CSE331 TERM PROJECT

by

Burak Ok

Emirhan Önder

Eren Yağız Gürbüz

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Yeditepe University

Faculty of Engineering

Department of Computer Engineering

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1. INTRODUCTION

In a traditional Linux environment, the CPU scheduling policies distribute the computational resources among running processes. However, these policies don't consider the ownership of these processes, potentially leading to a situation where a user running a large number of processes can monopolize the system's computational power. This situation may not be an issue in a single-user system, but it can significantly impact fairness in a multi-user environment, where equitable distribution of resources is crucial.

Our project aimed to resolve this issue by developing a fair-share scheduling policy. The primary objective of this policy is to ensure that each user gets an equitable share of the CPU, irrespective of the number of processes they are running. The fair-share scheduler accomplishes this by grouping processes by their owning user and then distributing CPU resources among these groups. As a result, each user gets a fair share of the CPU, and within each user's group, the CPU time is further divided among their respective processes.

The implementation of the fair-share scheduling policy required a deep understanding of the Linux kernel, specifically the kernel's scheduling policies and their implementation. It also necessitated a careful and meticulous design process to ensure minimal disruption to the existing kernel functionalities, and to maintain system stability and performance while improving fairness.

By implementing the fair-share scheduling policy, we strived to make the Linux operating environment more equitable for all users. This project was not only about enhancing the performance of the system but also about ensuring fairness and maximizing the efficient utilization of computational resources. In the following sections, we will delve deeper into the design, implementation, and testing of our fair-share scheduler.

2. DESIGN and IMPLEMENTATION

Linux uses two different process scheduling algorithms. These are time-sharing and real-time algorithms. Time-sharing algorithm is fair and preemptive scheduling between multiple processes. This algorithm, which is the Linux default scheduler(SCHED_OTHER), simultaneously divides the time in 10ms intervals. On the other hand in Real-time algorithms(SCHED_FIFO,SCHED_RR),absolute priorities are more important than fairness. It is used to allow the processor to allocate more time to processes that need to run in real time.

In Linux default scheduler, each process has a value called nice. Nice values determine the dynamic priority of the process it belongs to. The nice values of newly created processes are set to 0 by default. If the nice value of a process is negative, this process has a high priority. If it is a positive value, the priority of the process is low. The priority of the process is calculated with 20-nice.If a process has I/O burst ,system lowers nice value of a process to provide higher priority but if a process only has CPU burst , nice values is not changed.

The time slices allocated with the priority of the process is directly proportional. The system keeps the time slices allocated to the processes with the counter variable and each process has a counter variable. The counter variable specifies how many time slices the process is allocated. When the calculated counters are finished, the counter values of the processes are recalculated, this event is called epoch.

Task Structure

Task structure is the structure that holds the information of a process. Values such as nice, counter, state, etc. are kept in the task structure. The system obtains the information of the processes through task structure and makes the process selection according to this information.

```
struct task_struct {
    /*
     * offsets of these are hardcoded elsewhere - touch with care
     */
    volatile long state;    /* -1 unrunnable, 0 runnable, >0 stopped */
    unsigned long flags;    /* per process flags, defined below */
    int sigpending;
    mm_segment_t addr_limit;        /* thread address space:
                                        0-0xBFFFFFFF for user-thead
                                        0-0xFFFFFFFF for kernel-thread
                                    */
    struct exec_domain *exec_domain;
    volatile long need_resched;
    unsigned long ptrace;

    int lock_depth;         /* Lock depth */

/*
 * offset 32 begins here on 32-bit platforms. We keep
 * all fields in a single cacheline that are needed for
 * the goodness() loop in schedule().
 */
    long counter;
    long nice;
```

Figure 2.1 Task struct

Process Selection

Linux makes the process selection with the schedule() function. The system enters the schedule() function every 10ms to find the process with the highest counter .Inside the Schedule() function, it navigates the processes waiting in the ready state with the for loop and checks whether the processes are scheduled or not. At the same time, the goodness value is calculated according to the priority of each process. The goodness value is used to find the best candidate process to run. If the calculated goodness value is -1000, the process must never be selected. If the goodness value is 0, the process has exhausted .If the goodness value is between 0 and 1000, the process can run and its value is calculated with (20-nice)+counter. On the other hand if goodness value is >=1000 this process is a real time process and higher priority to run. The system repeats this algorithm every 10ms time slices(In figure 2.2).

```
repeat_schedule:
        /*
         * Default process to select..
         */
        next = idle_task(this_cpu);
        c = -1000;
        list_for_each(tmp, &runqueue_head) {
                p = list_entry(tmp, struct task_struct, run_list);
                if (can_schedule(p, this_cpu)) {
                        int weight = goodness(p, this_cpu, prev->active_mm);
                        if (weight > c)
                                c = weight, next = p;
                }
        }

        /* Do we need to re-calculate counters? */
        if (unlikely(!c)) {
                struct task_struct *p;

                spin_unlock_irq(&runqueue_lock);
                read_lock(&tasklist_lock);
                for_each_task(p)
                        p->counter = (p->counter >> 1) + NICE_TO_TICKS(p->nice);
                read_unlock(&tasklist_lock);
                spin_lock_irq(&runqueue_lock);
                goto repeat_schedule;
        }

        /*
         * from this point on nothing can prevent us from
         * switching to the next task, save this fact in
         * sched_data.
         */
        sched_data->curr = next;
        task_set_cpu(next, this_cpu);
        spin_unlock_irq(&runqueue_lock);

        if (unlikely(prev == next)) {
                /* We won't go through the normal tail, so do this by hand */
                prev->policy &= ~SCHED_YIELD;
                goto same_process;
        }
```
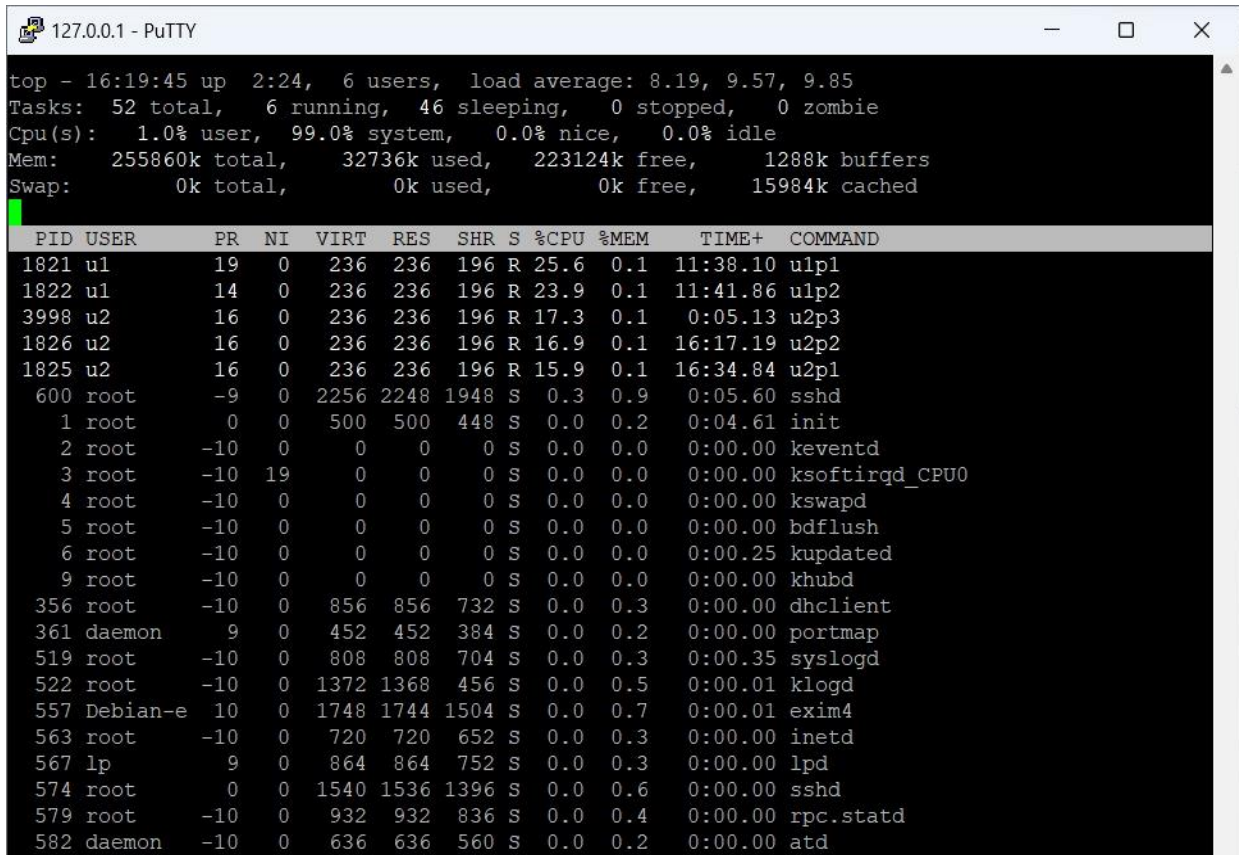
Figure 2.2 Default scheduler

2.1 LINUX DEFAULT SCHEDULER(SCHED_OTHER)

Linux default schedular is a process based algorithm. In this algorithm, regardless of the number of users, the CPU is directly proportional to the number of processes. For example, in a system has 3 users and first user has 1 process , second user has 2 process and third user has 1 process. In this case CPU is distributed equally (~25%) to each process(In figure 2.1).

Figure 2.1.1 Default scheduler example

2.2 FAIR SHARE SCHEDULER

Fair share schedule is a user based algorithm. The fair share schedule provides a user-based fairness, unlike the default schedule.

For example, if the system has 2 different users and first user has 2 processes and second user has 3 processes. Fair share schedule ensures that the CPU is distributed according to the number of users. (~ 50% for each user) Moreover, it redistributes the CPU according to the number of processes the user has. Therefore each process of the first user gets ~25% and each process of the second user gets ~16.6%.(In figure 2.2)

Figure 2.2.1 Fair share scheduler example

We use a system call to switch from the default schedular to fair share scheduler. In this system call decides which scheduler the system will switch to by looking at the value of the variable in it.

```c
#include <linux/mysyscall.h>
#include <linux/kernel.h>
#include <asm/uaccess.h>

extern int xyZeren;
extern int howmanyuser;
asmlinkage int sys_mysyscall(int arg1,int *arg2){
xyZeren=arg1;
int a;
int i=0;
cli();
copy_from_user(&a,arg2,sizeof(int));

a=howmanyuser;
copy_to_user(arg2,&a,sizeof(int));
sti();


return 0;

}
```

Figure 2.2.2 mysystemcall.c

2.2.1   FAIR SHARE SCHEDULER PROCESS SELECTION

In order to create a user-based fairness in the fair share schedule, we first created a two-dimensional array. In this array, we kept the user IDs of the running processes that matched this ID (In figure 2.2.1.1).

```c
if (unlikely(!c)) {
    struct task_struct *p;
    howmanyuser=0;
    int i=0;
    spin_unlock_irq(&runqueue_lock);
    read_lock(&tasklist_lock);
    int A[UIDHASH_SZ][2];
    int x;
    for(x=0 ; x<UIDHASH_SZ ; x++)
    {
        A[x][0] = -999;
        A[x][1] = 0;
    }
```

Figure 2.2.1.1 Two-dimensional array

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To fill the array, we first visited all the processes in the running state with the help of the for_each_task. Then, we assigned the user IDs of the processes to the first column of the array and the number of running processes owned by the user id hold in the first column is written in the second column. While doing these, we also counted the number of users in the system (In figure 2.2.1.2).

```
for_each_task(p){
    if(p->state == TASK_RUNNING)
    {
        int a;
        int flag = 1;
        for(a=0 ; a<i+1 ; a++)
        {
            if(A[a][0] == p->user->uid)
            {
                flag=0;
                A[a][1] += 1 ;
            }
        }
        if(flag==1)
        {
            A[i][0] = p->user->uid;
            A[i][1] += 1;
            i++;
        }
    }
}

howmanyuser = i;
```

Figure 2.2.1.2 Fill the array

After these processes are finished, we calculated the ekok variable as the number of users times 6 so that each process gets a divisible counter value.(In figure 2.2.1.3).

Finally, with the help of the for_each_task, we navigated the processes in our two-dimensional array that matched the user IDs and assigned the counters of each process by dividing them by the number of running processes that matched user ID have (In figure 2.2.1.3).

```
howmanyuser = i;
int ekok=howmanyuser*6;
for_each_task(p)
{
    int b;
    for(b=0; b<howmanyuser; b++)
    {
        if(p->user->uid == A[b][0])
        {
            p->counter = ekok/A[b][1];
        }
    }
}
```

Figure 2.2.1.3 Assign counter values of each process

```c
if (unlikely(!c)) {
    struct task_struct *p;
    howmanyuser=0;
    int i=0;
    spin_unlock_irq(&runqueue_lock);
    read_lock(&tasklist_lock);
    int A[UIDHASH_SZ][2];
    int x;
    for(x=0 ; x<UIDHASH_SZ ; x++)
    {
        A[x][0] = -999;
        A[x][1] = 0;
    }

    for_each_task(p){
        if(p->state == TASK_RUNNING)
        {
            int a;
            int flag = 1;
            for(a=0 ; a<i+1 ; a++)
            {
                if(A[a][0] == p->user->uid)
                {
                    flag=0;
                    A[a][1] += 1 ;
                }
            }
            if(flag==1)
            {
                A[i][0] = p->user->uid;
                A[i][1] += 1;
                i++;
            }
        }
    }

    howmanyuser = i;
    int ekok=howmanyuser*6;
    for_each_task(p)
    {
        int b;
        for(b=0; b<howmanyuser; b++)
        {
            if(p->user->uid == A[b][0])
            {
                p->counter = ekok/A[b][1];
            }
        }

    }
    read_unlock(&tasklist_lock);
    spin_lock_irq(&runqueue_lock);
    goto repeat_schedule;
}
```

Figure 2.2.1.4 Full code

3.   TESTS and RESULTS

The reason we run performance tests is to measure how fast and efficiently the code written by us works and to detect potential bottlenecks or performance issues. In this way, we will be able to make the necessary adjustments to better optimize the code and improve the user experience. Also, by performing performance tests, we can evaluate the use of system resources and the scalability of the code and understand how ready we are to meet future growth and demands.

Since performance tests are important for the success of the application and user satisfaction, these tests should be carried out regularly and their results should be taken into account. During testing, we can observe how the code performs under different scenarios and user loads, thus making it suitable for a wider range of users.

Also, through performance tests, we can evaluate how the code works in different hardware and software environments, thus ensuring a wider range of application compatibility. This will help the app reach more users and provide a better user experience.

As a result, we ensure that the code we write is constantly developed and optimized by performing performance tests. This helps make the application faster, more reliable, and more scalable, thus providing a better foundation to meet and exceed users' expectations. Therefore, we should not ignore the importance of performance tests and consider them as an integral part of the software development process.

In the tests we made below, we tried to test whether the CPU is fair by increasing the number of processes and the number of users. We repeated the tests we made a certain number of times and tested whether we were staying within the limits we determined with the random distribution, whether we wrote a really fair code, and analyzed these results statistically.

In general, we observed that when we do more repetitions in terms of number, we reach a value closer to the expected result. We will present these results to you with pictures in the next section.

3.1. DEFAULT SCHEDULING ALGORITHM

3.1.1. AVERAGE CPU USAGE

3.1.1.1. TestCase-1:

In test case-1 , we have 3 users.

User1 -> 3 processes

User2 -> 2 processes

User3 -> 1 process

Figure 3.1.1.1.1 Average CPU Usage of u1p1

Figure 3.1.1.1.2 Average CPU Usage of u1p2

Figure 3.1.1.1.3 Average CPU Usage of u1p3

Figure 3.1.1.1.4 Average CPU Usage of u2p1

Figure 3.1.1.1.5 Average CPU Usage of u2p2

Figure 3.1.1.1.6 Average CPU Usage of u3p1

3.1.1.2. TestCase-2:

In test case-2 , we have 4 users.

User1 -> 3 processes

User2 -> 2 processes

User3 -> 1 process

User4 -> 4 processes

```
CSE331:~# bash average2.sh
The average of averages is 9.87
```
Figure 3.1.1.2.1 Average CPU Usage of u1p1

```
CSE331:~# bash average2.sh
The average of averages is 10.13
```
Figure 3.1.1.2.2 Average CPU Usage of u1p2

```
CSE331:~# bash average2.sh
The average of averages is 10.05
```
Figure 3.1.1.2.3 Average CPU Usage of u1p3

```
CSE331:~# bash average2.sh
The average of averages is 10.03
```
Figure 3.1.1.2.4 Average CPU Usage of u2p1

```
CSE331:~# bash average2.sh
The average of averages is 9.94
```
Figure 3.1.1.2.5 Average CPU Usage of u2p2

```
CSE331:~# bash average2.sh
The average of averages is 10.08
```
Figure 3.1.1.2.6 Average CPU Usage of u3p1

```
CSE331:~# bash average2.sh
The average of averages is 9.98
```
Figure 3.1.1.2.7 Average CPU Usage of u4p1

```
CSE331:~# bash average2.sh
The average of averages is 10.09
```

Figure 3.1.1.2.8 Average CPU Usage of u4p2

```
CSE331:~# bash average2.sh
The average of averages is 9.99
```

Figure 3.1.1.2.9 Average CPU Usage of u4p3

```
CSE331:~# bash average2.sh
The average of averages is 9.93
```

Figure 3.1.1.2.10 Average CPU Usage of u4p4

3.1.1.3. TestCase-3:

In test case-3 , we have 2 users.

User1 -> 2 processes

User2 -> 3 processes

```
CSE331:~# bash average2.sh
The average of averages is 20.07
```

Figure 3.1.1.3.1 Average CPU Usage of u1p1

```
CSE331:~# bash average2.sh
The average of averages is 19.96
```

Figure 3.1.1.3.2 Average CPU Usage of u1p2

```
CSE331:~# bash average2.sh
The average of averages is 20.00
```

Figure 3.1.1.3.3 Average CPU Usage of u2p1

```
CSE331:~# bash average2.sh
The average of averages is 20.10
```

Figure 3.1.1.3.4 Average CPU Usage of u2p2

```
CSE331:~# bash average2.sh
The average of averages is 20.02
```

Figure 3.1.1.3.5 Average CPU Usage of u2p3

3.1.1.4. TestCase-4:

In test case-4 , we have 3 users.

User1 -> 1 process

User2 -> 2 processes

User3 -> 1 process

```
CSE331:~# bash average2.sh
The average of averages is 25.04
```

Figure 3.1.1.4.1 Average CPU Usage of u1p1

```
CSE331:~# bash average2.sh
The average of averages is 25.07
```

Figure 3.1.1.4.2 Average CPU Usage of u2p1

```
CSE331:~# bash average2.sh
The average of averages is 25.00
```

Figure 3.1.1.4.3 Average CPU Usage of u2p2

```
CSE331:~# bash average2.sh
The average of averages is 25.02
```

Figure 3.1.1.4.4 Average CPU Usage of u3p1

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3.1.1.5. TestCase-5:

In test case-5 , we have 5 users.

User1 -> 1 process

User2 -> 2 processes

User3 -> 1 process

User4 -> 4 processes

User5 -> 3 processes

```
CSE331:~# bash average2.sh
The average of averages is 9.06
```

Figure 3.1.1.5.1 Average CPU Usage of u1p1

```
CSE331:~# bash average2.sh
The average of averages is 9.03
```

Figure 3.1.1.5.2 Average CPU Usage of u2p1

```
CSE331:~# bash average2.sh
The average of averages is 9.12
```

Figure 3.1.1.5.3 Average CPU Usage of u2p2

```
CSE331:~# bash average2.sh
The average of averages is 9.12
```

Figure 3.1.1.5.4 Average CPU Usage of u3p1

```
CSE331:~# bash average2.sh
The average of averages is 9.27
```

Figure 3.1.1.5.5 Average CPU Usage of u4p1

```
CSE331:~# bash average2.sh
The average of averages is 9.12
```

Figure 3.1.1.5.6 Average CPU Usage of u4p2

```
CSE331:~# bash average2.sh
The average of averages is 9.03
```

Figure 3.1.1.5.7 Average CPU Usage of u4p3

```
CSE331:~# bash average2.sh
The average of averages is 9.06
```

Figure 3.1.1.5.8 Average CPU Usage of u4p4

```
CSE331:~# bash average2.sh
The average of averages is 9.07
```

Figure 3.1.1.5.9 Average CPU Usage of u5p1

```
CSE331:~# bash average2.sh
The average of averages is 9.12
```

Figure 3.1.1.5.10 Average CPU Usage of u5p2

```
CSE331:~# bash average2.sh
The average of averages is 9.11
```

Figure 3.1.1.5.11 Average CPU Usage of u5p3

3.1.2. MEAN SQUARE ERROR

3.1.2.1. TestCase-1:

In test case-1 , we have 3 users.

User1 -> 3 processes

User2 -> 2 processes

User3 -> 1 process


```
CSE331:~# bash error.sh
Content of average1.txt: 16.506
Difference: 0.1607
Squared difference: 0.0258
Sum of squared errors: 0.0258
Content of average2.txt: 17.166
Difference: -0.4993
Squared difference: 0.2493
Sum of squared errors: 0.2751
Content of average3.txt: 17.163
Difference: -0.4963
Squared difference: 0.2463
Sum of squared errors: 0.5214
Content of average4.txt: 17.312
Difference: -0.6453
Squared difference: 0.4164
Sum of squared errors: 0.9378
Content of average5.txt: 16.789
Difference: -0.1223
Squared difference: 0.0150
Sum of squared errors: 0.9528
Content of average6.txt: 16.47
Difference: 0.1967
Squared difference: 0.0387
Sum of squared errors: 0.9915
Content of average7.txt: 17.11
Difference: -0.4433
Squared difference: 0.1965
Sum of squared errors: 1.1880
Content of average8.txt: 16.629
Difference: 0.0377
Squared difference: 0.0014
Sum of squared errors: 1.1894
Content of average9.txt: 16.904
Difference: -0.2373
Squared difference: 0.0563
Sum of squared errors: 1.2457
Content of average10.txt: 16.564
Difference: 0.1027
Squared difference: 0.0105
Sum of squared errors: 1.2562
Mean Squared Error: 0.1256
CSE331:~#
```

Figure 3.1.2.1.1 Mean Square Error of u1p1

```
CSE331:~# bash error.sh
Content of average1.txt: 17.414
Difference: -0.7473
Squared difference: 0.5585
Sum of squared errors: 0.5585
Content of average2.txt: 16.239
Difference: 0.4277
Squared difference: 0.1829
Sum of squared errors: 0.7414
Content of average3.txt: 17.07
Difference: -0.4033
Squared difference: 0.1627
Sum of squared errors: 0.9041
Content of average4.txt: 16.88
Difference: -0.2133
Squared difference: 0.0455
Sum of squared errors: 0.9496
Content of average5.txt: 17.099
Difference: -0.4323
Squared difference: 0.1869
Sum of squared errors: 1.1365
Content of average6.txt: 16.814
Difference: -0.1473
Squared difference: 0.0217
Sum of squared errors: 1.1582
Content of average7.txt: 17.007
Difference: -0.3403
Squared difference: 0.1158
Sum of squared errors: 1.2740
Content of average8.txt: 17.671
Difference: -1.0043
Squared difference: 1.0086
Sum of squared errors: 2.2826
Content of average9.txt: 17.266
Difference: -0.5993
Squared difference: 0.3592
Sum of squared errors: 2.6418
Content of average10.txt: 16.877
Difference: -0.2103
Squared difference: 0.0442
Sum of squared errors: 2.6860
Mean Squared Error: 0.2686
CSE331:~#
```

Figure 3.1.2.1.2 Mean Square Error of u1p2

```
CSE331:~# bash error.sh
Content of average1.txt: 16.494
Difference: 0.1727
Squared difference: 0.0298
Sum of squared errors: 0.0298
Content of average2.txt: 16.364
Difference: 0.3027
Squared difference: 0.0916
Sum of squared errors: 0.1214
Content of average3.txt: 16.444
Difference: 0.2227
Squared difference: 0.0496
Sum of squared errors: 0.1710
Content of average4.txt: 16.567
Difference: 0.0997
Squared difference: 0.0099
Sum of squared errors: 0.1809
Content of average5.txt: 16.402
Difference: 0.2647
Squared difference: 0.0701
Sum of squared errors: 0.2510
Content of average6.txt: 16.814
Difference: -0.1473
Squared difference: 0.0217
Sum of squared errors: 0.2727
Content of average7.txt: 16.3
Difference: 0.3667
Squared difference: 0.1345
Sum of squared errors: 0.4072
Content of average8.txt: 16.094
Difference: 0.5727
Squared difference: 0.3280
Sum of squared errors: 0.7352
Content of average9.txt: 16.6
Difference: 0.0667
Squared difference: 0.0044
Sum of squared errors: 0.7396
Content of average10.txt: 16.474
Difference: 0.1927
Squared difference: 0.0371
Sum of squared errors: 0.7767
Mean Squared Error: 0.0777
```

```
CSE331:~# bash error.sh
Content of average1.txt: 16.08
Difference: 0.5867
Squared difference: 0.3442
Sum of squared errors: 0.3442
Content of average2.txt: 16.386
Difference: 0.2807
Squared difference: 0.0788
Sum of squared errors: 0.4230
Content of average3.txt: 16.319
Difference: 0.3477
Squared difference: 0.1209
Sum of squared errors: 0.5439
Content of average4.txt: 16.104
Difference: 0.5627
Squared difference: 0.3166
Sum of squared errors: 0.8605
Content of average5.txt: 16.46
Difference: 0.2067
Squared difference: 0.0427
Sum of squared errors: 0.9032
Content of average6.txt: 16.669
Difference: -0.0023
Squared difference: 0.0000
Sum of squared errors: 0.9032
Content of average7.txt: 16.557
Difference: 0.1097
Squared difference: 0.0120
Sum of squared errors: 0.9152
Content of average8.txt: 16.284
Difference: 0.3827
Squared difference: 0.1465
Sum of squared errors: 1.0617
Content of average9.txt: 16.481
Difference: 0.1857
Squared difference: 0.0345
Sum of squared errors: 1.0962
Content of average10.txt: 16.699
Difference: -0.0323
Squared difference: 0.0010
Sum of squared errors: 1.0972
Mean Squared Error: 0.1097
CSE331:~#
```

Figure 3.1.2.1.3 Mean Square Error of u1p3   **Figure 3.1.2.1.4** Mean Square Error of u2p1

```
CSE331:~# bash error.sh
Content of average1.txt: 16.922
Difference: -0.2553
Squared difference: 0.0652
Sum of squared errors: 0.0652
Content of average2.txt: 17.009
Difference: -0.3423
Squared difference: 0.1172
Sum of squared errors: 0.1824
Content of average3.txt: 16.963
Difference: -0.2963
Squared difference: 0.0878
Sum of squared errors: 0.2702
Content of average4.txt: 16.855
Difference: -0.1883
Squared difference: 0.0355
Sum of squared errors: 0.3057
Content of average5.txt: 16.454
Difference: 0.2127
Squared difference: 0.0452
Sum of squared errors: 0.3509
Content of average6.txt: 16.515
Difference: 0.1517
Squared difference: 0.0230
Sum of squared errors: 0.3739
Content of average7.txt: 16.706
Difference: -0.0393
Squared difference: 0.0015
Sum of squared errors: 0.3754
Content of average8.txt: 16.622
Difference: 0.0447
Squared difference: 0.0020
Sum of squared errors: 0.3774
Content of average9.txt: 16.517
Difference: 0.1497
Squared difference: 0.0224
Sum of squared errors: 0.3998
Content of average10.txt: 16.658
Difference: 0.0087
Squared difference: 0.0001
Sum of squared errors: 0.3999
Mean Squared Error: 0.0400
```

Figure 3.1.2.1.5 Mean Square Error of u2p2

```
CSE331:~# bash error.sh
Content of average1.txt: 16.603
Difference: 0.0637
Squared difference: 0.0041
Sum of squared errors: 0.0041
Content of average2.txt: 16.945
Difference: -0.2783
Squared difference: 0.0775
Sum of squared errors: 0.0816
Content of average3.txt: 16.147
Difference: 0.5197
Squared difference: 0.2701
Sum of squared errors: 0.3517
Content of average4.txt: 16.353
Difference: 0.3137
Squared difference: 0.0984
Sum of squared errors: 0.4501
Content of average5.txt: 16.839
Difference: -0.1723
Squared difference: 0.0297
Sum of squared errors: 0.4798
Content of average6.txt: 16.802
Difference: -0.1353
Squared difference: 0.0183
Sum of squared errors: 0.4981
Content of average7.txt: 16.414
Difference: 0.2527
Squared difference: 0.0639
Sum of squared errors: 0.5620
Content of average8.txt: 16.768
Difference: -0.1013
Squared difference: 0.0103
Sum of squared errors: 0.5723
Content of average9.txt: 16.291
Difference: 0.3757
Squared difference: 0.1412
Sum of squared errors: 0.7135
Content of average10.txt: 16.71
Difference: -0.0433
Squared difference: 0.0019
Sum of squared errors: 0.7154
Mean Squared Error: 0.0715
CSE331:~#
```

Figure 3.1.2.1.6 Mean Square Error of u3p1

3.1.2.2. TestCase-2:

In test case-1 , we have 4 users.

User1 -> 3 processes

User2 -> 2 processes

User3 -> 1 process

User4 -> 4 processes


```
CSE331:~# bash error.sh
Content of average1.txt: 9.778
Difference: 0.2220
Squared difference: 0.0493
Sum of squared errors: 0.0493
Content of average2.txt: 9.835
Difference: 0.1650
Squared difference: 0.0272
Sum of squared errors: 0.0765
Content of average3.txt: 10.09
Difference: -0.0900
Squared difference: 0.0081
Sum of squared errors: 0.0846
Content of average4.txt: 9.697
Difference: 0.3030
Squared difference: 0.0918
Sum of squared errors: 0.1764
Content of average5.txt: 9.809
Difference: 0.1910
Squared difference: 0.0365
Sum of squared errors: 0.2129
Content of average6.txt: 9.8
Difference: 0.2000
Squared difference: 0.0400
Sum of squared errors: 0.2529
Content of average7.txt: 9.888
Difference: 0.1120
Squared difference: 0.0125
Sum of squared errors: 0.2654
Content of average8.txt: 9.867
Difference: 0.1330
Squared difference: 0.0177
Sum of squared errors: 0.2831
Content of average9.txt: 10.045
Difference: -0.0450
Squared difference: 0.0020
Sum of squared errors: 0.2851
Content of average10.txt: 9.926
Difference: 0.0740
Squared difference: 0.0055
Sum of squared errors: 0.2906
Mean Squared Error: 0.0291
CSE331:~#
```

```
CSE331:~# bash error.sh
Content of average1.txt: 10.248
Difference: -0.2480
Squared difference: 0.0615
Sum of squared errors: 0.0615
Content of average2.txt: 10.197
Difference: -0.1970
Squared difference: 0.0388
Sum of squared errors: 0.1003
Content of average3.txt: 10.11
Difference: -0.1100
Squared difference: 0.0121
Sum of squared errors: 0.1124
Content of average4.txt: 10.295
Difference: -0.2950
Squared difference: 0.0870
Sum of squared errors: 0.1994
Content of average5.txt: 10.352
Difference: -0.3520
Squared difference: 0.1239
Sum of squared errors: 0.3233
Content of average6.txt: 10.052
Difference: -0.0520
Squared difference: 0.0027
Sum of squared errors: 0.3260
Content of average7.txt: 10.267
Difference: -0.2670
Squared difference: 0.0713
Sum of squared errors: 0.3973
Content of average8.txt: 9.928
Difference: 0.0720
Squared difference: 0.0052
Sum of squared errors: 0.4025
Content of average9.txt: 9.875
Difference: 0.1250
Squared difference: 0.0156
Sum of squared errors: 0.4181
Content of average10.txt: 9.988
Difference: 0.0120
Squared difference: 0.0001
Sum of squared errors: 0.4182
Mean Squared Error: 0.0418
CSE331:~#
```

Figure 3.1.2.2.1 Mean Square Error of u1p1   **Figure 3.1.2.2.2** Mean Square Error of u1p2

```
CSE331:~# bash error.sh
Content of average1.txt: 10.025
Difference: -0.0250
Squared difference: 0.0006
Sum of squared errors: 0.0006
Content of average2.txt: 9.741
Difference: 0.2590
Squared difference: 0.0671
Sum of squared errors: 0.0677
Content of average3.txt: 9.995
Difference: 0.0050
Squared difference: 0.0000
Sum of squared errors: 0.0677
Content of average4.txt: 9.913
Difference: 0.0870
Squared difference: 0.0076
Sum of squared errors: 0.0753
Content of average5.txt: 9.996
Difference: 0.0040
Squared difference: 0.0000
Sum of squared errors: 0.0753
Content of average6.txt: 10.16
Difference: -0.1600
Squared difference: 0.0256
Sum of squared errors: 0.1009
Content of average7.txt: 9.944
Difference: 0.0560
Squared difference: 0.0031
Sum of squared errors: 0.1040
Content of average8.txt: 10.174
Difference: -0.1740
Squared difference: 0.0303
Sum of squared errors: 0.1343
Content of average9.txt: 10.123
Difference: -0.1230
Squared difference: 0.0151
Sum of squared errors: 0.1494
Content of average10.txt: 10.444
Difference: -0.4440
Squared difference: 0.1971
Sum of squared errors: 0.3465
Mean Squared Error: 0.0347
CSE331:~#
```

Figure 3.1.2.2.3 Mean Square Error of u1p3

```
CSE331:~# bash error.sh
Content of average1.txt: 9.912
Difference: 0.0880
Squared difference: 0.0077
Sum of squared errors: 0.0077
Content of average2.txt: 10.174
Difference: -0.1740
Squared difference: 0.0303
Sum of squared errors: 0.0380
Content of average3.txt: 10.15
Difference: -0.1500
Squared difference: 0.0225
Sum of squared errors: 0.0605
Content of average4.txt: 9.888
Difference: 0.1120
Squared difference: 0.0125
Sum of squared errors: 0.0730
Content of average5.txt: 9.831
Difference: 0.1690
Squared difference: 0.0286
Sum of squared errors: 0.1016
Content of average6.txt: 9.792
Difference: 0.2080
Squared difference: 0.0433
Sum of squared errors: 0.1449
Content of average7.txt: 10.009
Difference: -0.0090
Squared difference: 0.0001
Sum of squared errors: 0.1450
Content of average8.txt: 10.208
Difference: -0.2080
Squared difference: 0.0433
Sum of squared errors: 0.1883
Content of average9.txt: 10.214
Difference: -0.2140
Squared difference: 0.0458
Sum of squared errors: 0.2341
Content of average10.txt: 10.163
Difference: -0.1630
Squared difference: 0.0266
Sum of squared errors: 0.2607
Mean Squared Error: 0.0261
CSE331:~#
```

Figure 3.1.2.2.4 Mean Square Error of u2p1

```
CSE331:~# bash error.sh
Content of average1.txt: 10.33
Difference: -0.3300
Squared difference: 0.1089
Sum of squared errors: 0.1089
Content of average2.txt: 9.973
Difference: 0.0270
Squared difference: 0.0007
Sum of squared errors: 0.1096
Content of average3.txt: 10.495
Difference: -0.4950
Squared difference: 0.2450
Sum of squared errors: 0.3546
Content of average4.txt: 10.043
Difference: -0.0430
Squared difference: 0.0018
Sum of squared errors: 0.3564
Content of average5.txt: 10.243
Difference: -0.2430
Squared difference: 0.0590
Sum of squared errors: 0.4154
Content of average6.txt: 10.084
Difference: -0.0840
Squared difference: 0.0071
Sum of squared errors: 0.4225
Content of average7.txt: 9.933
Difference: 0.0670
Squared difference: 0.0045
Sum of squared errors: 0.4270
Content of average8.txt: 9.993
Difference: 0.0070
Squared difference: 0.0000
Sum of squared errors: 0.4270
Content of average9.txt: 9.924
Difference: 0.0760
Squared difference: 0.0058
Sum of squared errors: 0.4328
Content of average10.txt: 9.871
Difference: 0.1290
Squared difference: 0.0166
Sum of squared errors: 0.4494
Mean Squared Error: 0.0449
CSE331:~#
```

```
CSE331:~# bash error.sh
Content of average1.txt: 10.049
Difference: -0.0490
Squared difference: 0.0024
Sum of squared errors: 0.0024
Content of average2.txt: 9.644
Difference: 0.3560
Squared difference: 0.1267
Sum of squared errors: 0.1291
Content of average3.txt: 9.667
Difference: 0.3330
Squared difference: 0.1109
Sum of squared errors: 0.2400
Content of average4.txt: 10.318
Difference: -0.3180
Squared difference: 0.1011
Sum of squared errors: 0.3411
Content of average5.txt: 10.034
Difference: -0.0340
Squared difference: 0.0012
Sum of squared errors: 0.3423
Content of average6.txt: 10.055
Difference: -0.0550
Squared difference: 0.0030
Sum of squared errors: 0.3453
Content of average7.txt: 9.833
Difference: 0.1670
Squared difference: 0.0279
Sum of squared errors: 0.3732
Content of average8.txt: 9.954
Difference: 0.0460
Squared difference: 0.0021
Sum of squared errors: 0.3753
Content of average9.txt: 10.053
Difference: -0.0530
Squared difference: 0.0028
Sum of squared errors: 0.3781
Content of average10.txt: 9.874
Difference: 0.1260
Squared difference: 0.0159
Sum of squared errors: 0.3940
Mean Squared Error: 0.0394
CSE331:~#
```

Figure 3.1.2.2.5 Mean Square Error of u2p2   **Figure 3.1.2.2.6** Mean Square Error of u3p1

```
CSE331:~# bash error.sh
Content of average1.txt: 9.897
Difference: 0.1030
Squared difference: 0.0106
Sum of squared errors: 0.0106
Content of average2.txt: 10.469
Difference: -0.4690
Squared difference: 0.2200
Sum of squared errors: 0.2306
Content of average3.txt: 9.873
Difference: 0.1270
Squared difference: 0.0161
Sum of squared errors: 0.2467
Content of average4.txt: 9.984
Difference: 0.0160
Squared difference: 0.0003
Sum of squared errors: 0.2470
Content of average5.txt: 10.02
Difference: -0.0200
Squared difference: 0.0004
Sum of squared errors: 0.2474
Content of average6.txt: 10.113
Difference: -0.1130
Squared difference: 0.0128
Sum of squared errors: 0.2602
Content of average7.txt: 10.148
Difference: -0.1480
Squared difference: 0.0219
Sum of squared errors: 0.2821
Content of average8.txt: 10.175
Difference: -0.1750
Squared difference: 0.0306
Sum of squared errors: 0.3127
Content of average9.txt: 10.164
Difference: -0.1640
Squared difference: 0.0269
Sum of squared errors: 0.3396
Content of average10.txt: 10.113
Difference: -0.1130
Squared difference: 0.0128
Sum of squared errors: 0.3524
Mean Squared Error: 0.0352
CSE331:~#
```

Figure 3.1.2.2.7 Mean Square Error of u4p1

```
CSE331:~# bash error.sh
Content of average1.txt: 10.047
Difference: -0.0470
Squared difference: 0.0022
Sum of squared errors: 0.0022
Content of average2.txt: 9.983
Difference: 0.0170
Squared difference: 0.0003
Sum of squared errors: 0.0025
Content of average3.txt: 9.936
Difference: 0.0640
Squared difference: 0.0041
Sum of squared errors: 0.0066
Content of average4.txt: 10.12
Difference: -0.1200
Squared difference: 0.0144
Sum of squared errors: 0.0210
Content of average5.txt: 9.932
Difference: 0.0680
Squared difference: 0.0046
Sum of squared errors: 0.0256
Content of average6.txt: 9.904
Difference: 0.0960
Squared difference: 0.0092
Sum of squared errors: 0.0348
Content of average7.txt: 10.172
Difference: -0.1720
Squared difference: 0.0296
Sum of squared errors: 0.0644
Content of average8.txt: 9.904
Difference: 0.0960
Squared difference: 0.0092
Sum of squared errors: 0.0736
Content of average9.txt: 9.914
Difference: 0.0860
Squared difference: 0.0074
Sum of squared errors: 0.0810
Content of average10.txt: 9.902
Difference: 0.0980
Squared difference: 0.0096
Sum of squared errors: 0.0906
Mean Squared Error: 0.0091
CSE331:~#
```

Figure 3.1.2.2.8 Mean Square Error of u4p2

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```
CSE331:~# bash error.sh
Content of average1.txt: 9.676
Difference: 0.3240
Squared difference: 0.1050
Sum of squared errors: 0.1050
Content of average2.txt: 10.076
Difference: -0.0760
Squared difference: 0.0058
Sum of squared errors: 0.1108
Content of average3.txt: 10.075
Difference: -0.0750
Squared difference: 0.0056
Sum of squared errors: 0.1164
Content of average4.txt: 9.949
Difference: 0.0510
Squared difference: 0.0026
Sum of squared errors: 0.1190
Content of average5.txt: 9.991
Difference: 0.0090
Squared difference: 0.0001
Sum of squared errors: 0.1191
Content of average6.txt: 9.903
Difference: 0.0970
Squared difference: 0.0094
Sum of squared errors: 0.1285
Content of average7.txt: 9.948
Difference: 0.0520
Squared difference: 0.0027
Sum of squared errors: 0.1312
Content of average8.txt: 9.908
Difference: 0.0920
Squared difference: 0.0085
Sum of squared errors: 0.1397
Content of average9.txt: 9.865
Difference: 0.1350
Squared difference: 0.0182
Sum of squared errors: 0.1579
Content of average10.txt: 9.966
Difference: 0.0340
Squared difference: 0.0012
Sum of squared errors: 0.1591
Mean Squared Error: 0.0159
CSE331:~#
```

Figure 3.1.2.2.9 Mean Square Error of u4p3

```
CSE331:~# bash error.sh
Content of average1.txt: 10.204
Difference: -0.2040
Squared difference: 0.0416
Sum of squared errors: 0.0416
Content of average2.txt: 9.956
Difference: 0.0440
Squared difference: 0.0019
Sum of squared errors: 0.0435
Content of average3.txt: 9.801
Difference: 0.1990
Squared difference: 0.0396
Sum of squared errors: 0.0831
Content of average4.txt: 9.916
Difference: 0.0840
Squared difference: 0.0071
Sum of squared errors: 0.0902
Content of average5.txt: 9.957
Difference: 0.0430
Squared difference: 0.0018
Sum of squared errors: 0.0920
Content of average6.txt: 10.222
Difference: -0.2220
Squared difference: 0.0493
Sum of squared errors: 0.1413
Content of average7.txt: 9.928
Difference: 0.0720
Squared difference: 0.0052
Sum of squared errors: 0.1465
Content of average8.txt: 10.068
Difference: -0.0680
Squared difference: 0.0046
Sum of squared errors: 0.1511
Content of average9.txt: 9.973
Difference: 0.0270
Squared difference: 0.0007
Sum of squared errors: 0.1518
Content of average10.txt: 9.913
Difference: 0.0870
Squared difference: 0.0076
Sum of squared errors: 0.1594
Mean Squared Error: 0.0159
CSE331:~#
```

Figure 3.1.2.2.10 Mean Square Error of u4p4

3.1.2.3. TestCase-3:

In test case-1 , we have 2 users.

User1 -> 2 processes

User2 -> 3 processes

```
CSE331:~# bash error.sh
Content of average1.txt: 20.124
Difference: -0.1240
Squared difference: 0.0154
Sum of squared errors: 0.0154
Content of average2.txt: 20.337
Difference: -0.3370
Squared difference: 0.1136
Sum of squared errors: 0.1290
Content of average3.txt: 20.176
Difference: -0.1760
Squared difference: 0.0310
Sum of squared errors: 0.1600
Content of average4.txt: 20.101
Difference: -0.1010
Squared difference: 0.0102
Sum of squared errors: 0.1702
Content of average5.txt: 20.092
Difference: -0.0920
Squared difference: 0.0085
Sum of squared errors: 0.1787
Content of average6.txt: 19.956
Difference: 0.0440
Squared difference: 0.0019
Sum of squared errors: 0.1806
Content of average7.txt: 19.742
Difference: 0.2580
Squared difference: 0.0666
Sum of squared errors: 0.2472
Content of average8.txt: 19.856
Difference: 0.1440
Squared difference: 0.0207
Sum of squared errors: 0.2679
Content of average9.txt: 20.213
Difference: -0.2130
Squared difference: 0.0454
Sum of squared errors: 0.3133
Content of average10.txt: 20.103
Difference: -0.1030
Squared difference: 0.0106
Sum of squared errors: 0.3239
Mean Squared Error: 0.0324
CSE331:~#
```

Figure 3.1.2.3.1 Mean Square Error of u1p1

```
CSE331:~# bash error.sh
Content of average1.txt: 20.264
Difference: -0.2640
Squared difference: 0.0697
Sum of squared errors: 0.0697
Content of average2.txt: 19.625
Difference: 0.3750
Squared difference: 0.1406
Sum of squared errors: 0.2103
Content of average3.txt: 19.874
Difference: 0.1260
Squared difference: 0.0159
Sum of squared errors: 0.2262
Content of average4.txt: 20.241
Difference: -0.2410
Squared difference: 0.0581
Sum of squared errors: 0.2843
Content of average5.txt: 19.838
Difference: 0.1620
Squared difference: 0.0262
Sum of squared errors: 0.3105
Content of average6.txt: 20.21
Difference: -0.2100
Squared difference: 0.0441
Sum of squared errors: 0.3546
Content of average7.txt: 19.535
Difference: 0.4650
Squared difference: 0.2162
Sum of squared errors: 0.5708
Content of average8.txt: 20.297
Difference: -0.2970
Squared difference: 0.0882
Sum of squared errors: 0.6590
Content of average9.txt: 19.913
Difference: 0.0870
Squared difference: 0.0076
Sum of squared errors: 0.6666
Content of average10.txt: 19.813
Difference: 0.1870
Squared difference: 0.0350
Sum of squared errors: 0.7016
Mean Squared Error: 0.0702
CSE331:~#
```

Figure 3.1.2.3.1 Mean Square Error of u1p2

```
CSE331:~# bash error.sh
Content of average1.txt: 20.422
Difference: -0.4220
Squared difference: 0.1781
Sum of squared errors: 0.1781
Content of average2.txt: 20.114
Difference: -0.1140
Squared difference: 0.0130
Sum of squared errors: 0.1911
Content of average3.txt: 20.128
Difference: -0.1280
Squared difference: 0.0164
Sum of squared errors: 0.2075
Content of average4.txt: 19.728
Difference: 0.2720
Squared difference: 0.0740
Sum of squared errors: 0.2815
Content of average5.txt: 20.273
Difference: -0.2730
Squared difference: 0.0745
Sum of squared errors: 0.3560
Content of average6.txt: 19.731
Difference: 0.2690
Squared difference: 0.0724
Sum of squared errors: 0.4284
Content of average7.txt: 20.237
Difference: -0.2370
Squared difference: 0.0562
Sum of squared errors: 0.4846
Content of average8.txt: 19.844
Difference: 0.1560
Squared difference: 0.0243
Sum of squared errors: 0.5089
Content of average9.txt: 20.039
Difference: -0.0390
Squared difference: 0.0015
Sum of squared errors: 0.5104
Content of average10.txt: 20.532
Difference: -0.5320
Squared difference: 0.2830
Sum of squared errors: 0.7934
Mean Squared Error: 0.0793
CSE331:~#
```

Figure 3.1.2.3.3 Mean Square Error of u2p1

```
CSE331:~# bash error.sh
Content of average1.txt: 19.538
Difference: 0.4620
Squared difference: 0.2134
Sum of squared errors: 0.2134
Content of average2.txt: 20.101
Difference: -0.1010
Squared difference: 0.0102
Sum of squared errors: 0.2236
Content of average3.txt: 19.86
Difference: 0.1400
Squared difference: 0.0196
Sum of squared errors: 0.2432
Content of average4.txt: 20.169
Difference: -0.1690
Squared difference: 0.0286
Sum of squared errors: 0.2718
Content of average5.txt: 20.067
Difference: -0.0670
Squared difference: 0.0045
Sum of squared errors: 0.2763
Content of average6.txt: 20.341
Difference: -0.3410
Squared difference: 0.1163
Sum of squared errors: 0.3926
Content of average7.txt: 20.185
Difference: -0.1850
Squared difference: 0.0342
Sum of squared errors: 0.4268
Content of average8.txt: 19.975
Difference: 0.0250
Squared difference: 0.0006
Sum of squared errors: 0.4274
Content of average9.txt: 19.762
Difference: 0.2380
Squared difference: 0.0566
Sum of squared errors: 0.4840
Content of average10.txt: 20.011
Difference: -0.0110
Squared difference: 0.0001
Sum of squared errors: 0.4841
Mean Squared Error: 0.0484
CSE331:~#
```

Figure 3.1.2.3.4 Mean Square Error of u2p2

```
CSE331:~# bash error.sh
Content of average1.txt: 19.853
Difference: 0.1470
Squared difference: 0.0216
Sum of squared errors: 0.0216
Content of average2.txt: 19.963
Difference: 0.0370
Squared difference: 0.0014
Sum of squared errors: 0.0230
Content of average3.txt: 20.144
Difference: -0.1440
Squared difference: 0.0207
Sum of squared errors: 0.0437
Content of average4.txt: 19.937
Difference: 0.0630
Squared difference: 0.0040
Sum of squared errors: 0.0477
Content of average5.txt: 19.884
Difference: 0.1160
Squared difference: 0.0135
Sum of squared errors: 0.0612
Content of average6.txt: 20.009
Difference: -0.0090
Squared difference: 0.0001
Sum of squared errors: 0.0613
Content of average7.txt: 20.457
Difference: -0.4570
Squared difference: 0.2088
Sum of squared errors: 0.2701
Content of average8.txt: 20.171
Difference: -0.1710
Squared difference: 0.0292
Sum of squared errors: 0.2993
Content of average9.txt: 20.225
Difference: -0.2250
Squared difference: 0.0506
Sum of squared errors: 0.3499
Content of average10.txt: 19.635
Difference: 0.3650
Squared difference: 0.1332
Sum of squared errors: 0.4831
Mean Squared Error: 0.0483
CSE331:~#
```

Figure 3.1.2.3.5 Mean Square Error of u2p3

3.1.2.4. TestCase-4:

In test case-1 , we have 3 users.

User1 -> 1 process

User2 -> 2 processes

User3 -> 1 process


```
CSE331:~# bash error.sh
Content of average1.txt: 25.101
Difference: -0.1010
Squared difference: 0.0102
Sum of squared errors: 0.0102
Content of average2.txt: 25.21
Difference: -0.2100
Squared difference: 0.0441
Sum of squared errors: 0.0543
Content of average3.txt: 25.33
Difference: -0.3300
Squared difference: 0.1089
Sum of squared errors: 0.1632
Content of average4.txt: 24.898
Difference: 0.1020
Squared difference: 0.0104
Sum of squared errors: 0.1736
Content of average5.txt: 24.891
Difference: 0.1090
Squared difference: 0.0119
Sum of squared errors: 0.1855
Content of average6.txt: 24.772
Difference: 0.2280
Squared difference: 0.0520
Sum of squared errors: 0.2375
Content of average7.txt: 24.633
Difference: 0.3670
Squared difference: 0.1347
Sum of squared errors: 0.3722
Content of average8.txt: 25.627
Difference: -0.6270
Squared difference: 0.3931
Sum of squared errors: 0.7653
Content of average9.txt: 24.834
Difference: 0.1660
Squared difference: 0.0276
Sum of squared errors: 0.7929
Content of average10.txt: 25.139
Difference: -0.1390
Squared difference: 0.0193
Sum of squared errors: 0.8122
Mean Squared Error: 0.0812
CSE331:~#
```

Figure 3.1.2.4.1 Mean Square Error of u1p1

```
CSE331:~# bash error.sh
Content of average1.txt: 25.183
Difference: -0.1830
Squared difference: 0.0335
Sum of squared errors: 0.0335
Content of average2.txt: 25.091
Difference: -0.0910
Squared difference: 0.0083
Sum of squared errors: 0.0418
Content of average3.txt: 24.733
Difference: 0.2670
Squared difference: 0.0713
Sum of squared errors: 0.1131
Content of average4.txt: 24.875
Difference: 0.1250
Squared difference: 0.0156
Sum of squared errors: 0.1287
Content of average5.txt: 25.223
Difference: -0.2230
Squared difference: 0.0497
Sum of squared errors: 0.1784
Content of average6.txt: 25.454
Difference: -0.4540
Squared difference: 0.2061
Sum of squared errors: 0.3845
Content of average7.txt: 25.185
Difference: -0.1850
Squared difference: 0.0342
Sum of squared errors: 0.4187
Content of average8.txt: 25.131
Difference: -0.1310
Squared difference: 0.0172
Sum of squared errors: 0.4359
Content of average9.txt: 24.992
Difference: 0.0080
Squared difference: 0.0001
Sum of squared errors: 0.4360
Content of average10.txt: 24.871
Difference: 0.1290
Squared difference: 0.0166
Sum of squared errors: 0.4526
Mean Squared Error: 0.0453
CSE331:~#
```

Figure 3.1.2.4.2 Mean Square Error of u2p1

```
CSE331:~# bash error.sh
Content of average1.txt: 25.145
Difference: -0.1450
Squared difference: 0.0210
Sum of squared errors: 0.0210
Content of average2.txt: 24.525
Difference: 0.4750
Squared difference: 0.2256
Sum of squared errors: 0.2466
Content of average3.txt: 25.169
Difference: -0.1690
Squared difference: 0.0286
Sum of squared errors: 0.2752
Content of average4.txt: 25.15
Difference: -0.1500
Squared difference: 0.0225
Sum of squared errors: 0.2977
Content of average5.txt: 25.139
Difference: -0.1390
Squared difference: 0.0193
Sum of squared errors: 0.3170
Content of average6.txt: 24.76
Difference: 0.2400
Squared difference: 0.0576
Sum of squared errors: 0.3746
Content of average7.txt: 25.426
Difference: -0.4260
Squared difference: 0.1815
Sum of squared errors: 0.5561
Content of average8.txt: 24.987
Difference: 0.0130
Squared difference: 0.0002
Sum of squared errors: 0.5563
Content of average9.txt: 24.99
Difference: 0.0100
Squared difference: 0.0001
Sum of squared errors: 0.5564
Content of average10.txt: 24.941
Difference: 0.0590
Squared difference: 0.0035
Sum of squared errors: 0.5599
Mean Squared Error: 0.0560
CSE331:~# █
```

```
CSE331:~# bash error.sh
Content of average1.txt: 24.765
Difference: 0.2350
Squared difference: 0.0552
Sum of squared errors: 0.0552
Content of average2.txt: 25.359
Difference: -0.3590
Squared difference: 0.1289
Sum of squared errors: 0.1841
Content of average3.txt: 24.893
Difference: 0.1070
Squared difference: 0.0114
Sum of squared errors: 0.1955
Content of average4.txt: 25.189
Difference: -0.1890
Squared difference: 0.0357
Sum of squared errors: 0.2312
Content of average5.txt: 24.901
Difference: 0.0990
Squared difference: 0.0098
Sum of squared errors: 0.2410
Content of average6.txt: 25.197
Difference: -0.1970
Squared difference: 0.0388
Sum of squared errors: 0.2798
Content of average7.txt: 24.832
Difference: 0.1680
Squared difference: 0.0282
Sum of squared errors: 0.3080
Content of average8.txt: 24.398
Difference: 0.6020
Squared difference: 0.3624
Sum of squared errors: 0.6704
Content of average9.txt: 25.335
Difference: -0.3350
Squared difference: 0.1122
Sum of squared errors: 0.7826
Content of average10.txt: 25.195
Difference: -0.1950
Squared difference: 0.0380
Sum of squared errors: 0.8206
Mean Squared Error: 0.0821
CSE331:~# █
```

Figure 3.1.2.4.3 Mean Square Error of u2p2   **Figure 3.1.2.4.4** Mean Square Error of u3p1

3.1.2.5. TestCase-5:

In test case-1 , we have 5 users.

User1 -> 1 process

User2 -> 2 processes

User3 -> 1 process

User4 -> 4 process

User5 -> 3 process

```
CSE331:~# bash error.sh
Content of average1.txt: 9.116
Difference: -0.1160
Squared difference: 0.0135
Sum of squared errors: 0.0135
Content of average2.txt: 9.367
Difference: -0.3670
Squared difference: 0.1347
Sum of squared errors: 0.1482
Content of average3.txt: 9.083
Difference: -0.0830
Squared difference: 0.0069
Sum of squared errors: 0.1551
Content of average4.txt: 9.14
Difference: -0.1400
Squared difference: 0.0196
Sum of squared errors: 0.1747
Content of average5.txt: 9.23
Difference: -0.2300
Squared difference: 0.0529
Sum of squared errors: 0.2276
Content of average6.txt: 9.013
Difference: -0.0130
Squared difference: 0.0002
Sum of squared errors: 0.2278
Content of average7.txt: 9.011
Difference: -0.0110
Squared difference: 0.0001
Sum of squared errors: 0.2279
Content of average8.txt: 8.726
Difference: 0.2740
Squared difference: 0.0751
Sum of squared errors: 0.3030
Content of average9.txt: 8.983
Difference: 0.0170
Squared difference: 0.0003
Sum of squared errors: 0.3033
Content of average10.txt: 9.017
Difference: -0.0170
Squared difference: 0.0003
Sum of squared errors: 0.3036
Mean Squared Error: 0.0304
CSE331:~#
```

Figure 3.1.2.5.1 Mean Square Error of u1p1

```
CSE331:~# bash error.sh
Content of average1.txt: 8.944
Difference: 0.0560
Squared difference: 0.0031
Sum of squared errors: 0.0031
Content of average2.txt: 9.2
Difference: -0.2000
Squared difference: 0.0400
Sum of squared errors: 0.0431
Content of average3.txt: 9.372
Difference: -0.3720
Squared difference: 0.1384
Sum of squared errors: 0.1815
Content of average4.txt: 8.909
Difference: 0.0910
Squared difference: 0.0083
Sum of squared errors: 0.1898
Content of average5.txt: 9.012
Difference: -0.0120
Squared difference: 0.0001
Sum of squared errors: 0.1899
Content of average6.txt: 9.108
Difference: -0.1080
Squared difference: 0.0117
Sum of squared errors: 0.2016
Content of average7.txt: 9.21
Difference: -0.2100
Squared difference: 0.0441
Sum of squared errors: 0.2457
Content of average8.txt: 8.865
Difference: 0.1350
Squared difference: 0.0182
Sum of squared errors: 0.2639
Content of average9.txt: 8.896
Difference: 0.1040
Squared difference: 0.0108
Sum of squared errors: 0.2747
Content of average10.txt: 8.837
Difference: 0.1630
Squared difference: 0.0266
Sum of squared errors: 0.3013
Mean Squared Error: 0.0301
CSE331:~#
```

Figure 3.1.2.5.2 Mean Square Error of u2p1

```
CSE331:~# bash error.sh
Content of average1.txt: 9.266
Difference: -0.2660
Squared difference: 0.0708
Sum of squared errors: 0.0708
Content of average2.txt: 9.168
Difference: -0.1680
Squared difference: 0.0282
Sum of squared errors: 0.0990
Content of average3.txt: 8.852
Difference: 0.1480
Squared difference: 0.0219
Sum of squared errors: 0.1209
Content of average4.txt: 9.247
Difference: -0.2470
Squared difference: 0.0610
Sum of squared errors: 0.1819
Content of average5.txt: 9.142
Difference: -0.1420
Squared difference: 0.0202
Sum of squared errors: 0.2021
Content of average6.txt: 8.938
Difference: 0.0620
Squared difference: 0.0038
Sum of squared errors: 0.2059
Content of average7.txt: 8.991
Difference: 0.0090
Squared difference: 0.0001
Sum of squared errors: 0.2060
Content of average8.txt: 9.031
Difference: -0.0310
Squared difference: 0.0010
Sum of squared errors: 0.2070
Content of average9.txt: 9.053
Difference: -0.0530
Squared difference: 0.0028
Sum of squared errors: 0.2098
Content of average10.txt: 9.567
Difference: -0.5670
Squared difference: 0.3215
Sum of squared errors: 0.5313
Mean Squared Error: 0.0531
CSE331:~#
```

Figure 3.1.2.5.3 Mean Square Error of u2p2

```
CSE331:~# bash error.sh
Content of average1.txt: 8.976
Difference: 0.0240
Squared difference: 0.0006
Sum of squared errors: 0.0006
Content of average2.txt: 8.999
Difference: 0.0010
Squared difference: 0.0000
Sum of squared errors: 0.0006
Content of average3.txt: 9.107
Difference: -0.1070
Squared difference: 0.0114
Sum of squared errors: 0.0120
Content of average4.txt: 8.913
Difference: 0.0870
Squared difference: 0.0076
Sum of squared errors: 0.0196
Content of average5.txt: 8.817
Difference: 0.1830
Squared difference: 0.0335
Sum of squared errors: 0.0531
Content of average6.txt: 9.306
Difference: -0.3060
Squared difference: 0.0936
Sum of squared errors: 0.1467
Content of average7.txt: 9.581
Difference: -0.5810
Squared difference: 0.3376
Sum of squared errors: 0.4843
Content of average8.txt: 9.236
Difference: -0.2360
Squared difference: 0.0557
Sum of squared errors: 0.5400
Content of average9.txt: 9.169
Difference: -0.1690
Squared difference: 0.0286
Sum of squared errors: 0.5686
Content of average10.txt: 9.146
Difference: -0.1460
Squared difference: 0.0213
Sum of squared errors: 0.5899
Mean Squared Error: 0.0590
CSE331:~#
```

Figure 3.1.2.5.4 Mean Square Error of u3p1

```
CSE331:~# bash error.sh
Content of average1.txt: 9.165
Difference: -0.1650
Squared difference: 0.0272
Sum of squared errors: 0.0272
Content of average2.txt: 8.992
Difference: 0.0080
Squared difference: 0.0001
Sum of squared errors: 0.0273
Content of average3.txt: 9.259
Difference: -0.2590
Squared difference: 0.0671
Sum of squared errors: 0.0944
Content of average4.txt: 9.514
Difference: -0.5140
Squared difference: 0.2642
Sum of squared errors: 0.3586
Content of average5.txt: 9.282
Difference: -0.2820
Squared difference: 0.0795
Sum of squared errors: 0.4381
Content of average6.txt: 8.717
Difference: 0.2830
Squared difference: 0.0801
Sum of squared errors: 0.5182
Content of average7.txt: 8.86
Difference: 0.1400
Squared difference: 0.0196
Sum of squared errors: 0.5378
Content of average8.txt: 9.341
Difference: -0.3410
Squared difference: 0.1163
Sum of squared errors: 0.6541
Content of average9.txt: 9.091
Difference: -0.0910
Squared difference: 0.0083
Sum of squared errors: 0.6624
Content of average10.txt: 9.014
Difference: -0.0140
Squared difference: 0.0002
Sum of squared errors: 0.6626
Mean Squared Error: 0.0663
CSE331:~#
```

```
CSE331:~# bash error.sh
Content of average1.txt: 9.386
Difference: -0.3860
Squared difference: 0.1490
Sum of squared errors: 0.1490
Content of average2.txt: 8.993
Difference: 0.0070
Squared difference: 0.0000
Sum of squared errors: 0.1490
Content of average3.txt: 9.064
Difference: -0.0640
Squared difference: 0.0041
Sum of squared errors: 0.1531
Content of average4.txt: 9.287
Difference: -0.2870
Squared difference: 0.0824
Sum of squared errors: 0.2355
Content of average5.txt: 9.111
Difference: -0.1110
Squared difference: 0.0123
Sum of squared errors: 0.2478
Content of average6.txt: 8.693
Difference: 0.3070
Squared difference: 0.0942
Sum of squared errors: 0.3420
Content of average7.txt: 9.001
Difference: -0.0010
Squared difference: 0.0000
Sum of squared errors: 0.3420
Content of average8.txt: 9.027
Difference: -0.0270
Squared difference: 0.0007
Sum of squared errors: 0.3427
Content of average9.txt: 8.901
Difference: 0.0990
Squared difference: 0.0098
Sum of squared errors: 0.3525
Content of average10.txt: 8.884
Difference: 0.1160
Squared difference: 0.0135
Sum of squared errors: 0.3660
Mean Squared Error: 0.0366
CSE331:~#
```

Figure 3.1.2.5.5 Mean Square Error of u4p1   **Figure 3.1.2.5.6** Mean Square Error of u4p2

```
CSE331:~# bash error.sh
Content of average1.txt: 9.134
Difference: -0.1340
Squared difference: 0.0180
Sum of squared errors: 0.0180
Content of average2.txt: 9.219
Difference: -0.2190
Squared difference: 0.0480
Sum of squared errors: 0.0660
Content of average3.txt: 9.104
Difference: -0.1040
Squared difference: 0.0108
Sum of squared errors: 0.0768
Content of average4.txt: 9.094
Difference: -0.0940
Squared difference: 0.0088
Sum of squared errors: 0.0856
Content of average5.txt: 9.151
Difference: -0.1510
Squared difference: 0.0228
Sum of squared errors: 0.1084
Content of average6.txt: 9.519
Difference: -0.5190
Squared difference: 0.2694
Sum of squared errors: 0.3778
Content of average7.txt: 8.947
Difference: 0.0530
Squared difference: 0.0028
Sum of squared errors: 0.3806
Content of average8.txt: 9.639
Difference: -0.6390
Squared difference: 0.4083
Sum of squared errors: 0.7889
Content of average9.txt: 9.299
Difference: -0.2990
Squared difference: 0.0894
Sum of squared errors: 0.8783
Content of average10.txt: 9.624
Difference: -0.6240
Squared difference: 0.3894
Sum of squared errors: 1.2677
Mean Squared Error: 0.1268
CSE331:~#
```

Figure 3.1.2.5.7 Mean Square Error of u4p3

```
CSE331:~# bash error.sh
Content of average1.txt: 8.986
Difference: 0.0140
Squared difference: 0.0002
Sum of squared errors: 0.0002
Content of average2.txt: 8.972
Difference: 0.0280
Squared difference: 0.0008
Sum of squared errors: 0.0010
Content of average3.txt: 9.243
Difference: -0.2430
Squared difference: 0.0590
Sum of squared errors: 0.0600
Content of average4.txt: 9.096
Difference: -0.0960
Squared difference: 0.0092
Sum of squared errors: 0.0692
Content of average5.txt: 9.022
Difference: -0.0220
Squared difference: 0.0005
Sum of squared errors: 0.0697
Content of average6.txt: 9.02
Difference: -0.0200
Squared difference: 0.0004
Sum of squared errors: 0.0701
Content of average7.txt: 9.299
Difference: -0.2990
Squared difference: 0.0894
Sum of squared errors: 0.1595
Content of average8.txt: 8.952
Difference: 0.0480
Squared difference: 0.0023
Sum of squared errors: 0.1618
Content of average9.txt: 8.981
Difference: 0.0190
Squared difference: 0.0004
Sum of squared errors: 0.1622
Content of average10.txt: 9.059
Difference: -0.0590
Squared difference: 0.0035
Sum of squared errors: 0.1657
Mean Squared Error: 0.0166
CSE331:~#
```

Figure 3.1.2.5.8 Mean Square Error of u4p4

```
CSE331:~# bash error.sh
Content of average1.txt: 8.916
Difference: 0.0840
Squared difference: 0.0071
Sum of squared errors: 0.0071
Content of average2.txt: 9.302
Difference: -0.3020
Squared difference: 0.0912
Sum of squared errors: 0.0983
Content of average3.txt: 8.992
Difference: 0.0080
Squared difference: 0.0001
Sum of squared errors: 0.0984
Content of average4.txt: 8.819
Difference: 0.1810
Squared difference: 0.0328
Sum of squared errors: 0.1312
Content of average5.txt: 9.324
Difference: -0.3240
Squared difference: 0.1050
Sum of squared errors: 0.2362
Content of average6.txt: 9.046
Difference: -0.0460
Squared difference: 0.0021
Sum of squared errors: 0.2383
Content of average7.txt: 9.318
Difference: -0.3180
Squared difference: 0.1011
Sum of squared errors: 0.3394
Content of average8.txt: 9.077
Difference: -0.0770
Squared difference: 0.0059
Sum of squared errors: 0.3453
Content of average9.txt: 8.915
Difference: 0.0850
Squared difference: 0.0072
Sum of squared errors: 0.3525
Content of average10.txt: 9.054
Difference: -0.0540
Squared difference: 0.0029
Sum of squared errors: 0.3554
Mean Squared Error: 0.0355
CSE331:~#
```

Figure 3.1.2.5.9 Mean Square Error of u5p1

```
CSE331:~# bash error.sh
Content of average1.txt: 9.037
Difference: -0.0370
Squared difference: 0.0014
Sum of squared errors: 0.0014
Content of average2.txt: 9.148
Difference: -0.1480
Squared difference: 0.0219
Sum of squared errors: 0.0233
Content of average3.txt: 8.833
Difference: 0.1670
Squared difference: 0.0279
Sum of squared errors: 0.0512
Content of average4.txt: 9.19
Difference: -0.1900
Squared difference: 0.0361
Sum of squared errors: 0.0873
Content of average5.txt: 9.075
Difference: -0.0750
Squared difference: 0.0056
Sum of squared errors: 0.0929
Content of average6.txt: 9.485
Difference: -0.4850
Squared difference: 0.2352
Sum of squared errors: 0.3281
Content of average7.txt: 8.876
Difference: 0.1240
Squared difference: 0.0154
Sum of squared errors: 0.3435
Content of average8.txt: 9.226
Difference: -0.2260
Squared difference: 0.0511
Sum of squared errors: 0.3946
Content of average9.txt: 9.459
Difference: -0.4590
Squared difference: 0.2107
Sum of squared errors: 0.6053
Content of average10.txt: 8.951
Difference: 0.0490
Squared difference: 0.0024
Sum of squared errors: 0.6077
Mean Squared Error: 0.0608
CSE331:~#
```

Figure 3.1.2.5.10 Mean Square Error of u5p2

```
CSE331:~# bash error.sh
Content of average1.txt: 9.247
Difference: -0.2470
Squared difference: 0.0610
Sum of squared errors: 0.0610
Content of average2.txt: 8.802
Difference: 0.1980
Squared difference: 0.0392
Sum of squared errors: 0.1002
Content of average3.txt: 9.264
Difference: -0.2640
Squared difference: 0.0697
Sum of squared errors: 0.1699
Content of average4.txt: 8.876
Difference: 0.1240
Squared difference: 0.0154
Sum of squared errors: 0.1853
Content of average5.txt: 9.062
Difference: -0.0620
Squared difference: 0.0038
Sum of squared errors: 0.1891
Content of average6.txt: 9.369
Difference: -0.3690
Squared difference: 0.1362
Sum of squared errors: 0.3253
Content of average7.txt: 9.058
Difference: -0.0580
Squared difference: 0.0034
Sum of squared errors: 0.3287
Content of average8.txt: 9.09
Difference: -0.0900
Squared difference: 0.0081
Sum of squared errors: 0.3368
Content of average9.txt: 9.403
Difference: -0.4030
Squared difference: 0.1624
Sum of squared errors: 0.4992
Content of average10.txt: 9.027
Difference: -0.0270
Squared difference: 0.0007
Sum of squared errors: 0.4999
Mean Squared Error: 0.0500
CSE331:~#
```

Figure 3.1.2.5.11 Mean Square Error of u5p3

3.2.   FAIR-SHARE ALGORITHM

3.2.1.   AVERAGE CPU USAGE

3.2.1.1. TestCase-1:

In test case-1 , we have 3 users.

User1 -> 3 processes

User2 -> 2 processes

User3 -> 1 process

```
CSE331:~# bash average2.sh
The average of averages is 11.29
```

Figure 3.2.1.1.1 Average CPU Usage of u1p1

```
CSE331:~# bash average2.sh
The average of averages is 11.22
```

Figure 3.2.1.1.2 Average CPU Usage of u1p2

```
CSE331:~# bash average2.sh
The average of averages is 11.04
```

Figure 3.2.1.1.3 Average CPU Usage of u1p3

```
CSE331:~# bash average2.sh
The average of averages is 16.69
```

Figure 3.2.1.1.4 Average CPU Usage of u2p1

```
CSE331:~# bash average2.sh
The average of averages is 16.78
```

Figure 3.2.1.1.5 Average CPU Usage of u2p2

```
CSE331:~# bash average2.sh
The average of averages is 32.97
```

Figure 3.2.1.1.6 Average CPU Usage of u3p1

3.2.1.2. TestCase-2:

In test case-2 , we have 4 users.

User1 -> 3 processes

User2 -> 2 processes

User3 -> 1 process

User4 -> 4 processes

```
CSE331:~# bash average2.sh
The average of averages is 8.51
```

Figure 3.2.1.2.1 Average CPU Usage of u1p1

```
CSE331:~# bash average2.sh
The average of averages is 8.51
```

Figure 3.2.1.2.2 Average CPU Usage of u1p2

```
CSE331:~# bash average2.sh
The average of averages is 8.33
```

Figure 3.2.1.2.3 Average CPU Usage of u1p3

```
CSE331:~# bash average2.sh
The average of averages is 12.39
```

Figure 3.2.1.2.4 Average CPU Usage of u2p1

```
CSE331:~# bash average2.sh
The average of averages is 12.19
```

Figure 3.2.1.2.5 Average CPU Usage of u2p2

```
CSE331:~# bash average2.sh
The average of averages is 24.58
```

Figure 3.2.1.2.6 Average CPU Usage of u3p1

```
CSE331:~# bash average2.sh
The average of averages is 6.29
```

Figure 3.2.1.2.7 Average CPU Usage of u4p1

```
CSE331:~# bash average2.sh
The average of averages is 6.41
```

Figure 3.2.1.2.8 Average CPU Usage of u4p2

```
CSE331:~# bash average2.sh
The average of averages is 6.42
```

Figure 3.2.1.2.9 Average CPU Usage of u4p3

```
CSE331:~# bash average2.sh
The average of averages is 6.35
```

Figure 3.2.1.2.10 Average CPU Usage of u4p4

3.2.1.3. TestCase-3:

In test case-3 , we have 2 users.

User1 -> 2 processes

User2 -> 3 processes

Figure 3.2.1.3.1 Average CPU Usage of u1p1

Figure 3.2.1.3.2 Average CPU Usage of u1p2

Figure 3.2.1.3.3 Average CPU Usage of u2p1

Figure 3.2.1.3.4 Average CPU Usage of u2p2

Figure 3.2.1.3.5 Average CPU Usage of u2p3

3.2.1.4. TestCase-4:

In test case-1 , we have 3 users.

User1 -> 1 process

User2 -> 2 processes

User3 -> 1 process

```
CSE331:~# bash average2.sh
The average of averages is 32.96
```

Figure 3.2.1.4.1 Average CPU Usage of u1p1

```
CSE331:~# bash average2.sh
The average of averages is 16.94
```

Figure 3.2.1.4.2 Average CPU Usage of u2p1

```
CSE331:~# bash average2.sh
The average of averages is 16.90
```

Figure 3.2.1.4.3 Average CPU Usage of u2p2

```
CSE331:~# bash average2.sh
The average of averages is 33.23
```

Figure 3.2.1.4.4 Average CPU Usage of u3p1

3.2.1.5. TestCase-5:

In test case-1 , we have 5 users.

User1 -> 1 process

User2 -> 2 processes

User3 -> 1 process

User4 -> 4 process

User5 -> 3 process

```
CSE331:~# bash average2.sh
The average of averages is 20.21
```

Figure 3.2.1.5.1 Average CPU Usage of u1p1

```
CSE331:~# bash average2.sh
The average of averages is 10.15
```

Figure 3.2.1.5.2 Average CPU Usage of u2p1

```
CSE331:~# bash average2.sh
The average of averages is 10.11
```

Figure 3.2.1.5.3 Average CPU Usage of u2p2

```
CSE331:~# bash average2.sh
The average of averages is 20.20
```

Figure 3.2.1.5.4 Average CPU Usage of u3p1

```
CSE331:~# bash average2.sh
The average of averages is 4.65
```

Figure 3.2.1.5.5 Average CPU Usage of u4p1

```
CSE331:~# bash average2.sh
The average of averages is 4.65
```

Figure 3.2.1.5.6 Average CPU Usage of u4p2

```
CSE331:~# bash average2.sh
The average of averages is 4.93
```

Figure 3.2.1.5.7 Average CPU Usage of u4p3

```
CSE331:~# bash average2.sh
The average of averages is 4.79
```

Figure 3.2.1.5.8 Average CPU Usage of u4p4

```
CSE331:~# bash average2.sh
The average of averages is 6.74
```

Figure 3.2.1.5.9 Average CPU Usage of u5p1

```
CSE331:~# bash average2.sh
The average of averages is 6.82
```

Figure 3.2.1.5.10 Average CPU Usage of u5p2

```
CSE331:~# bash average2.sh
The average of averages is 6.73
```

Figure 3.2.1.5.11 Average CPU Usage of u5p3

3.2.2. MEAN SQUARE ERROR

3.2.2.1. TestCase-1:

In test case-1 , we have 3 users.

User1 -> 3 processes

User2 -> 2 processes

User3 -> 1 process

```
CSE331:~# bash error.sh
Content of average1.txt: 11.132
Difference: -0.0209
Squared difference: 0.0004
Sum of squared errors: 0.0004
Content of average2.txt: 12.007
Difference: -0.8959
Squared difference: 0.8026
Sum of squared errors: 0.8030
Content of average3.txt: 11.431
Difference: -0.3199
Squared difference: 0.1023
Sum of squared errors: 0.9053
Content of average4.txt: 11.286
Difference: -0.1749
Squared difference: 0.0306
Sum of squared errors: 0.9359
Content of average5.txt: 11.486
Difference: -0.3749
Squared difference: 0.1406
Sum of squared errors: 1.0765
Content of average6.txt: 10.887
Difference: 0.2241
Squared difference: 0.0502
Sum of squared errors: 1.1267
Content of average7.txt: 11.276
Difference: -0.1649
Squared difference: 0.0272
Sum of squared errors: 1.1539
Content of average8.txt: 11.129
Difference: -0.0179
Squared difference: 0.0003
Sum of squared errors: 1.1542
Content of average9.txt: 11.08
Difference: 0.0311
Squared difference: 0.0010
Sum of squared errors: 1.1552
Content of average10.txt: 11.282
Difference: -0.1709
Squared difference: 0.0292
Sum of squared errors: 1.1844
Mean Squared Error: 0.1184
CSE331:~#
```

Figure 3.2.2.1.1 Mean Square Error of u1p1

```
CSE331:~# bash error.sh
Content of average1.txt: 10.993
Difference: 0.1181
Squared difference: 0.0139
Sum of squared errors: 0.0139
Content of average2.txt: 11.302
Difference: -0.1909
Squared difference: 0.0364
Sum of squared errors: 0.0503
Content of average3.txt: 11.268
Difference: -0.1569
Squared difference: 0.0246
Sum of squared errors: 0.0749
Content of average4.txt: 11.003
Difference: 0.1081
Squared difference: 0.0117
Sum of squared errors: 0.0866
Content of average5.txt: 11.188
Difference: -0.0769
Squared difference: 0.0059
Sum of squared errors: 0.0925
Content of average6.txt: 11.786
Difference: -0.6749
Squared difference: 0.4555
Sum of squared errors: 0.5480
Content of average7.txt: 11.473
Difference: -0.3619
Squared difference: 0.1310
Sum of squared errors: 0.6790
Content of average8.txt: 11.118
Difference: -0.0069
Squared difference: 0.0000
Sum of squared errors: 0.6790
Content of average9.txt: 11.081
Difference: 0.0301
Squared difference: 0.0009
Sum of squared errors: 0.6799
Content of average10.txt: 11.042
Difference: 0.0691
Squared difference: 0.0048
Sum of squared errors: 0.6847
Mean Squared Error: 0.0685
CSE331:~#
```

Figure 3.2.2.1.2 Mean Square Error of u1p2

```
CSE331:~# bash error.sh
Content of average1.txt: 11.291
Difference: -0.1799
Squared difference: 0.0324
Sum of squared errors: 0.0324
Content of average2.txt: 10.949
Difference: 0.1621
Squared difference: 0.0263
Sum of squared errors: 0.0587
Content of average3.txt: 11.099
Difference: 0.0121
Squared difference: 0.0001
Sum of squared errors: 0.0588
Content of average4.txt: 11.212
Difference: -0.1009
Squared difference: 0.0102
Sum of squared errors: 0.0690
Content of average5.txt: 10.765
Difference: 0.3461
Squared difference: 0.1198
Sum of squared errors: 0.1888
Content of average6.txt: 11.184
Difference: -0.0729
Squared difference: 0.0053
Sum of squared errors: 0.1941
Content of average7.txt: 11.041
Difference: 0.0701
Squared difference: 0.0049
Sum of squared errors: 0.1990
Content of average8.txt: 11.13
Difference: -0.0189
Squared difference: 0.0004
Sum of squared errors: 0.1994
Content of average9.txt: 10.808
Difference: 0.3031
Squared difference: 0.0919
Sum of squared errors: 0.2913
Content of average10.txt: 10.966
Difference: 0.1451
Squared difference: 0.0211
Sum of squared errors: 0.3124
Mean Squared Error: 0.0312
CSE331:~#
```

```
CSE331:~# bash error.sh
Content of average1.txt: 17.163
Difference: -0.4964
Squared difference: 0.2464
Sum of squared errors: 0.2464
Content of average2.txt: 16.245
Difference: 0.4216
Squared difference: 0.1777
Sum of squared errors: 0.4241
Content of average3.txt: 16.702
Difference: -0.0354
Squared difference: 0.0013
Sum of squared errors: 0.4254
Content of average4.txt: 16.573
Difference: 0.0936
Squared difference: 0.0088
Sum of squared errors: 0.4342
Content of average5.txt: 17.19
Difference: -0.5234
Squared difference: 0.2739
Sum of squared errors: 0.7081
Content of average6.txt: 16.896
Difference: -0.2294
Squared difference: 0.0526
Sum of squared errors: 0.7607
Content of average7.txt: 16.557
Difference: 0.1096
Squared difference: 0.0120
Sum of squared errors: 0.7727
Content of average8.txt: 16.56
Difference: 0.1066
Squared difference: 0.0114
Sum of squared errors: 0.7841
Content of average9.txt: 16.344
Difference: 0.3226
Squared difference: 0.1041
Sum of squared errors: 0.8882
Content of average10.txt: 16.709
Difference: -0.0424
Squared difference: 0.0018
Sum of squared errors: 0.8900
Mean Squared Error: 0.0890
CSE331:~#
```

Figure 3.2.2.1.3 Mean Square Error of u1p3   **Figure 3.2.2.1.4** Mean Square Error of u2p1

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```
CSE331:~# bash error.sh
Content of average1.txt: 16.9
Difference: -0.2334
Squared difference: 0.0545
Sum of squared errors: 0.0545
Content of average2.txt: 16.582
Difference: 0.0846
Squared difference: 0.0072
Sum of squared errors: 0.0617
Content of average3.txt: 16.455
Difference: 0.2116
Squared difference: 0.0448
Sum of squared errors: 0.1065
Content of average4.txt: 17.062
Difference: -0.3954
Squared difference: 0.1563
Sum of squared errors: 0.2628
Content of average5.txt: 16.839
Difference: -0.1724
Squared difference: 0.0297
Sum of squared errors: 0.2925
Content of average6.txt: 16.395
Difference: 0.2716
Squared difference: 0.0738
Sum of squared errors: 0.3663
Content of average7.txt: 16.854
Difference: -0.1874
Squared difference: 0.0351
Sum of squared errors: 0.4014
Content of average8.txt: 17.488
Difference: -0.8214
Squared difference: 0.6747
Sum of squared errors: 1.0761
Content of average9.txt: 16.373
Difference: 0.2936
Squared difference: 0.0862
Sum of squared errors: 1.1623
Content of average10.txt: 16.854
Difference: -0.1874
Squared difference: 0.0351
Sum of squared errors: 1.1974
Mean Squared Error: 0.1197
CSE331:~# █
```

Figure 3.2.2.1.5 Mean Square Error of u2p2

```
CSE331:~# bash error.sh
Content of average1.txt: 32.549
Difference: 0.7843
Squared difference: 0.6151
Sum of squared errors: 0.6151
Content of average2.txt: 32.936
Difference: 0.3973
Squared difference: 0.1578
Sum of squared errors: 0.7729
Content of average3.txt: 33.057
Difference: 0.2763
Squared difference: 0.0763
Sum of squared errors: 0.8492
Content of average4.txt: 32.881
Difference: 0.4523
Squared difference: 0.2046
Sum of squared errors: 1.0538
Content of average5.txt: 32.556
Difference: 0.7773
Squared difference: 0.6042
Sum of squared errors: 1.6580
Content of average6.txt: 32.843
Difference: 0.4903
Squared difference: 0.2404
Sum of squared errors: 1.8984
Content of average7.txt: 32.813
Difference: 0.5203
Squared difference: 0.2707
Sum of squared errors: 2.1691
Content of average8.txt: 32.611
Difference: 0.7223
Squared difference: 0.5217
Sum of squared errors: 2.6908
Content of average9.txt: 34.3
Difference: -0.9667
Squared difference: 0.9345
Sum of squared errors: 3.6253
Content of average10.txt: 33.185
Difference: 0.1483
Squared difference: 0.0220
Sum of squared errors: 3.6473
Mean Squared Error: 0.3647
CSE331:~# █
```

Figure 3.2.2.1.6 Mean Square Error of u3p1

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3.2.2.2. TestCase-2:

In test case-1 , we have 4 users.

User1 -> 3 processes

User2 -> 2 processes

User3 -> 1 process

User4 -> 4 processes

```
CSE331:~# bash error.sh
Content of average1.txt: 8.4
Difference: -0.0667
Squared difference: 0.0044
Sum of squared errors: 0.0044
Content of average2.txt: 8.459
Difference: -0.1257
Squared difference: 0.0158
Sum of squared errors: 0.0202
Content of average3.txt: 8.356
Difference: -0.0227
Squared difference: 0.0005
Sum of squared errors: 0.0207
Content of average4.txt: 8.502
Difference: -0.1687
Squared difference: 0.0285
Sum of squared errors: 0.0492
Content of average5.txt: 8.312
Difference: 0.0213
Squared difference: 0.0005
Sum of squared errors: 0.0497
Content of average6.txt: 9.058
Difference: -0.7247
Squared difference: 0.5252
Sum of squared errors: 0.5749
Content of average7.txt: 8.388
Difference: -0.0547
Squared difference: 0.0030
Sum of squared errors: 0.5779
Content of average8.txt: 8.598
Difference: -0.2647
Squared difference: 0.0701
Sum of squared errors: 0.6480
Content of average9.txt: 8.549
Difference: -0.2157
Squared difference: 0.0465
Sum of squared errors: 0.6945
Content of average10.txt: 8.487
Difference: -0.1537
Squared difference: 0.0236
Sum of squared errors: 0.7181
Mean Squared Error: 0.0718
CSE331:~#
```

Figure 3.2.2.2.1 Mean Square Error of u1p1

```
CSE331:~# bash error.sh
Content of average1.txt: 8.4
Difference: -0.0667
Squared difference: 0.0044
Sum of squared errors: 0.0044
Content of average2.txt: 8.459
Difference: -0.1257
Squared difference: 0.0158
Sum of squared errors: 0.0202
Content of average3.txt: 8.356
Difference: -0.0227
Squared difference: 0.0005
Sum of squared errors: 0.0207
Content of average4.txt: 8.502
Difference: -0.1687
Squared difference: 0.0285
Sum of squared errors: 0.0492
Content of average5.txt: 8.312
Difference: 0.0213
Squared difference: 0.0005
Sum of squared errors: 0.0497
Content of average6.txt: 9.058
Difference: -0.7247
Squared difference: 0.5252
Sum of squared errors: 0.5749
Content of average7.txt: 8.388
Difference: -0.0547
Squared difference: 0.0030
Sum of squared errors: 0.5779
Content of average8.txt: 8.598
Difference: -0.2647
Squared difference: 0.0701
Sum of squared errors: 0.6480
Content of average9.txt: 8.549
Difference: -0.2157
Squared difference: 0.0465
Sum of squared errors: 0.6945
Content of average10.txt: 8.487
Difference: -0.1537
Squared difference: 0.0236
Sum of squared errors: 0.7181
Mean Squared Error: 0.0718
CSE331:~#
```

Figure 3.2.2.2.2 Mean Square Error of u1p2

```
CSE331:~# bash error.sh
Content of average1.txt: 8.39
Difference: -0.0567
Squared difference: 0.0032
Sum of squared errors: 0.0032
Content of average2.txt: 8.166
Difference: 0.1673
Squared difference: 0.0280
Sum of squared errors: 0.0312
Content of average3.txt: 8.328
Difference: 0.0053
Squared difference: 0.0000
Sum of squared errors: 0.0312
Content of average4.txt: 8.434
Difference: -0.1007
Squared difference: 0.0101
Sum of squared errors: 0.0413
Content of average5.txt: 8.351
Difference: -0.0177
Squared difference: 0.0003
Sum of squared errors: 0.0416
Content of average6.txt: 8.274
Difference: 0.0593
Squared difference: 0.0035
Sum of squared errors: 0.0451
Content of average7.txt: 8.242
Difference: 0.0913
Squared difference: 0.0083
Sum of squared errors: 0.0534
Content of average8.txt: 8.396
Difference: -0.0627
Squared difference: 0.0039
Sum of squared errors: 0.0573
Content of average9.txt: 8.367
Difference: -0.0337
Squared difference: 0.0011
Sum of squared errors: 0.0584
Content of average10.txt: 8.355
Difference: -0.0217
Squared difference: 0.0005
Sum of squared errors: 0.0589
Mean Squared Error: 0.0059
CSE331:~#
```

Figure 3.2.2.2.3 Mean Square Error of u1p3

```
CSE331:~# bash error.sh
Content of average1.txt: 12.253
Difference: 0.2470
Squared difference: 0.0610
Sum of squared errors: 0.0610
Content of average2.txt: 12.307
Difference: 0.1930
Squared difference: 0.0372
Sum of squared errors: 0.0982
Content of average3.txt: 12.108
Difference: 0.3920
Squared difference: 0.1537
Sum of squared errors: 0.2519
Content of average4.txt: 12.572
Difference: -0.0720
Squared difference: 0.0052
Sum of squared errors: 0.2571
Content of average5.txt: 12.613
Difference: -0.1130
Squared difference: 0.0128
Sum of squared errors: 0.2699
Content of average6.txt: 12.226
Difference: 0.2740
Squared difference: 0.0751
Sum of squared errors: 0.3450
Content of average7.txt: 12.46
Difference: 0.0400
Squared difference: 0.0016
Sum of squared errors: 0.3466
Content of average8.txt: 12.702
Difference: -0.2020
Squared difference: 0.0408
Sum of squared errors: 0.3874
Content of average9.txt: 12.292
Difference: 0.2080
Squared difference: 0.0433
Sum of squared errors: 0.4307
Content of average10.txt: 12.387
Difference: 0.1130
Squared difference: 0.0128
Sum of squared errors: 0.4435
Mean Squared Error: 0.0444
CSE331:~#
```

Figure 3.2.2.2.1 Mean Square Error of u2p1

```
CSE331:~# bash error.sh
Content of average1.txt: 12.21
Difference: 0.2900
Squared difference: 0.0841
Sum of squared errors: 0.0841
Content of average2.txt: 12.382
Difference: 0.1180
Squared difference: 0.0139
Sum of squared errors: 0.0980
Content of average3.txt: 12.332
Difference: 0.1680
Squared difference: 0.0282
Sum of squared errors: 0.1262
Content of average4.txt: 12.23
Difference: 0.2700
Squared difference: 0.0729
Sum of squared errors: 0.1991
Content of average5.txt: 12.191
Difference: 0.3090
Squared difference: 0.0955
Sum of squared errors: 0.2946
Content of average6.txt: 12.065
Difference: 0.4350
Squared difference: 0.1892
Sum of squared errors: 0.4838
Content of average7.txt: 12.059
Difference: 0.4410
Squared difference: 0.1945
Sum of squared errors: 0.6783
Content of average8.txt: 12.072
Difference: 0.4280
Squared difference: 0.1832
Sum of squared errors: 0.8615
Content of average9.txt: 12.138
Difference: 0.3620
Squared difference: 0.1310
Sum of squared errors: 0.9925
Content of average10.txt: 12.243
Difference: 0.2570
Squared difference: 0.0660
Sum of squared errors: 1.0585
Mean Squared Error: 0.1058
CSE331:~#
```

Figure 3.2.2.2.5 Mean Square Error of u2p2

```
CSE331:~# bash error.sh
Content of average1.txt: 24.724
Difference: 0.2760
Squared difference: 0.0762
Sum of squared errors: 0.0762
Content of average2.txt: 24.646
Difference: 0.3540
Squared difference: 0.1253
Sum of squared errors: 0.2015
Content of average3.txt: 24.501
Difference: 0.4990
Squared difference: 0.2490
Sum of squared errors: 0.4505
Content of average4.txt: 24.727
Difference: 0.2730
Squared difference: 0.0745
Sum of squared errors: 0.5250
Content of average5.txt: 24.381
Difference: 0.6190
Squared difference: 0.3832
Sum of squared errors: 0.9082
Content of average6.txt: 24.551
Difference: 0.4490
Squared difference: 0.2016
Sum of squared errors: 1.1098
Content of average7.txt: 24.603
Difference: 0.3970
Squared difference: 0.1576
Sum of squared errors: 1.2674
Content of average8.txt: 24.373
Difference: 0.6270
Squared difference: 0.3931
Sum of squared errors: 1.6605
Content of average9.txt: 24.685
Difference: 0.3150
Squared difference: 0.0992
Sum of squared errors: 1.7597
Content of average10.txt: 24.645
Difference: 0.3550
Squared difference: 0.1260
Sum of squared errors: 1.8857
Mean Squared Error: 0.1886
CSE331:~#
```

Figure 3.2.2.2.6 Mean Square Error of u3p1

```
CSE331:~# bash error.sh
Content of average1.txt: 6.444
Difference: -0.1940
Squared difference: 0.0376
Sum of squared errors: 0.0376
Content of average2.txt: 6.462
Difference: -0.2120
Squared difference: 0.0449
Sum of squared errors: 0.0825
Content of average3.txt: 6.564
Difference: -0.3140
Squared difference: 0.0986
Sum of squared errors: 0.1811
Content of average4.txt: 6.164
Difference: 0.0860
Squared difference: 0.0074
Sum of squared errors: 0.1885
Content of average5.txt: 6.56
Difference: -0.3100
Squared difference: 0.0961
Sum of squared errors: 0.2846
Content of average6.txt: 6.034
Difference: 0.2160
Squared difference: 0.0467
Sum of squared errors: 0.3313
Content of average7.txt: 6.202
Difference: 0.0480
Squared difference: 0.0023
Sum of squared errors: 0.3336
Content of average8.txt: 6.078
Difference: 0.1720
Squared difference: 0.0296
Sum of squared errors: 0.3632
Content of average9.txt: 6.031
Difference: 0.2190
Squared difference: 0.0480
Sum of squared errors: 0.4112
Content of average10.txt: 6.413
Difference: -0.1630
Squared difference: 0.0266
Sum of squared errors: 0.4378
Mean Squared Error: 0.0438
CSE331:~#
```

```
CSE331:~# bash error.sh
Content of average1.txt: 6.589
Difference: -0.3390
Squared difference: 0.1149
Sum of squared errors: 0.1149
Content of average2.txt: 6.494
Difference: -0.2440
Squared difference: 0.0595
Sum of squared errors: 0.1744
Content of average3.txt: 6.561
Difference: -0.3110
Squared difference: 0.0967
Sum of squared errors: 0.2711
Content of average4.txt: 6.474
Difference: -0.2240
Squared difference: 0.0502
Sum of squared errors: 0.3213
Content of average5.txt: 6.21
Difference: 0.0400
Squared difference: 0.0016
Sum of squared errors: 0.3229
Content of average6.txt: 6.484
Difference: -0.2340
Squared difference: 0.0548
Sum of squared errors: 0.3777
Content of average7.txt: 6.508
Difference: -0.2580
Squared difference: 0.0666
Sum of squared errors: 0.4443
Content of average8.txt: 6.197
Difference: 0.0530
Squared difference: 0.0028
Sum of squared errors: 0.4471
Content of average9.txt: 6.482
Difference: -0.2320
Squared difference: 0.0538
Sum of squared errors: 0.5009
Content of average10.txt: 6.102
Difference: 0.1480
Squared difference: 0.0219
Sum of squared errors: 0.5228
Mean Squared Error: 0.0523
CSE331:~#
```

Figure 3.2.2.2.7 Mean Square Error of u4p1   **Figure 3.2.2.2.8** Mean Square Error of u4p2

```
CSE331:~# bash error.sh
Content of average1.txt: 6.235
Difference: 0.0150
Squared difference: 0.0002
Sum of squared errors: 0.0002
Content of average2.txt: 6.47
Difference: -0.2200
Squared difference: 0.0484
Sum of squared errors: 0.0486
Content of average3.txt: 6.324
Difference: -0.0740
Squared difference: 0.0055
Sum of squared errors: 0.0541
Content of average4.txt: 6.38
Difference: -0.1300
Squared difference: 0.0169
Sum of squared errors: 0.0710
Content of average5.txt: 6.53
Difference: -0.2800
Squared difference: 0.0784
Sum of squared errors: 0.1494
Content of average6.txt: 6.507
Difference: -0.2570
Squared difference: 0.0660
Sum of squared errors: 0.2154
Content of average7.txt: 6.628
Difference: -0.3780
Squared difference: 0.1429
Sum of squared errors: 0.3583
Content of average8.txt: 6.365
Difference: -0.1150
Squared difference: 0.0132
Sum of squared errors: 0.3715
Content of average9.txt: 6.33
Difference: -0.0800
Squared difference: 0.0064
Sum of squared errors: 0.3779
Content of average10.txt: 6.44
Difference: -0.1900
Squared difference: 0.0361
Sum of squared errors: 0.4140
Mean Squared Error: 0.0414
CSE331:~#
```

Figure 3.2.2.2.9 Mean Square Error of u4p3

```
CSE331:~# bash error.sh
Content of average1.txt: 6.209
Difference: 0.0410
Squared difference: 0.0017
Sum of squared errors: 0.0017
Content of average2.txt: 6.463
Difference: -0.2130
Squared difference: 0.0454
Sum of squared errors: 0.0471
Content of average3.txt: 6.392
Difference: -0.1420
Squared difference: 0.0202
Sum of squared errors: 0.0673
Content of average4.txt: 6.352
Difference: -0.1020
Squared difference: 0.0104
Sum of squared errors: 0.0777
Content of average5.txt: 6.453
Difference: -0.2030
Squared difference: 0.0412
Sum of squared errors: 0.1189
Content of average6.txt: 6.271
Difference: -0.0210
Squared difference: 0.0004
Sum of squared errors: 0.1193
Content of average7.txt: 6.401
Difference: -0.1510
Squared difference: 0.0228
Sum of squared errors: 0.1421
Content of average8.txt: 6.444
Difference: -0.1940
Squared difference: 0.0376
Sum of squared errors: 0.1797
Content of average9.txt: 6.274
Difference: -0.0240
Squared difference: 0.0006
Sum of squared errors: 0.1803
Content of average10.txt: 6.31
Difference: -0.0600
Squared difference: 0.0036
Sum of squared errors: 0.1839
Mean Squared Error: 0.0184
CSE331:~#
```

Figure 3.2.2.2.10 Mean Square Error of u4p4

3.2.2.3. TestCase-3:

In test case-1 , we have 2 users.

User1 -> 2 processes

User2 -> 3 processes

```
CSE331:~# bash error.sh
Content of average1.txt: 24.935
Difference: 0.0650
Squared difference: 0.0042
Sum of squared errors: 0.0042
Content of average2.txt: 24.638
Difference: 0.3620
Squared difference: 0.1310
Sum of squared errors: 0.1352
Content of average3.txt: 25.063
Difference: -0.0630
Squared difference: 0.0040
Sum of squared errors: 0.1392
Content of average4.txt: 24.968
Difference: 0.0320
Squared difference: 0.0010
Sum of squared errors: 0.1402
Content of average5.txt: 24.545
Difference: 0.4550
Squared difference: 0.2070
Sum of squared errors: 0.3472
Content of average6.txt: 25.417
Difference: -0.4170
Squared difference: 0.1739
Sum of squared errors: 0.5211
Content of average7.txt: 25.061
Difference: -0.0610
Squared difference: 0.0037
Sum of squared errors: 0.5248
Content of average8.txt: 24.707
Difference: 0.2930
Squared difference: 0.0858
Sum of squared errors: 0.6106
Content of average9.txt: 25.484
Difference: -0.4840
Squared difference: 0.2343
Sum of squared errors: 0.8449
Content of average10.txt: 24.628
Difference: 0.3720
Squared difference: 0.1384
Sum of squared errors: 0.9833
Mean Squared Error: 0.0983
CSE331:~# █
```

Figure 3.2.2.3.1 Mean Square Error of u1p1

```
CSE331:~# bash error.sh
Content of average1.txt: 24.473
Difference: 0.5270
Squared difference: 0.2777
Sum of squared errors: 0.2777
Content of average2.txt: 24.477
Difference: 0.5230
Squared difference: 0.2735
Sum of squared errors: 0.5512
Content of average3.txt: 24.506
Difference: 0.4940
Squared difference: 0.2440
Sum of squared errors: 0.7952
Content of average4.txt: 25.519
Difference: -0.5190
Squared difference: 0.2694
Sum of squared errors: 1.0646
Content of average5.txt: 24.385
Difference: 0.6150
Squared difference: 0.3782
Sum of squared errors: 1.4428
Content of average6.txt: 25.119
Difference: -0.1190
Squared difference: 0.0142
Sum of squared errors: 1.4570
Content of average7.txt: 24.651
Difference: 0.3490
Squared difference: 0.1218
Sum of squared errors: 1.5788
Content of average8.txt: 25.256
Difference: -0.2560
Squared difference: 0.0655
Sum of squared errors: 1.6443
Content of average9.txt: 24.385
Difference: 0.6150
Squared difference: 0.3782
Sum of squared errors: 2.0225
Content of average10.txt: 24.683
Difference: 0.3170
Squared difference: 0.1005
Sum of squared errors: 2.1230
Mean Squared Error: 0.2123
CSE331:~# █
```

Figure 3.2.2.3.2 Mean Square Error of u1p2

```
CSE331:~# bash error.sh
Content of average1.txt: 16.67
Difference: -0.0033
Squared difference: 0.0000
Sum of squared errors: 0.0000
Content of average2.txt: 16.866
Difference: -0.1993
Squared difference: 0.0397
Sum of squared errors: 0.0397
Content of average3.txt: 16.503
Difference: 0.1637
Squared difference: 0.0268
Sum of squared errors: 0.0665
Content of average4.txt: 16.292
Difference: 0.3747
Squared difference: 0.1404
Sum of squared errors: 0.2069
Content of average5.txt: 16.642
Difference: 0.0247
Squared difference: 0.0006
Sum of squared errors: 0.2075
Content of average6.txt: 16.261
Difference: 0.4057
Squared difference: 0.1646
Sum of squared errors: 0.3721
Content of average7.txt: 17.037
Difference: -0.3703
Squared difference: 0.1371
Sum of squared errors: 0.5092
Content of average8.txt: 16.8
Difference: -0.1333
Squared difference: 0.0178
Sum of squared errors: 0.5270
Content of average9.txt: 16.762
Difference: -0.0953
Squared difference: 0.0091
Sum of squared errors: 0.5361
Content of average10.txt: 16.688
Difference: -0.0213
Squared difference: 0.0005
Sum of squared errors: 0.5366
Mean Squared Error: 0.0537
CSE331:~#
```

```
CSE331:~# bash error.sh
Content of average1.txt: 16.744
Difference: -0.0773
Squared difference: 0.0060
Sum of squared errors: 0.0060
Content of average2.txt: 16.937
Difference: -0.2703
Squared difference: 0.0731
Sum of squared errors: 0.0791
Content of average3.txt: 16.921
Difference: -0.2543
Squared difference: 0.0647
Sum of squared errors: 0.1438
Content of average4.txt: 16.521
Difference: 0.1457
Squared difference: 0.0212
Sum of squared errors: 0.1650
Content of average5.txt: 17.544
Difference: -0.8773
Squared difference: 0.7697
Sum of squared errors: 0.9347
Content of average6.txt: 16.945
Difference: -0.2783
Squared difference: 0.0775
Sum of squared errors: 1.0122
Content of average7.txt: 16.604
Difference: 0.0627
Squared difference: 0.0039
Sum of squared errors: 1.0161
Content of average8.txt: 16.993
Difference: -0.3263
Squared difference: 0.1065
Sum of squared errors: 1.1226
Content of average9.txt: 16.602
Difference: 0.0647
Squared difference: 0.0042
Sum of squared errors: 1.1268
Content of average10.txt: 17.205
Difference: -0.5383
Squared difference: 0.2898
Sum of squared errors: 1.4166
Mean Squared Error: 0.1417
CSE331:~#
```

Figure 3.2.2.3.3 Mean Square Error of u2p1   **Figure 3.2.2.3.4** Mean Square Error of u2p2

```
CSE331:~# bash error.sh
Content of average1.txt: 17.251
Difference: -0.5843
Squared difference: 0.3414
Sum of squared errors: 0.3414
Content of average2.txt: 17.131
Difference: -0.4643
Squared difference: 0.2156
Sum of squared errors: 0.5570
Content of average3.txt: 17.099
Difference: -0.4323
Squared difference: 0.1869
Sum of squared errors: 0.7439
Content of average4.txt: 16.796
Difference: -0.1293
Squared difference: 0.0167
Sum of squared errors: 0.7606
Content of average5.txt: 17.026
Difference: -0.3593
Squared difference: 0.1291
Sum of squared errors: 0.8897
Content of average6.txt: 16.386
Difference: 0.2807
Squared difference: 0.0788
Sum of squared errors: 0.9685
Content of average7.txt: 16.802
Difference: -0.1353
Squared difference: 0.0183
Sum of squared errors: 0.9868
Content of average8.txt: 16.36
Difference: 0.3067
Squared difference: 0.0941
Sum of squared errors: 1.0809
Content of average9.txt: 16.855
Difference: -0.1883
Squared difference: 0.0355
Sum of squared errors: 1.1164
Content of average10.txt: 16.885
Difference: -0.2183
Squared difference: 0.0477
Sum of squared errors: 1.1641
Mean Squared Error: 0.1164
CSE331:~#
```

Figure 3.2.2.3.5 Mean Square Error of u2p3

3.2.2.4. TestCase-4:

In test case-1 , we have 3 users.

User1 -> 1 process

User2 -> 2 processes

User3 -> 1 process

```
CSE331:~# bash error.sh
Content of average1.txt: 33.159
Difference: 0.1743
Squared difference: 0.0304
Sum of squared errors: 0.0304
Content of average2.txt: 33.123
Difference: 0.2103
Squared difference: 0.0442
Sum of squared errors: 0.0746
Content of average3.txt: 32.949
Difference: 0.3843
Squared difference: 0.1477
Sum of squared errors: 0.2223
Content of average4.txt: 32.928
Difference: 0.4053
Squared difference: 0.1643
Sum of squared errors: 0.3866
Content of average5.txt: 33.025
Difference: 0.3083
Squared difference: 0.0950
Sum of squared errors: 0.4816
Content of average6.txt: 32.722
Difference: 0.6113
Squared difference: 0.3737
Sum of squared errors: 0.8553
Content of average7.txt: 33.047
Difference: 0.2863
Squared difference: 0.0820
Sum of squared errors: 0.9373
Content of average8.txt: 32.978
Difference: 0.3553
Squared difference: 0.1262
Sum of squared errors: 1.0635
Content of average9.txt: 32.966
Difference: 0.3673
Squared difference: 0.1349
Sum of squared errors: 1.1984
Content of average10.txt: 32.766
Difference: 0.5673
Squared difference: 0.3218
Sum of squared errors: 1.5202
Mean Squared Error: 0.1520
CSE331:~#
```

Figure 3.2.2.4.1 Mean Square Error of u1p1

```
CSE331:~# bash error.sh
Content of average1.txt: 17.033
Difference: -0.3663
Squared difference: 0.1342
Sum of squared errors: 0.1342
Content of average2.txt: 16.756
Difference: -0.0893
Squared difference: 0.0080
Sum of squared errors: 0.1422
Content of average3.txt: 17.004
Difference: -0.3373
Squared difference: 0.1138
Sum of squared errors: 0.2560
Content of average4.txt: 16.925
Difference: -0.2583
Squared difference: 0.0667
Sum of squared errors: 0.3227
Content of average5.txt: 16.941
Difference: -0.2743
Squared difference: 0.0752
Sum of squared errors: 0.3979
Content of average6.txt: 16.802
Difference: -0.1353
Squared difference: 0.0183
Sum of squared errors: 0.4162
Content of average7.txt: 16.935
Difference: -0.2683
Squared difference: 0.0720
Sum of squared errors: 0.4882
Content of average8.txt: 17.086
Difference: -0.4193
Squared difference: 0.1758
Sum of squared errors: 0.6640
Content of average9.txt: 16.56
Difference: 0.1067
Squared difference: 0.0114
Sum of squared errors: 0.6754
Content of average10.txt: 17.397
Difference: -0.7303
Squared difference: 0.5333
Sum of squared errors: 1.2087
Mean Squared Error: 0.1209
CSE331:~#
```

Figure 3.2.2.4.2 Mean Square Error of u2p1

```
CSE331:~# bash error.sh
Content of average1.txt: 16.514
Difference: 0.1527
Squared difference: 0.0233
Sum of squared errors: 0.0233
Content of average2.txt: 16.719
Difference: -0.0523
Squared difference: 0.0027
Sum of squared errors: 0.0260
Content of average3.txt: 16.826
Difference: -0.1593
Squared difference: 0.0254
Sum of squared errors: 0.0514
Content of average4.txt: 16.699
Difference: -0.0323
Squared difference: 0.0010
Sum of squared errors: 0.0524
Content of average5.txt: 17.338
Difference: -0.6713
Squared difference: 0.4506
Sum of squared errors: 0.5030
Content of average6.txt: 17.073
Difference: -0.4063
Squared difference: 0.1651
Sum of squared errors: 0.6681
Content of average7.txt: 17.139
Difference: -0.4723
Squared difference: 0.2231
Sum of squared errors: 0.8912
Content of average8.txt: 16.71
Difference: -0.0433
Squared difference: 0.0019
Sum of squared errors: 0.8931
Content of average9.txt: 17.162
Difference: -0.4953
Squared difference: 0.2453
Sum of squared errors: 1.1384
Content of average10.txt: 16.843
Difference: -0.1763
Squared difference: 0.0311
Sum of squared errors: 1.1695
Mean Squared Error: 0.1169
CSE331:~#
```

Figure 3.2.2.4.3 Mean Square Error of u2p2

```
CSE331:~# bash error.sh
Content of average1.txt: 33.312
Difference: 0.0213
Squared difference: 0.0005
Sum of squared errors: 0.0005
Content of average2.txt: 33.445
Difference: -0.1117
Squared difference: 0.0125
Sum of squared errors: 0.0130
Content of average3.txt: 33.278
Difference: 0.0553
Squared difference: 0.0031
Sum of squared errors: 0.0161
Content of average4.txt: 33.49
Difference: -0.1567
Squared difference: 0.0246
Sum of squared errors: 0.0407
Content of average5.txt: 32.738
Difference: 0.5953
Squared difference: 0.3544
Sum of squared errors: 0.3951
Content of average6.txt: 33.43
Difference: -0.0967
Squared difference: 0.0094
Sum of squared errors: 0.4045
Content of average7.txt: 32.921
Difference: 0.4123
Squared difference: 0.1700
Sum of squared errors: 0.5745
Content of average8.txt: 33.331
Difference: 0.0023
Squared difference: 0.0000
Sum of squared errors: 0.5745
Content of average9.txt: 33.344
Difference: -0.0107
Squared difference: 0.0001
Sum of squared errors: 0.5746
Content of average10.txt: 33.029
Difference: 0.3043
Squared difference: 0.0926
Sum of squared errors: 0.6672
Mean Squared Error: 0.0667
CSE331:~#
```

Figure 3.2.2.4.4 Mean Square Error of u3p1

3.2.2.5. TestCase-5:

In test case-1 , we have 5 users.

User1 -> 1 process

User2 -> 2 processes

User3 -> 1 process

User4 -> 4 processes

User5 -> 3 processes


```
CSE331:~# bash error.sh
Content of average1.txt: 20.135
Difference: -0.1350
Squared difference: 0.0182
Sum of squared errors: 0.0182
Content of average2.txt: 20.015
Difference: -0.0150
Squared difference: 0.0002
Sum of squared errors: 0.0184
Content of average3.txt: 20.086
Difference: -0.0860
Squared difference: 0.0074
Sum of squared errors: 0.0258
Content of average4.txt: 20.112
Difference: -0.1120
Squared difference: 0.0125
Sum of squared errors: 0.0383
Content of average5.txt: 20.26
Difference: -0.2600
Squared difference: 0.0676
Sum of squared errors: 0.1059
Content of average6.txt: 20.652
Difference: -0.6520
Squared difference: 0.4251
Sum of squared errors: 0.5310
Content of average7.txt: 20.336
Difference: -0.3360
Squared difference: 0.1129
Sum of squared errors: 0.6439
Content of average8.txt: 20.169
Difference: -0.1690
Squared difference: 0.0286
Sum of squared errors: 0.6725
Content of average9.txt: 20.246
Difference: -0.2460
Squared difference: 0.0605
Sum of squared errors: 0.7330
Content of average10.txt: 20.173
Difference: -0.1730
Squared difference: 0.0299
Sum of squared errors: 0.7629
Mean Squared Error: 0.0763
CSE331:~#
```

```
CSE331:~# bash error.sh
Content of average1.txt: 10.069
Difference: -0.0690
Squared difference: 0.0048
Sum of squared errors: 0.0048
Content of average2.txt: 10.444
Difference: -0.4440
Squared difference: 0.1971
Sum of squared errors: 0.2019
Content of average3.txt: 10.175
Difference: -0.1750
Squared difference: 0.0306
Sum of squared errors: 0.2325
Content of average4.txt: 10.076
Difference: -0.0760
Squared difference: 0.0058
Sum of squared errors: 0.2383
Content of average5.txt: 10.085
Difference: -0.0850
Squared difference: 0.0072
Sum of squared errors: 0.2455
Content of average6.txt: 9.981
Difference: 0.0190
Squared difference: 0.0004
Sum of squared errors: 0.2459
Content of average7.txt: 10
Difference: 0.0000
Squared difference: 0.0000
Sum of squared errors: 0.2459
Content of average8.txt: 10.137
Difference: -0.1370
Squared difference: 0.0188
Sum of squared errors: 0.2647
Content of average9.txt: 10.199
Difference: -0.1990
Squared difference: 0.0396
Sum of squared errors: 0.3043
Content of average10.txt: 10.361
Difference: -0.3610
Squared difference: 0.1303
Sum of squared errors: 0.4346
Mean Squared Error: 0.0435
CSE331:~#
```

Figure 3.2.2.5.1 Mean Square Error of u1p1   **Figure 3.2.2.5.2** Mean Square Error of u2p1

```
CSE331:~# bash error.sh
Content of average1.txt: 10.205
Difference: -0.2050
Squared difference: 0.0420
Sum of squared errors: 0.0420
Content of average2.txt: 9.966
Difference: 0.0340
Squared difference: 0.0012
Sum of squared errors: 0.0432
Content of average3.txt: 10.028
Difference: -0.0280
Squared difference: 0.0008
Sum of squared errors: 0.0440
Content of average4.txt: 10.204
Difference: -0.2040
Squared difference: 0.0416
Sum of squared errors: 0.0856
Content of average5.txt: 10.223
Difference: -0.2230
Squared difference: 0.0497
Sum of squared errors: 0.1353
Content of average6.txt: 10.235
Difference: -0.2350
Squared difference: 0.0552
Sum of squared errors: 0.1905
Content of average7.txt: 10.232
Difference: -0.2320
Squared difference: 0.0538
Sum of squared errors: 0.2443
Content of average8.txt: 10.176
Difference: -0.1760
Squared difference: 0.0310
Sum of squared errors: 0.2753
Content of average9.txt: 9.979
Difference: 0.0210
Squared difference: 0.0004
Sum of squared errors: 0.2757
Content of average10.txt: 9.855
Difference: 0.1450
Squared difference: 0.0210
Sum of squared errors: 0.2967
Mean Squared Error: 0.0297
CSE331:~#
```

```
CSE331:~# bash error.sh
Content of average1.txt: 20.306
Difference: -0.3060
Squared difference: 0.0936
Sum of squared errors: 0.0936
Content of average2.txt: 20.073
Difference: -0.0730
Squared difference: 0.0053
Sum of squared errors: 0.0989
Content of average3.txt: 20.306
Difference: -0.3060
Squared difference: 0.0936
Sum of squared errors: 0.1925
Content of average4.txt: 20.218
Difference: -0.2180
Squared difference: 0.0475
Sum of squared errors: 0.2400
Content of average5.txt: 20.288
Difference: -0.2880
Squared difference: 0.0829
Sum of squared errors: 0.3229
Content of average6.txt: 20.182
Difference: -0.1820
Squared difference: 0.0331
Sum of squared errors: 0.3560
Content of average7.txt: 20.292
Difference: -0.2920
Squared difference: 0.0853
Sum of squared errors: 0.4413
Content of average8.txt: 20.246
Difference: -0.2460
Squared difference: 0.0605
Sum of squared errors: 0.5018
Content of average9.txt: 19.982
Difference: 0.0180
Squared difference: 0.0003
Sum of squared errors: 0.5021
Content of average10.txt: 20.137
Difference: -0.1370
Squared difference: 0.0188
Sum of squared errors: 0.5209
Mean Squared Error: 0.0521
CSE331:~#
```

Figure 3.2.2.5.3 Mean Square Error of u2p2   **Figure 3.2.2.5.4** Mean Square Error of u3p1

```
CSE331:~# bash error.sh
Content of average1.txt: 4.702
Difference: 0.2980
Squared difference: 0.0888
Sum of squared errors: 0.0888
Content of average2.txt: 4.591
Difference: 0.4090
Squared difference: 0.1673
Sum of squared errors: 0.2561
Content of average3.txt: 4.707
Difference: 0.2930
Squared difference: 0.0858
Sum of squared errors: 0.3419
Content of average4.txt: 4.782
Difference: 0.2180
Squared difference: 0.0475
Sum of squared errors: 0.3894
Content of average5.txt: 4.636
Difference: 0.3640
Squared difference: 0.1325
Sum of squared errors: 0.5219
Content of average6.txt: 4.618
Difference: 0.3820
Squared difference: 0.1459
Sum of squared errors: 0.6678
Content of average7.txt: 4.631
Difference: 0.3690
Squared difference: 0.1362
Sum of squared errors: 0.8040
Content of average8.txt: 4.63
Difference: 0.3700
Squared difference: 0.1369
Sum of squared errors: 0.9409
Content of average9.txt: 4.61
Difference: 0.3900
Squared difference: 0.1521
Sum of squared errors: 1.0930
Content of average10.txt: 4.607
Difference: 0.3930
Squared difference: 0.1544
Sum of squared errors: 1.2474
Mean Squared Error: 0.1247
CSE331:~#
```

```
CSE331:~# bash error.sh
Content of average1.txt: 4.61
Difference: 0.3900
Squared difference: 0.1521
Sum of squared errors: 0.1521
Content of average2.txt: 4.603
Difference: 0.3970
Squared difference: 0.1576
Sum of squared errors: 0.3097
Content of average3.txt: 4.625
Difference: 0.3750
Squared difference: 0.1406
Sum of squared errors: 0.4503
Content of average4.txt: 4.634
Difference: 0.3660
Squared difference: 0.1340
Sum of squared errors: 0.5843
Content of average5.txt: 4.636
Difference: 0.3640
Squared difference: 0.1325
Sum of squared errors: 0.7168
Content of average6.txt: 4.688
Difference: 0.3120
Squared difference: 0.0973
Sum of squared errors: 0.8141
Content of average7.txt: 4.656
Difference: 0.3440
Squared difference: 0.1183
Sum of squared errors: 0.9324
Content of average8.txt: 4.631
Difference: 0.3690
Squared difference: 0.1362
Sum of squared errors: 1.0686
Content of average9.txt: 4.814
Difference: 0.1860
Squared difference: 0.0346
Sum of squared errors: 1.1032
Content of average10.txt: 4.618
Difference: 0.3820
Squared difference: 0.1459
Sum of squared errors: 1.2491
Mean Squared Error: 0.1249
CSE331:~#
```

Figure 3.2.2.5.5 Mean Square Error of u4p1   **Figure 3.2.2.5.6** Mean Square Error of u4p2

```
CSE331:~# bash error.sh
Content of average1.txt: 4.854
Difference: 0.1460
Squared difference: 0.0213
Sum of squared errors: 0.0213
Content of average2.txt: 4.792
Difference: 0.2080
Squared difference: 0.0433
Sum of squared errors: 0.0646
Content of average3.txt: 5.146
Difference: -0.1460
Squared difference: 0.0213
Sum of squared errors: 0.0859
Content of average4.txt: 5.024
Difference: -0.0240
Squared difference: 0.0006
Sum of squared errors: 0.0865
Content of average5.txt: 4.806
Difference: 0.1940
Squared difference: 0.0376
Sum of squared errors: 0.1241
Content of average6.txt: 4.837
Difference: 0.1630
Squared difference: 0.0266
Sum of squared errors: 0.1507
Content of average7.txt: 4.926
Difference: 0.0740
Squared difference: 0.0055
Sum of squared errors: 0.1562
Content of average8.txt: 4.979
Difference: 0.0210
Squared difference: 0.0004
Sum of squared errors: 0.1566
Content of average9.txt: 5.127
Difference: -0.1270
Squared difference: 0.0161
Sum of squared errors: 0.1727
Content of average10.txt: 4.815
Difference: 0.1850
Squared difference: 0.0342
Sum of squared errors: 0.2069
Mean Squared Error: 0.0207
```

Figure 3.2.2.5.7 Mean Square Error of u4p3

```
CSE331:~# bash error.sh
Content of average1.txt: 4.761
Difference: 0.2390
Squared difference: 0.0571
Sum of squared errors: 0.0571
Content of average2.txt: 5.127
Difference: -0.1270
Squared difference: 0.0161
Sum of squared errors: 0.0732
Content of average3.txt: 4.739
Difference: 0.2610
Squared difference: 0.0681
Sum of squared errors: 0.1413
Content of average4.txt: 4.619
Difference: 0.3810
Squared difference: 0.1452
Sum of squared errors: 0.2865
Content of average5.txt: 4.914
Difference: 0.0860
Squared difference: 0.0074
Sum of squared errors: 0.2939
Content of average6.txt: 4.698
Difference: 0.3020
Squared difference: 0.0912
Sum of squared errors: 0.3851
Content of average7.txt: 4.687
Difference: 0.3130
Squared difference: 0.0980
Sum of squared errors: 0.4831
Content of average8.txt: 4.774
Difference: 0.2260
Squared difference: 0.0511
Sum of squared errors: 0.5342
Content of average9.txt: 4.599
Difference: 0.4010
Squared difference: 0.1608
Sum of squared errors: 0.6950
Content of average10.txt: 5.033
Difference: -0.0330
Squared difference: 0.0011
Sum of squared errors: 0.6961
Mean Squared Error: 0.0696
CSE331:~#
```

Figure 3.2.2.5.8 Mean Square Error of u4p4

```
CSE331:~# bash error.sh
Content of average1.txt: 6.887
Difference: -0.2203
Squared difference: 0.0485
Sum of squared errors: 0.0485
Content of average2.txt: 6.701
Difference: -0.0343
Squared difference: 0.0012
Sum of squared errors: 0.0497
Content of average3.txt: 6.797
Difference: -0.1303
Squared difference: 0.0170
Sum of squared errors: 0.0667
Content of average4.txt: 6.655
Difference: 0.0117
Squared difference: 0.0001
Sum of squared errors: 0.0668
Content of average5.txt: 6.6
Difference: 0.0667
Squared difference: 0.0044
Sum of squared errors: 0.0712
Content of average6.txt: 6.761
Difference: -0.0943
Squared difference: 0.0089
Sum of squared errors: 0.0801
Content of average7.txt: 6.608
Difference: 0.0587
Squared difference: 0.0034
Sum of squared errors: 0.0835
Content of average8.txt: 6.811
Difference: -0.1443
Squared difference: 0.0208
Sum of squared errors: 0.1043
Content of average9.txt: 6.83
Difference: -0.1633
Squared difference: 0.0267
Sum of squared errors: 0.1310
Content of average10.txt: 6.755
Difference: -0.0883
Squared difference: 0.0078
Sum of squared errors: 0.1388
Mean Squared Error: 0.0139
CSE331:~#
```

```
CSE331:~# bash error.sh
Content of average1.txt: 6.87
Difference: -0.2033
Squared difference: 0.0413
Sum of squared errors: 0.0413
Content of average2.txt: 6.854
Difference: -0.1873
Squared difference: 0.0351
Sum of squared errors: 0.0764
Content of average3.txt: 6.755
Difference: -0.0883
Squared difference: 0.0078
Sum of squared errors: 0.0842
Content of average4.txt: 7.057
Difference: -0.3903
Squared difference: 0.1523
Sum of squared errors: 0.2365
Content of average5.txt: 6.8
Difference: -0.1333
Squared difference: 0.0178
Sum of squared errors: 0.2543
Content of average6.txt: 6.675
Difference: -0.0083
Squared difference: 0.0001
Sum of squared errors: 0.2544
Content of average7.txt: 6.891
Difference: -0.2243
Squared difference: 0.0503
Sum of squared errors: 0.3047
Content of average8.txt: 6.693
Difference: -0.0263
Squared difference: 0.0007
Sum of squared errors: 0.3054
Content of average9.txt: 6.708
Difference: -0.0413
Squared difference: 0.0017
Sum of squared errors: 0.3071
Content of average10.txt: 6.897
Difference: -0.2303
Squared difference: 0.0530
Sum of squared errors: 0.3601
Mean Squared Error: 0.0360
CSE331:~#
```

Figure 3.2.2.5.9 Mean Square Error of u5p1   **Figure 3.2.2.5.10** Mean Square Error of u5p2

```
CSE331:~# bash error.sh
Content of average1.txt: 6.64
Difference: 0.0267
Squared difference: 0.0007
Sum of squared errors: 0.0007
Content of average2.txt: 6.821
Difference: -0.1543
Squared difference: 0.0238
Sum of squared errors: 0.0245
Content of average3.txt: 6.722
Difference: -0.0553
Squared difference: 0.0031
Sum of squared errors: 0.0276
Content of average4.txt: 6.624
Difference: 0.0427
Squared difference: 0.0018
Sum of squared errors: 0.0294
Content of average5.txt: 6.807
Difference: -0.1403
Squared difference: 0.0197
Sum of squared errors: 0.0491
Content of average6.txt: 6.637
Difference: 0.0297
Squared difference: 0.0009
Sum of squared errors: 0.0500
Content of average7.txt: 6.721
Difference: -0.0543
Squared difference: 0.0029
Sum of squared errors: 0.0529
Content of average8.txt: 6.773
Difference: -0.1063
Squared difference: 0.0113
Sum of squared errors: 0.0642
Content of average9.txt: 6.877
Difference: -0.2103
Squared difference: 0.0442
Sum of squared errors: 0.1084
Content of average10.txt: 6.751
Difference: -0.0843
Squared difference: 0.0071
Sum of squared errors: 0.1155
Mean Squared Error: 0.0116
CSE331:~#
```

Figure 3.2.2.5.11 Mean Square Error of u5p3

3.3   GRAPHS

3.3.1.   Average CPU Usage

3.3.1.1. Testcase-1:

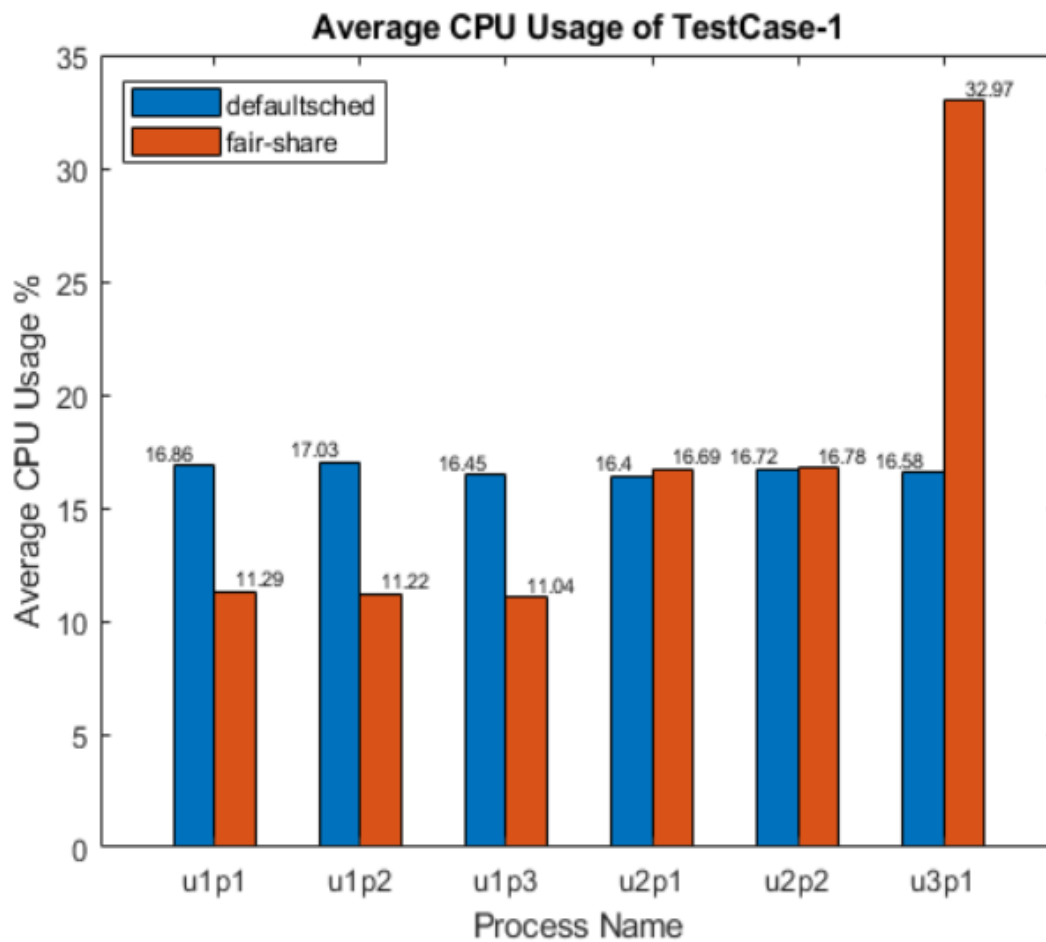**Figure 3.3.1.1.1.** Graph of TestCase-1(Average CPU Usage)

3.3.1.2. Testcase-2:

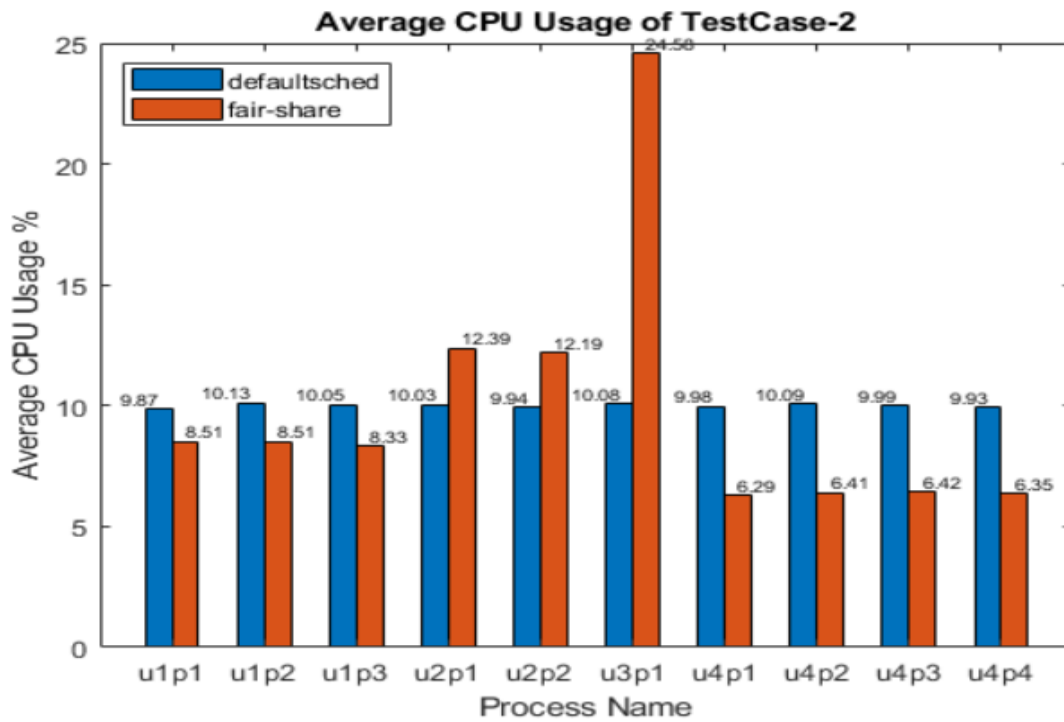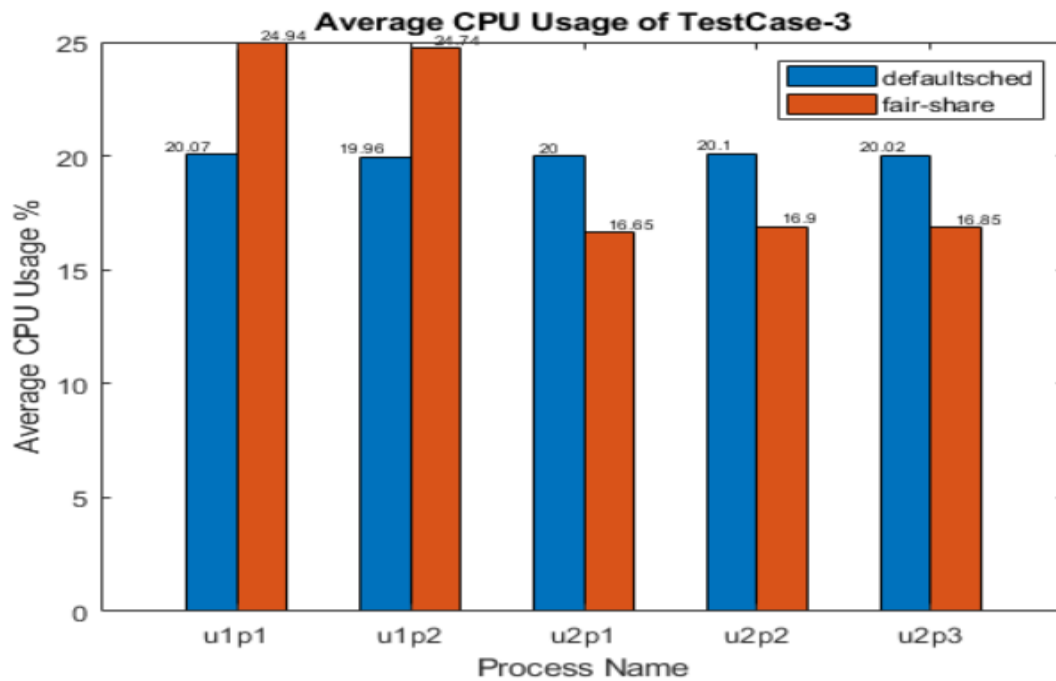**Figure 3.3.1.2.1** Graph of TestCase-2(Average CPU Usage)

3.3.1.3. Testcase-3:

Figure 3.3.1.3.1. Graph of TestCase-3(Average CPU Usage)
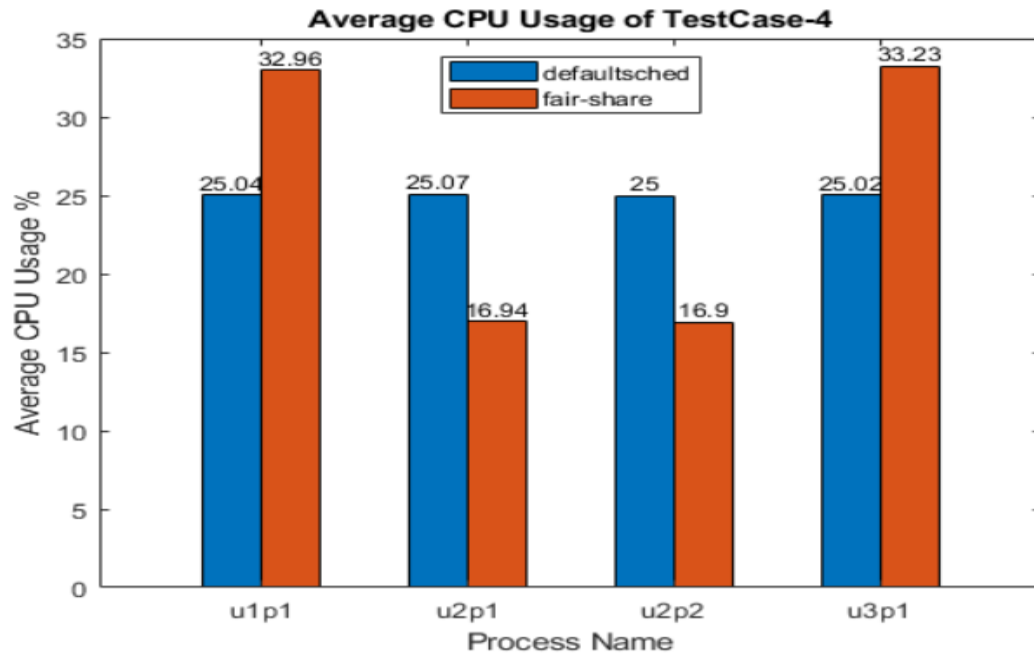
3.3.1.4. Testcase-4:

Figure 3.3.1.4.1. Graph of TestCase-4(Average CPU Usage)
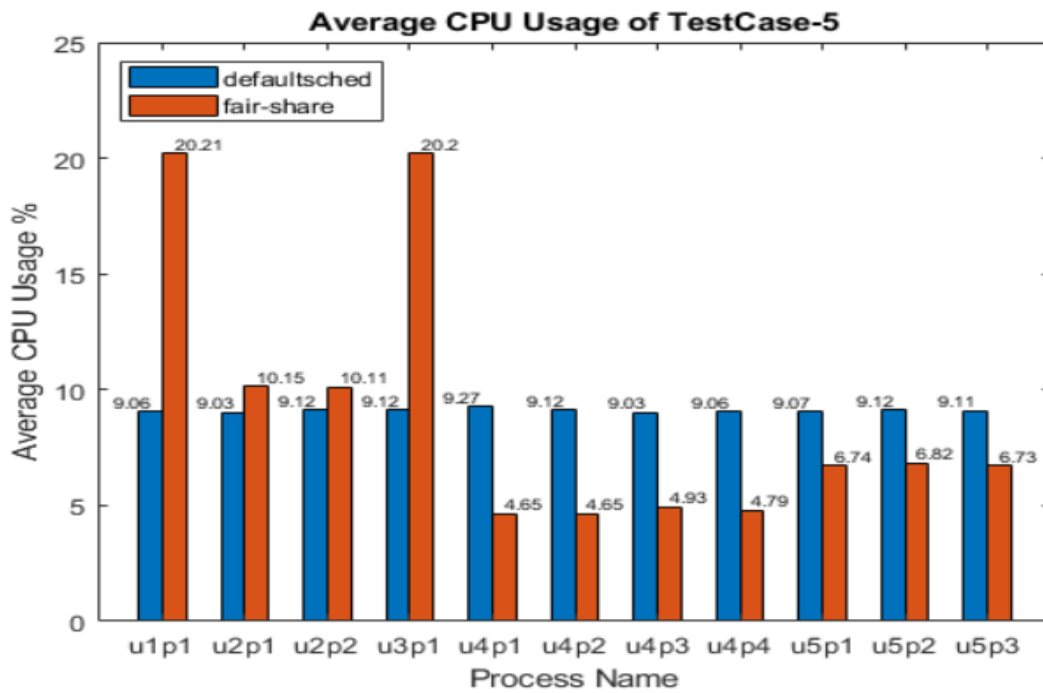
3.3.1.5. Testcase-5:

Figure 3.3.1.5.1. Graph of TestCase-5(Average CPU Usage)

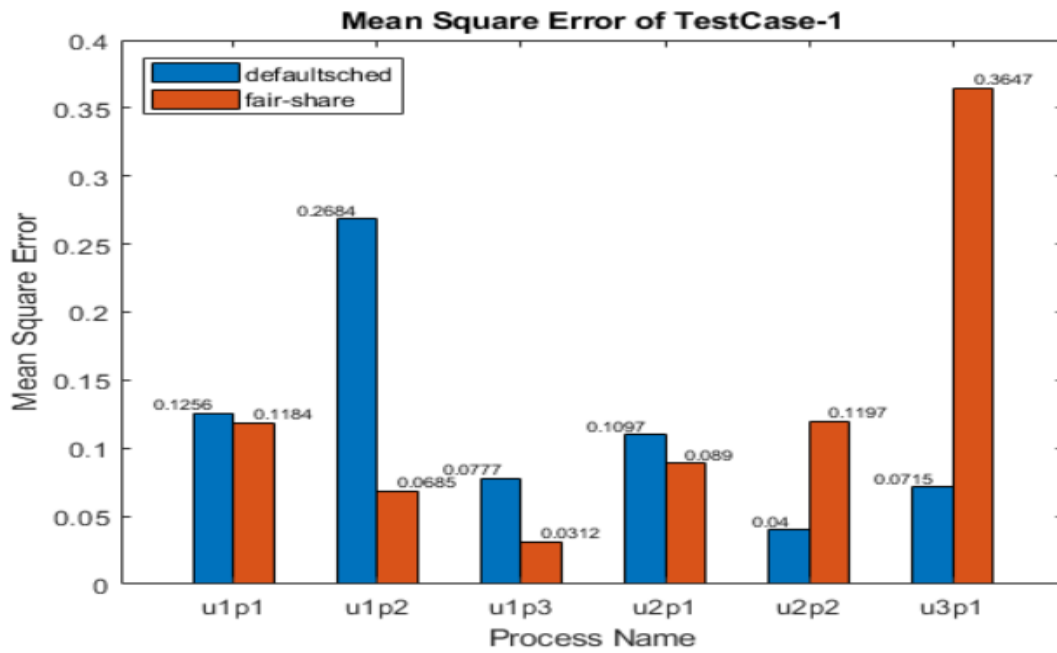### 3.3.2. Mean Square Error

3.3.2.1 TestCase-1:

Figure 3.3.2.1.1. Graph of TestCase-1(Mean Square Error)
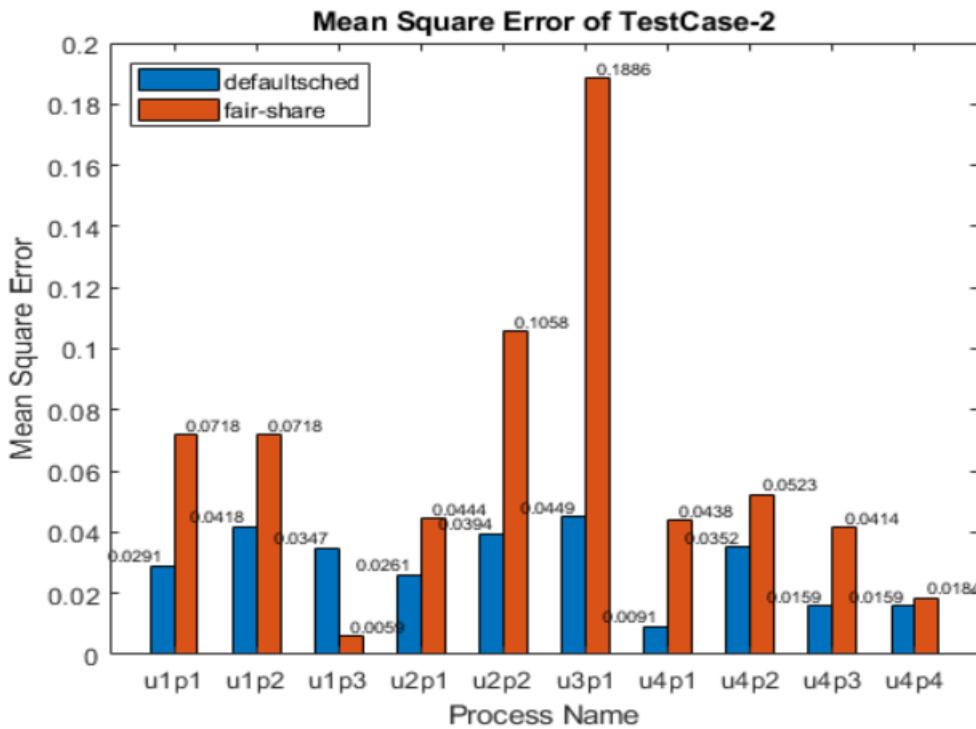
3.3.2.2 TestCase-2:

Figure 3.3.2.2.1. Graph of TestCase-2(Mean Square Error)
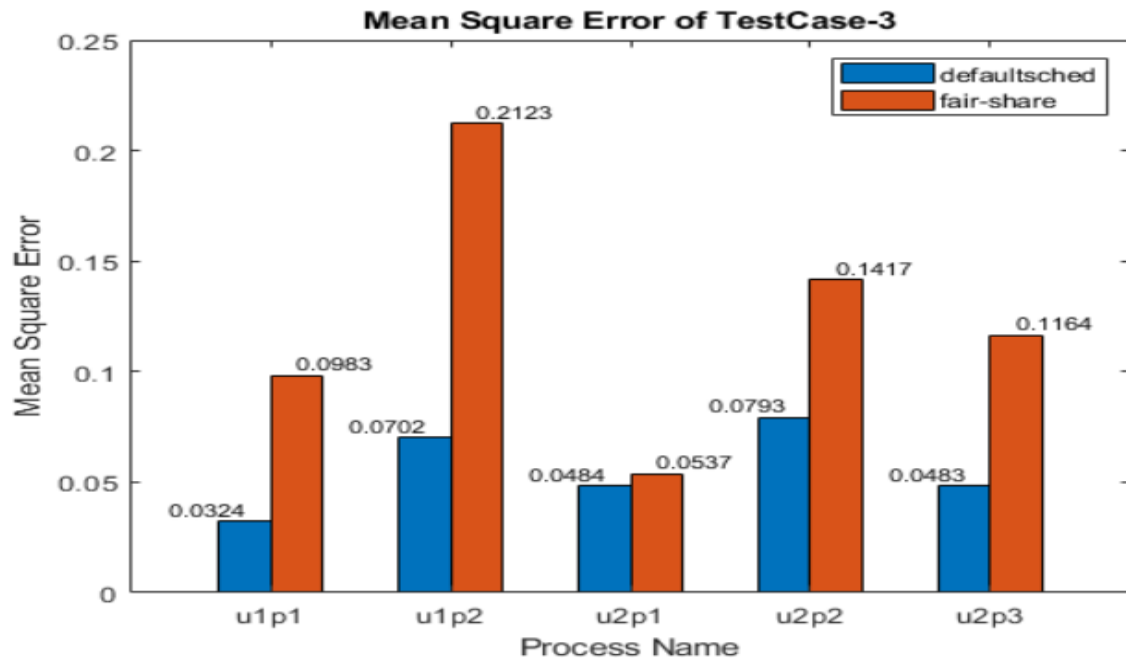
3.3.2.3 TestCase-3:

Figure 3.3.2.3.1. Graph of TestCase-3(Mean Square Error)
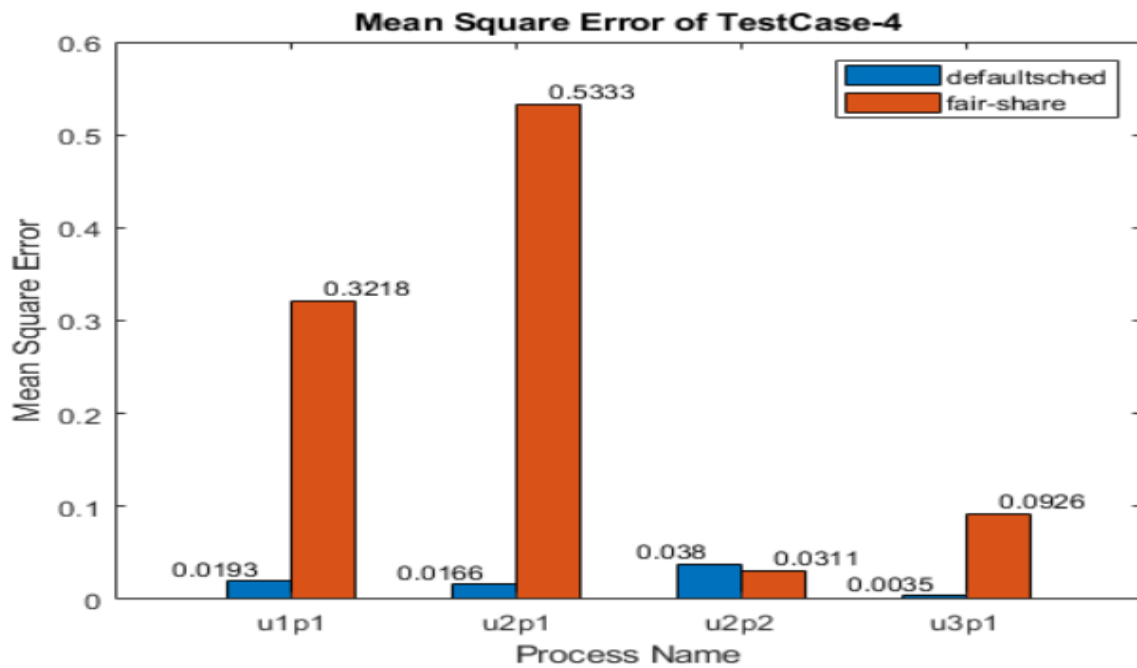
3.3.2.4 TestCase-4:

Figure 3.3.2.4.1. Graph of TestCase-4(Mean Square Error)
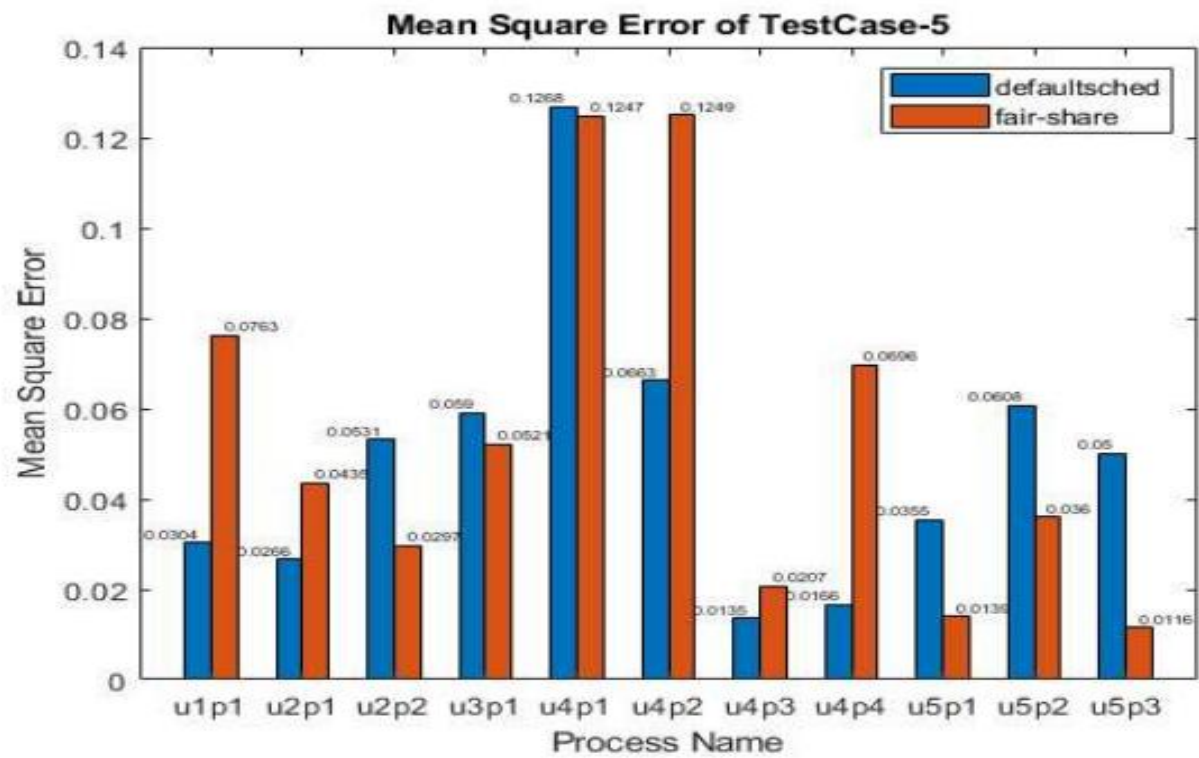
3.3.2.5 TestCase-5:

Figure 3.3.2.5.1. Graph of TestCase-5(Mean Square Error)

4.   CONCLUSION

The Linux operating system has been widely adopted due to its flexibility, open-source nature, and robust performance. However, managing system resources fairly among multiple users has been a challenge. In this report, we present the implementation of a user-based fair process divider scheduler, which aims to improve resource allocation and enhance the overall user experience in Linux systems.

The primary objective of this project is to develop and implement a user-based fair process divider scheduler that ensures equitable distribution of system resources among users, while maintaining optimal system performance and security.

- Analyze the existing Linux scheduler and identify areas for improvement.
- Design a user-based fair process divider scheduler that allocates resources fairly among users.
- Implement the scheduler in a Linux test environment.
- Evaluate the performance and resource allocation of the new scheduler compared to the existing one.
- Document the implementation process and results.

After implementing the user-based fair process divider scheduler, we observed the following improvements:

- Fair distribution of system resources: The new scheduler ensures that each user receives an equitable share of system resources, preventing any single user from monopolizing them.
- Improved system performance: By allocating resources fairly, the scheduler prevents resource contention and optimizes overall system performance.
- Enhanced user experience: Users can now manage their own scheduling priorities and tasks, allowing for a more personalized experience.
- Better resource management: System administrators can more effectively monitor and control resource usage, ensuring optimal system performance and security.

The implementation of a user-based fair process divider scheduler in Linux systems has successfully addressed the challenge of equitable resource allocation among multiple users. This new scheduler not only improves system performance and security but also enhances the user experience by allowing users to manage their own scheduling priorities and tasks.We believe that the widespread adoption of user-based fair process divider schedulers in Linux systems will significantly improve operating system performance and user experience for both individual users and enterprise

customers. By ensuring fair distribution of system resources, this scheduler paves the way for a more powerful and flexible operating system that caters to the diverse needs of its users.

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