avoiding any kind of harmful interference to the licensed users (PUs) important functionalities should be provided by cognitive radio such as spectrum sensing, dynamic frequency selection and transmit power control [3].

The priority scheduling for users becomes interesting topic. A pre-emptive system interrupts a service to low priority user (SU) when high priority user (PU) arrives at the system. Pre-emptive priority in a discrete time system presents the high priority at the beginning of a given slot. [4].

This paper focuses on the modelling of the performance of SUs and PUs in cognitive radio ad hoc network using the priority queueing models. Specifically, different scenarios such as a pre-emptive resume priority (PRP) and a pre-emptive repeat priority are studied, analyzed and simulated. For the sake of simplicity, all customers are assumed to have identical priority when accessing the server based on first in first out (FIFO).The main statistical parameters which are used in each scenario arelisted here: mean arrival rate of PUs, mean arrival rate of SUs, mean service time squared coefficient of variation for both arrival rate and service rate,and queue capacity of each class.

After this brief introduction, the rest of the paper is organized as follow. Section 2 describes the system model. In Section 3, model implementation for different scenarios in terms of (multiple PU and multiple servers) and (single PU and single servers) is introduced. Then, queuing system models are reported in Section 4. In Section 5, performance analysis and results are presented and discussed. Finally, conclusion is drawn in Section 6.

  

## 2. SYSTEM MODEL

### 2.1 Queuing Models

Queuing system model is a representation that captures and quantifies the phenomenon of waiting in lines in queues.It consists of three main elements; queues, servers and entities. Queues are waiting position of entities or the holding. There are two important properties of a queue: maximum size and queuing discipline.Maximum Queue Size (also called system capacity) is the maximum number of customers that may wait in the queue (plus the one(s) being served). Queue is always limited, but some theoretical models assume an unlimited queue length. If the queue length is limited, some customers are forced to renounce without being served.

Servers are represented production station or persons which are interact with the entity. Entities can be either object or customers. The queue discipline is one of the components of the queuing system. Two common types of disciplines are Shortest Process Time (SPT) and First Come First Served (FCFS). Queue discipline is the instruction that either objects or customers. The only parameter which is depending on the queue discipline is its standard deviation (or variance). As shown in Fig. 1, queueing system contains three main components; arrival process, queue discipline and service mechanism. The arrival process is described how customers arrive to the system, and queue discipline is referred how server choose the next customer from the queue [5,6]. The three common queue disciplines for queueing system are:

- FIFO: A first in –first out.
- LIFO: A last in –first out.
- Priority: customers who have high-priority are served first than customers of low-priority.

The service mechanism is articulated the number of servers and which server has own queue [7].

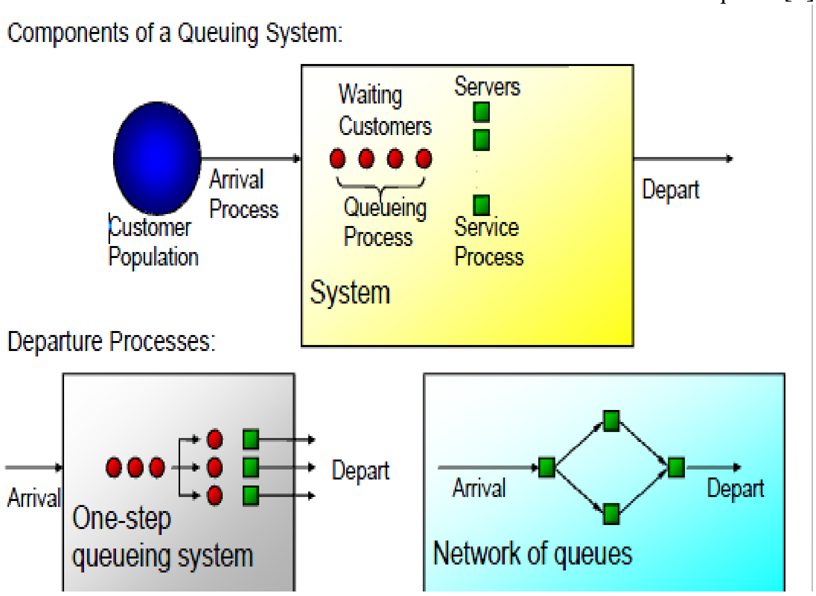


Figure 1. Components of queueing system [6]

#### 2.1.1 Single Class Model

Single class model shown in Fig.2 is considered as the simple queueing system. When jobs arrive to the system, wait until it can be attended to. If single server is available thus the jobs receive service and then depart. It means, each time there are jobs in the system, so each job is selected for service in order.This scheduling known as First Come First Served (FCFS) or (FIFO) First InFirst Out. Jobsdo not leave the queue before they have been served[8].

  

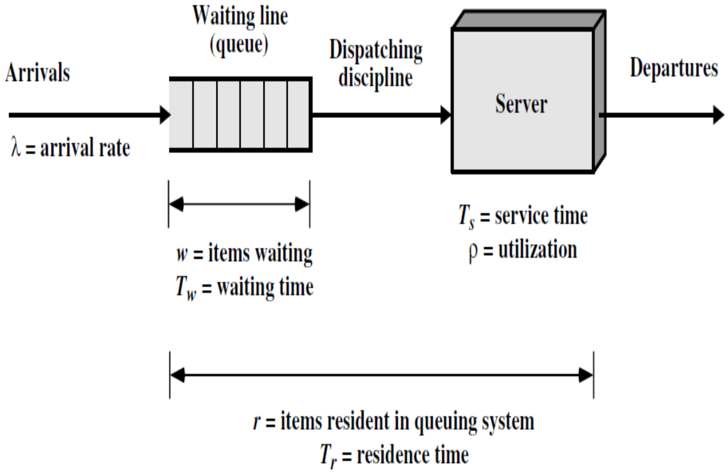


Figure 2. Structure of queuing system and parameters for single-server queue [9]

### 2.1.2 Multiple Class Model

Multiple class models workapproximately identical to single class model in performance measures, for example; throughput, response time, and utilization. Simple multiple class model diagram is shown in Fig. 3. There are several advantages of multiple class models over single class models; each customer's classes are giving result (output) such as response times. But signal estimate is represented for response time in single class model. Moreover, results from a multiple class model are more accurate.Some systems are modelling only through multiple class models.However, there are several disadvantages of multiple class models which are related to single class models. Technical solutions are much problematic to implement multiple class, it needs more requirement such as machine resources, than techniques in single class.

In a multiple class model, there are more than one customer in the system, so each one requires one set input parameters. Furthermore, measurement tools in a multiple class model are not sufficient enough to provide appropriate information about each customer class comparable with the accuracy in single class models measurement tools [5].

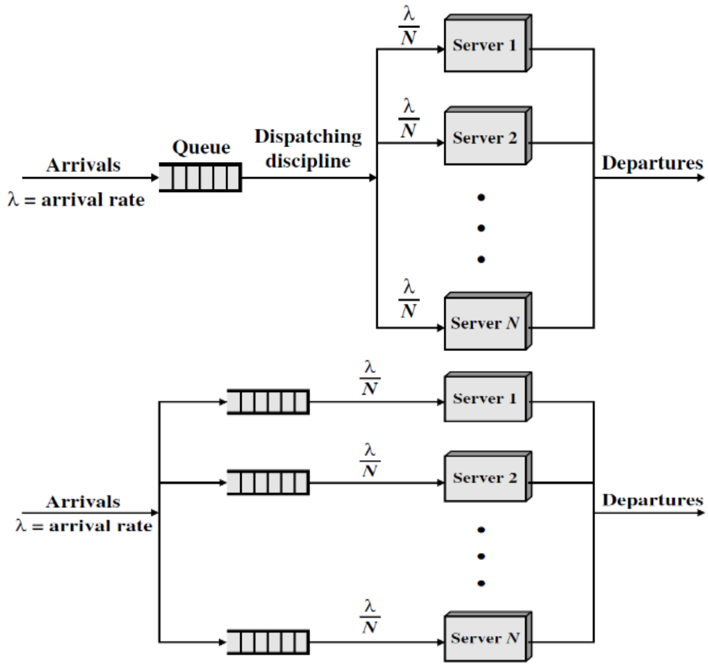


Figure3. Multiserver versus multiple single-server queues [9]

### 2.2 Priority Queueing Systems

There are some customers in queueing systems those are obtaining special treatment that known as priority queueing systems. Costumers are divided into two type of priority classes; higher priority and lower priority. The higher priority is given preferential treatment to serve over the low priority. There are two types of priority scheduling disciplines to resolve the situation, which are non-pre-emptive and pre-emptive scheduling [10].

In model of non-pre-emptive priority queues, the transmission packet will never be interrupted when it is in service. Hence, if a low priority packet is in service and high priority packets have arrived, the high priority packets have to wait until the low priority packet leaves the server [10]. If the customers present demanding then the server never become idle. Therefore, the performance of the queueing system might be affected by the queue discipline. In pre-emptive priority queues, the arrival of a message of higher priority pre-empteddirectly gets service to a message of any priority. In queue which is with priority scheduling discipline, when server is available, the high priority packets are transmitted faster than low priority packets. Thus, a high priority packet is scheduled for transmission. Only a low priority packet is transmitted when no high priority packet in the buffer at that time [10]. For pre-emptive priority disciplines, there are types which vary as to the amount of service sustained for the pre-empted message when the server returns to it.These types are depending on what will happen to an interrupted low priority packet when re-enters the server.When apacket does not have to be transmitted again, if pre-emption does not cause any losses, the packet can resume where it was interrupted.This is known as*pre-emptive resume*. Eitherin *pre-emptive repeat* the packet which is interrupted has to be totally transmission. The pre-emptive repeat priority scheduling is two types: with resampling and without resampling and also known as *repeat different* and *repeat identical* respectively. Resampling means not necessarily the length of a repeated service time is equal to the length of the first interrupted service time, so it is newly sample with the similar distribution [10].

## 3 MODEL IMPLEMENTATION

There are three classes of buffer management schemes: *Partial Buffer Sharing (PBS) policy and Complete Buffer Sharing (CBP)***.** In *partial buffer sharing*, the different in priority classes is based on threshold in buffer, so PBS can control incoming traffic from these classes. When PBS accepts high priority and low priority packets, that means that the buffer size below than threshold. Low priority packets cannot enter the buffer and are rejected when the buffer size is over a threshold. However, high priority packets can enter the buffer even it is full.

For the second class of buffering management; complete buffer sharing, the arrival packets of any class are allowed to enter the buffer as long as there is space in finite capacity queue. In addition, CBS can be reached to highest buffer utilization since all of the buffers are always busy unless there is no enough arriving traffic.

In complete partition policy class, buffer space is partitioned into diverse queues for a single class, the overall packet loss rate is increased owing the fact that arrival packets might be rejected and also complete buffer partition decreases the buffer utilization.

In the following subsections, many scenarios will be considered, implemented and simulated.

### 3.1 Scenario-A (Two Classes PU/SU and One Server)

A single server pre-emptive priority queue with PBS for low priority customers (SUs) in discrete time is assumed here.In PBS mechanism, SUs can only access the buffer if the buffer is less than certain threshold value.

This scenario considers a $GE/GE/1$ discrete time queue with pre-emptive, where GE refers to General Exponential distribution [11] it is explained later in Section 4.2. In $GE/GE/1$, both arrival and service processes are GE-type distribution.In addition; there are two types of customers, low priority and high priority customers, which are called SUs and PUs, respectively. Fig. 4 illustrates this model.

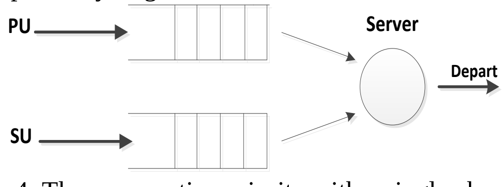


Figure 4. The pre-emptive priority with a single channel

PUs arrive in the system according to a GE arrival process with constant mean rate $\lambda$ and same for SUs with vary mean rate and mean service rates of the channel for both PUs and SUs have same value$C_P^2$ and $C_S^2$ are set to different values in each case and the threshold value for SUs is 40% of PUs buffer size. For priority queueing system, the service process of SU will be started if there is no PU in the system because PUs have pre-emptive priority over SUs.

### 3.2 Scenario-B (Two Classes PU/SU and Multiple Servers)

This scenario considers a $GE/GE/c$ discrete time queue model with pre-emptive and $c = 4$. Both arrival and service processes are GE-type distribution. Fig. 5 showstheis model. Pre-emptive priority queue for multiple servers with PBS for SUs, the threshold value of SUs is also equal 40% of PUs buffer size. In this, model PUs can pre-empt the SUs if it is in the server.In pre-emptive resume, the interrupted SUs can enjoy the head of line of low priority queue. However, the interrupted SUs will enjoy the low priority queue and transmit again as new arrival in the pre-emptive repeat.

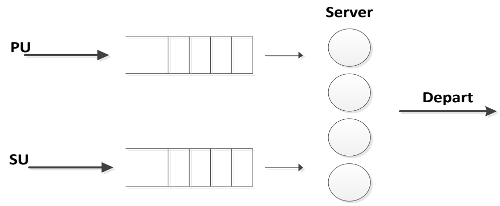


Figure 5. Two classes and multiple servers(c=4)

### 3.3 Scenario-C (One Class PU, Multiple Classes SU and Single Server)

This scenario is describing the pre-emptive priority model for one class PU, multiple classes SU and multiple servers as shown in Fig. 6.

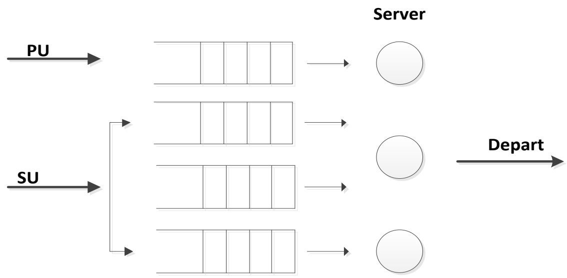


Figure 6. Multiple classes and multiple servers

In this scenario for resume and repeat, The mean service for all servers is set to be 20 customers per second and also Squared Coefficient of Variation(SCV)s are assumed to be 5.The buffer capacity of PUs class is set to be 100 customers and for SUs classes are assumed to be limited, that means SUs can access the buffer if the buffer less than threshold value which is 40% of the buffer capacity of PU class

## 4 QUEUING SYSTEM MODELS

### 4.1 Describing the Queueing System

Queueing system has been developed by David Kendall who has established and described the concept of a shorthand notation called the Kendall notation [12]. The queuing system is in the form $A/B/c/K/m/Z$, where$A$ describes the inter arrival time distribution, $B$ is the service time distribution, $c$is the number of servers, $K$is the system capacity,$m$is the number in the source and $Z$is the queue discipline. The shorter notation $A/B/c$is used when the queue size is unlimited.

The basic queuing theory notation and definitions are given as following:

$c$: number of servers.
$\lambda$; arrival rate of the customers in system.
$\mu$: the service rate of the customers in system.
$\rho$: server utilization.
$N$: random number describing the number of customers in the system.
$N_q$ random number describing the number of customers in the queue.
$L$ number of customers in system in steady state $E[N]$.
$L\_q$: number of customers in queue in steady state $E[N_q]$.
$W_s$: service time $E[s] = 1/\mu$.
$W$: time in the system in steady state

$W = W_q + W_s.$

$W_q$: time in the queue in steady state

$W_q = W - W_s.$

### 4.2 The GE-type Distribution

The cumulative distribution functions of generalized exponential distribution or the exponentiated exponential distribution can be written as [13] as below

$$F(t) = P(W \leq t) = 1 - \tau\, e^{-\sigma t}, \qquad \geq 0 \tag{1}$$

hence $\tau = \frac{2}{C_a^2+1}$ and $\sigma = \tau\, v$

$$F(t) = 1 - \frac{2}{C_a^2+1} e^{-\frac{2v}{C_a^2+1}t}, \qquad \geq 0 \tag{2}$$

For $t = 0$,

$$F(0) = 1 - \frac{2}{C_a^2+1} = \frac{C_a^2-1}{C_a^2+1} \tag{3}$$

Where $t$ is the random variable (RV) of the inter event distribution (arrival time or service time), the mean of the distribution is $1/\upsilon$ and the square coefficient of variation(SCV) is $C_a^2$.Therefore, SCV is defined by[14]:

$$SCV = C_a^2 = Var(t)/E^2(t) \tag{4}$$

Thus $t$ can be inter arrival time with parameters $\{1/\lambda,\ C_a^2\}$ and for service time $\{1/\mu,\ C_a^2\}$.The block diagram of GE-distribution is shown in Fig. 7.

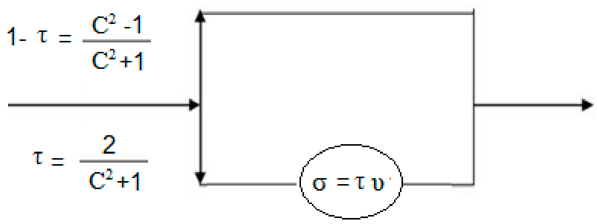


Figure 7. The GE-distribution with parameter σ

The GE-type cumulative distribution function (CDF) in Equation (1) is mixed time distribution (continuous time and discrete time). The GE-distribution is using to characterize the inter-event distribution. It is corresponding to a Compound Poisson Process with geometrically distributed batches reflecting the burstiness of the arrival process and service completion process with the queueing node. As depicted in Fig. 7, a random variable generated using generalized exponential distribution is used in an event driven simulation where more than one event might come at the same time in batches. Consequently, $a^{-1}$ might be interpreted as the mean of the batch sizes [14].The GE distribution is used to reflect traffic burstiness on the performance of node within a communication system through increasing the inter-arrival times SCV, $C_a^2$>1.

## 5 PERFORMANCE ANALYSIS AND RESULTES

In this section, the analysis and evaluation though simulation will be performed for the different scenarios discussed above. $GE/GE/c$ assumption is used for different number of servers ($c$). The primary users are assumed to have the exclusive right to use channels. The performance of each case is measured in terms of average delay being in the queue and probability of average packets loss versus the arrival rate of both primary and secondary users.

Results will be illustrated for pre-emptive resume and pre-emptive repeat priorities of two classes and single server.

First, it is assumed that both PU and SU queues have infinite capacity, SCVs for inter-arrival time and service time are set to 5. The $\lambda_p$ of PUs is assumed to be constant with value 5 customers per second and $\lambda_s$ of SUs is varied from 0.2 to 5 customers per second with interval 0.2 customers/sec, the mean service rate of the server for SUs and PUs are assumed to be the same $\mu = 10$ customers/sec, the buffer capacity of the both classes in first case are set to infinite ($\infty$).

**For Scenario-A**, Fig. 8 shows the performance measurements for pre-emptive resume and pre-emptive repeat priority of the SUs. The simulation size is chosen to be 40, that means the program takes the average of forty runs to measure the performance. Average delay of SUs in queue is plotted versus throughput of SUs. from Fig. 8, it can be seen that average delay of SUs with repeat priority is slightly higher than the average delay of SUs with resume priority. In the beginning they look the same but when arrival rate increases the average delay of SUs with repeat priority increases. This is because the customers which have interrupted have to retransmission again against the customer with resume priority, they have to resume the unfinished transmission.

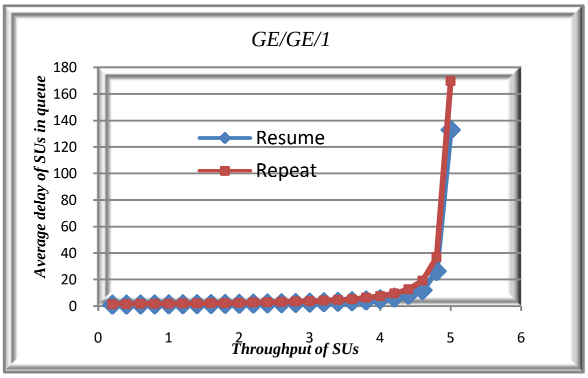


Figure 8. Average delay of SUs in queue

The impact of variation of mean rate of PUs with pre-emptive repeat priority on low priority class is also studied, the mean rate of PUs is assumed to be varied with three possible values:

- Greater thanthe mean rate of the SUs, i.e., $\lambda_p > \lambda_s$,
- Equal to the mean rate of the SUs, i.e., ($\lambda_p = \lambda_s$).
- Less than the mean rate of the SUs, i.e., $\lambda_p < \lambda_s$.

The Mean rate of SUs is varied from 0.2 to 5 with interval 0, while for PUs mean rate is assumed to take different values to compare the impact on pre-emptive repeat priority.

Average delay of SUs in queue is drawn in Fig. 9. It evidently shows that the average delay experienced by SUs in the low priority queue is highest when the arrival rate of PUs is greater than that of SUs, because, the rate of pre-emption of SUs by PUs increases. The delay experienced by SUs in the queue is the same when the arrival rates of PU and SUs are the same and when arrival rate of PUs is less than that of SUs.

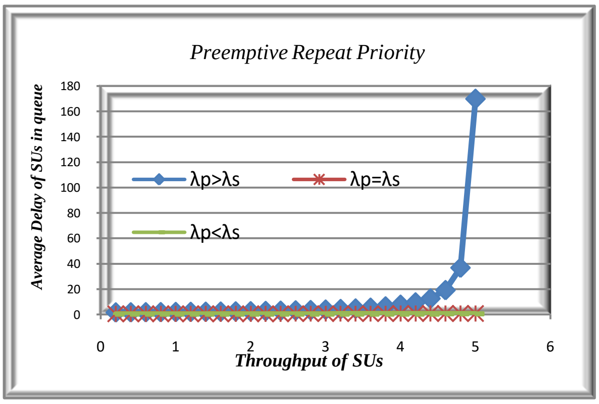


Figure 9 Average delay of SUs in queue of pre-emptive repeat priority with different value of arrival rate of PUs

**For Scenario-B, firstly**, the pre-emptive resume priority with PBS is studied in the following two figures. Fig. 10 shows the average delay od SUs as a function of arrival rate of secondary users. The secondary customers are assumed to be varied from 1.0 to 6.0 customers per second for number of servers $c = 4$. Different values of square coefficient of variation ($SCV = 5, 10$ and $20$ are chosen). From the figure, it can be seen that the average delay of the Sus in queue increases with increasing arrival rate. Also, this delay increases as the value of $SCV$; the variance parameter of the GE distribution.

Fig. 11 illustrates the relation the average packet loss of the secondary user transmission versus arrival rate of the SUs for the case of pre-emptive resume priority. The average packet loss increases as the arrival rate increase because SUs will retransmit again for every unfinished transmission (resume case).

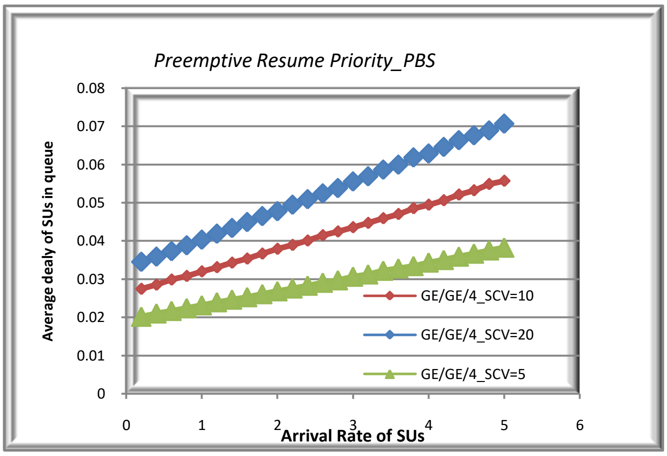


Figure 10. Mean delay of SUs pre-emptive resume priority with PBS for different values of SCV

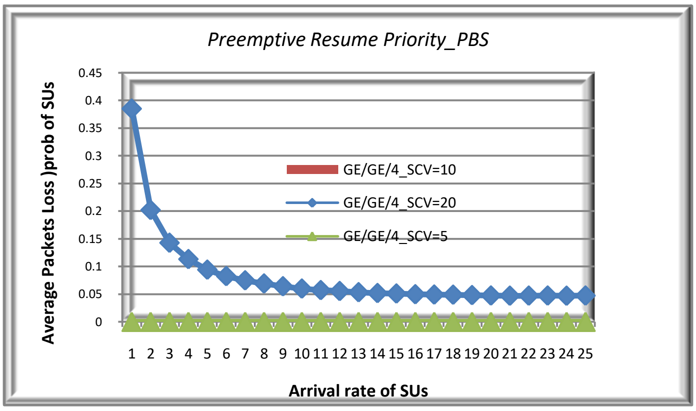


Figure 11. Mean packets loss probability of SUs pre-emptive resume priority with PBS for different values of SCV

**Secondly,** for pre-emptive repeat priority with PBS case, the average rate of PUs is greater than the average rate of SUs. Average service rate is chosen to be $= 15$ customers per second. SCV is also assumed to be $SCV = 5, 10$ and $20$. The average arrival rate is fixed to $\lambda_p = 20$ customers/sec. The three figures below illustrate the relation of the average delay of SUs in queue and average packets loss probability of SUs with respect to arrival rate of SUs for pre-emptive repeat and resume priorities respectively.

Fig. 12 and Fig. 13 show the mean delay and average packet loss probability of SUs versus the mean arrival rate. Fig. 14 reveals that delay of SUs in the queue is lowest in the first class of SUs because it has the highest priority of all SU classes, followed by the second class of SUs and this is also because it has higher priority over the third class, obviously, the third class of SUs give the highest SUs delay because it has the lowest priority of all the SU classes. The first has the best performance in the system after the PU class.

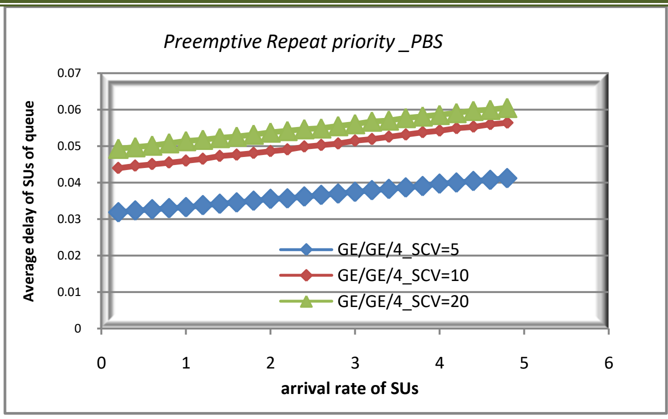


Figure 12. Mean delay of SUs pre-emptive resume priority with PBS for different values of SCV.

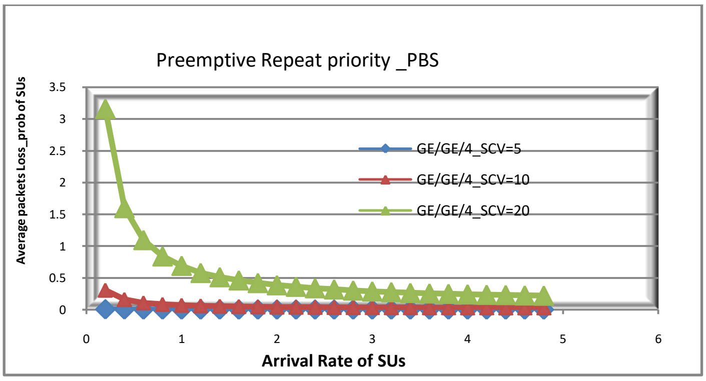


Figure 13.Mean packets loss probability of SUs pre-emptive resume priority with PBS for different values of SCV

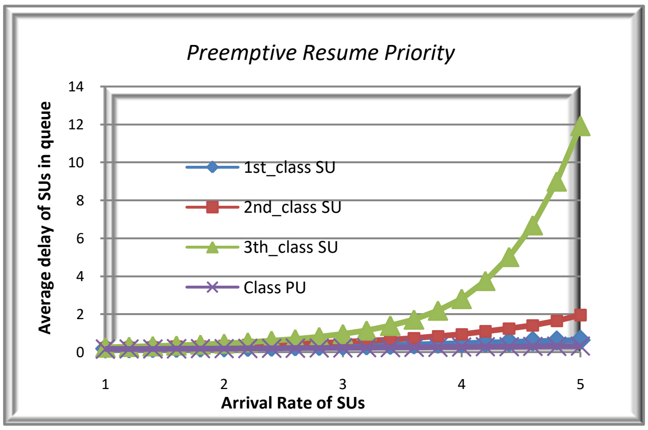


Figure 14. Mean delay one class PU, multiple classes SU for pre-emptive resume priority

**For Scenario-C, firstly**, the pre-emptive resume priority with PBS is simulated and plotted in Fig. 15 and Fig. 16 assuming varying values of arrival rate for the primary and the secondary customers. The rangeis chosen from 1.0 to 5.0.0 customers per second. In Fig. 15, the PUs have the lowest average delay in queue hence they have the top priority over all secondary users. As the mean arrival rate increases, this delay in queue increases for all classes. The third class of priority has the largest number of users staying in the queue.

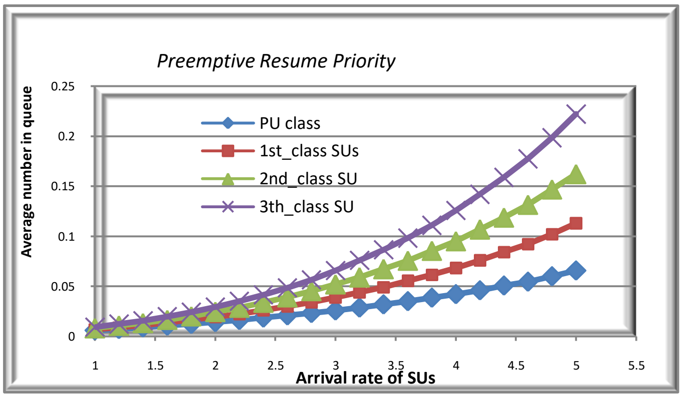


Figure 15.Mean number one class PU, multiple classes SU and multiple servers for pre-emptive resume priority

Same conclusion can be noticed in Fig. 16 for the case of pre-emptive resume priority case. The average delay of SUs being in the queue increases with arrival rate increases. First class SUs are suffering less than the high classes because of retransmitting after waiting above the threshold value, while the PUs are suffering from the less value of delay.

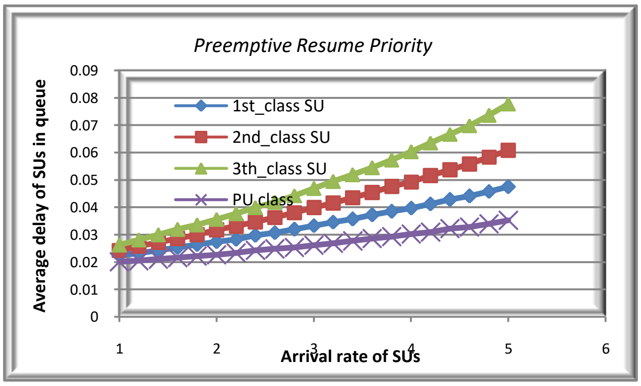


Figure 16.Mean delay one class PU, multiple classes SU and multiple servers for pre-emptive resume priority

**Secondly,** for pre-emptive repeat priority with PBS model, the value for arrival rate of primary is assumed to be diverse from 1.0 to 6.0 customers per second with increment of0.2 and arrival rate of secondary customers is assumed to be varied from 0.2 to 5.0 customers per second with same increment of 0.2. Both average number of SUs in queue and the average delay in queue versus the average arrival rate of SUs are plotted in Fig. 17 and Fig. 18 respectively. Similar conclusions can be drawn here. Both parameters increase with increasing the arrivals. The PUs should wait minimum delay compared to that of SUs. Also as the classes of SUs go up the average delay and number of SUs in queue become worst.

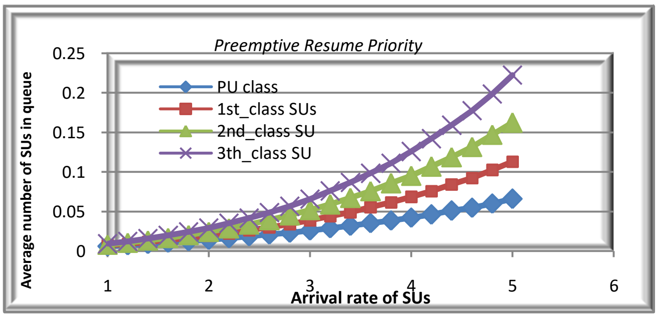


Figure 17. Mean number one class PU, multiple classes SU and multiple servers for pre-emptive resume priority

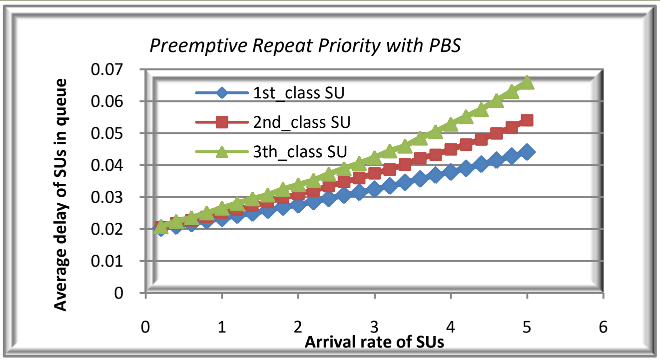


Figure 18. Mean delay one class PU, multiple classes SU and multiple servers for pre-emptive repeat priority

## 6 CONCLUSION

In this paper, we have considered three scenarios for CRN.The first is modelled using a single server and two classes of queues, one for the primary users and the other for secondary users. Analysis of this model was extended to multiple classes and multiple servers,

From the results obtained, the comparison between pre-emptive resume and pre-emptive repeat priority queuing models are studied.The simulation shows that pre-emptive resume gives better performance compared to pre-emptive repeat in terms of average number of SU in the queue, average delay experienced by SUs in the queue and SU packet loss probability. This is so because in the pre-emptive resume priority queuing model, the interrupted SU by the PU is sent to the head of the low priority queue to continue its transmission when the server is free unlike the pre-emptive repeat where when an SU is pre-empted by a PU, it has to starts the transmission right from the beginning when the server is idle.

Furthermore, comparative analysis is performed when the arrival rate of PU is greater than that of SU, when arrival rates of PUs and SUs are the same and when the arrival rate of PU is less than that of SU.

The results show that the performance of SUs in terms of average number of them in the queue, their average delay in the queue as well as the packet loss probability are the worst when the arrival rate of PU is greater than SUs, and a better performance when the arrival rate of both users are the same and gives the best performance when thearrival rate of SUs is greater than PUs.

The effect of varying the SCV is also carried out.The SUs experienced the worst performance when the SCV is greater. This shows that the performance of SUs degrades with increasing the value of SCV, SCV is used to characterize the burstiness of traffic, the higher the SCV, the burstier the traffic.

## REFERENCE

[1] D. Cabric, S. Mishra, and R. Brodersen, Implementation issues in spectrum sensing for cognitive radios, *Conference on Signals, Systems, and Computers*, 2004.

[2] Simon Haykin, Cognitive radio: brain-empowered wireless communications, *IEEE Journal of Selected. Areas in Communications, Vol. 23*, 201–220.

[3] Mohamed Elalem, Lian. Zhao, and Zaiyi. liao, Interference mitigation using power control in cognitive radio networks,*In Proc. IEEE Vehicular Technology. Conference (VTC)*, 2010, Taipei, Taiwan.

[4] F .Jolai, S.M. Asadzadeh , and M. R. Teghizadeh, A pre-emptive discrete time priority buffer system with partial buffer sharing,*Applied Mathematical Modelling, 34(8)*, 2010, 2148-2165.

[5] E. D. Lazowska ,J. Zahorjan ,G.S. Graham , and K. C .Sevcik, *Quantitative system performance: computer systemanalysis using queueing network models*(Prentice-Hall,Inc, 1984)

[6] Joris Walravens, Dieter Fiems, and Herwig Bruneel, Performance analysis of priority queueing system in discrete time, *Network Performance Engineering*, 2011, 203-232.

[7] A .O .Allen, *Probability, statistics, and queueing theory with computer science applications* (Academic Press, United States of America,Second Edition, 1990)

[8] I. Mitrani, Modelling of Computer and Communication Systems Cambridge University (Press, First Edition, 1987)

[9] William Stallings, *Queueing analysis* (Operating Systems, Seventh Edition Prentice Hall, 2011) http://www.electronicsteacher.com/download/queuing-analysis.pdf, [accessed 12/12/2021].

[10] L.M. Averill M. Law and W. David Kelton, *Simulation modeling and analysis* (The McGraw-Hill Companies, Third Edition, USA, 2000)

[11] G. Miskeen and D. Kouvatsos, On the simulation of GE, *Technical Tutorial, Net PEn Research Group, IRI*,(University of Bradford, Bradford, UK, 2011).

[12] Daley, D. J. and D. VereJones, David George Kendall and applied probability, Journal *of Applied Probability, 45(2)*, 2008, 293-296.

[13] Gupta, R. D. and Kundu, D., Generalized exponential distributions: different methods of estimation, *Journal of Statistical Computation and Simulation. Vol. 69*, 2001, 315-338.

[14] K.AL-begainand I.. Awan, Generalised analysis of buffer management in heterogeneous multi-service mobile networks,*International Journal of Simulation Systems, Science & Technology (IJSSS), 22(2)*, 2021, 1-7.

  