

Operating Systems Assignment-2

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1 Question 1

case 1 When the number of frames are set to $3N/4$ ($N = 160$), each process have pages around 40 (on an average) with Global page-replacement algorithm.

PID	Slow_down
1	1.80 %
2	1.28 %
3	1.29 %
4	1.22 %

Table 1: Global page-replacement, $3N/4$

Average Slow-down is: 1.39 %

case 2 When the number of frames are set to $N/2$ ($N = 160$), each process have pages around 40 (on an average) with Local page-replacement algorithm.

PID	Slow_down
1	3.69 %
2	3.83 %
3	3.48 %
4	2.52 %

Table 2: Local page-replacement, $N/2$

Average Slow-down is: 3.32 %

PID	Slow_down
1	5.77 %
2	4.87 %
3	8.33 %
4	4.50 %

Table 3: Local page-replacement, N/4

case 3 When the number of frames are set to N/4(N = 160), each process have pages around 40 (on an average) with Local page-replacement algorithm.

Average Slow-down is: 5.89 %

case 4 When the number of frames are set to N/8(N = 160), each process have pages around 40 (on an average) with Local page-replacement algorithm.

PID	Slow_down
1	15.62 %
2	14.69 %
3	8.28 %
4	7.48 %

Table 4: Local page-replacement, N/8

Average Slow-down is: 11.58 %

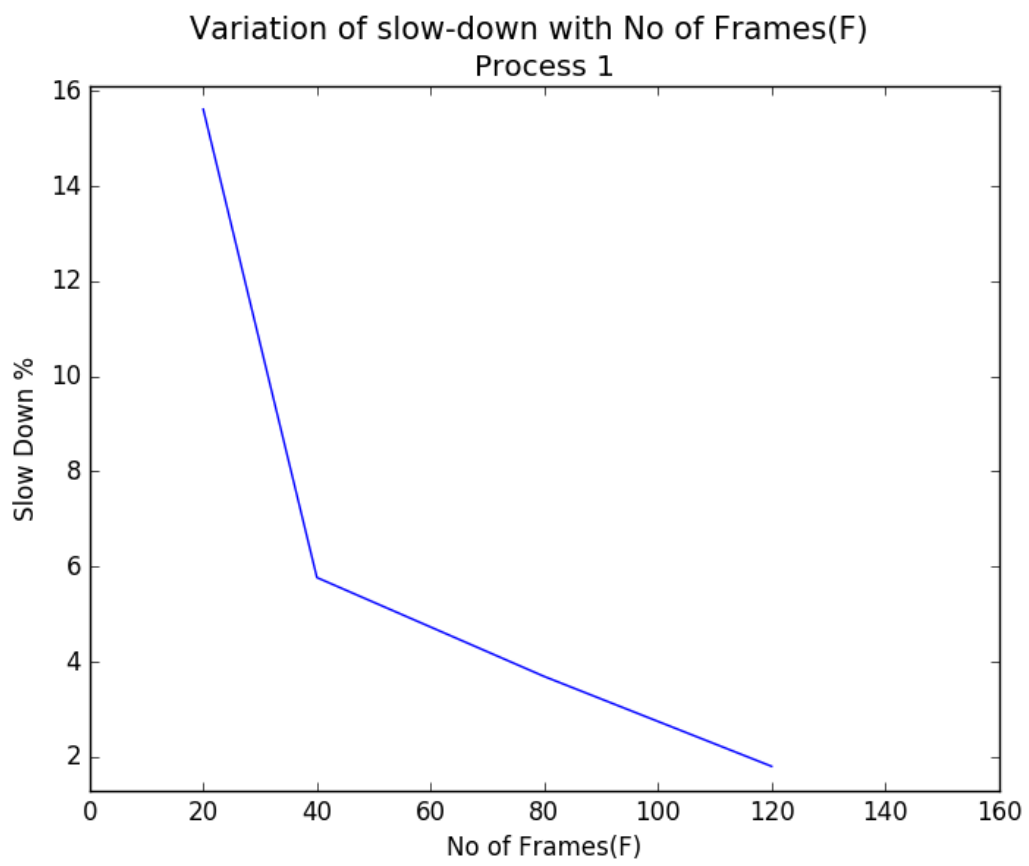


Figure 1: Slow-down vs Frames (Process 1)

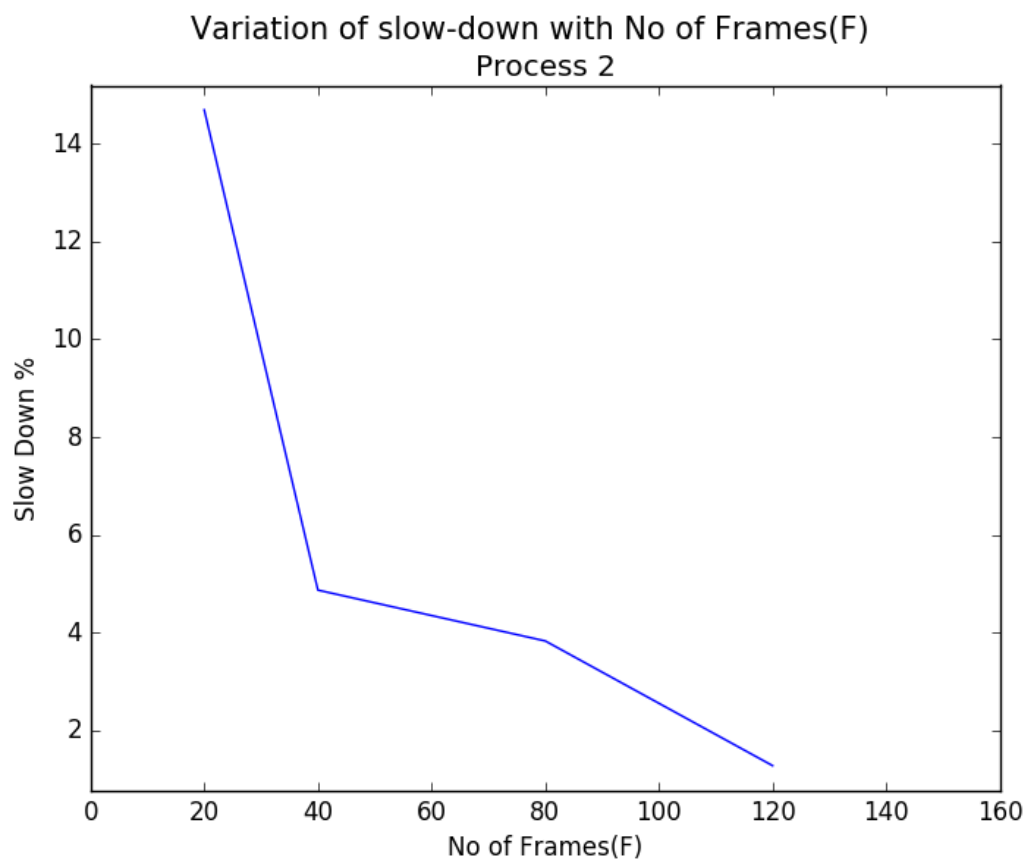


Figure 2: Slow-down vs Frames (Process 2)

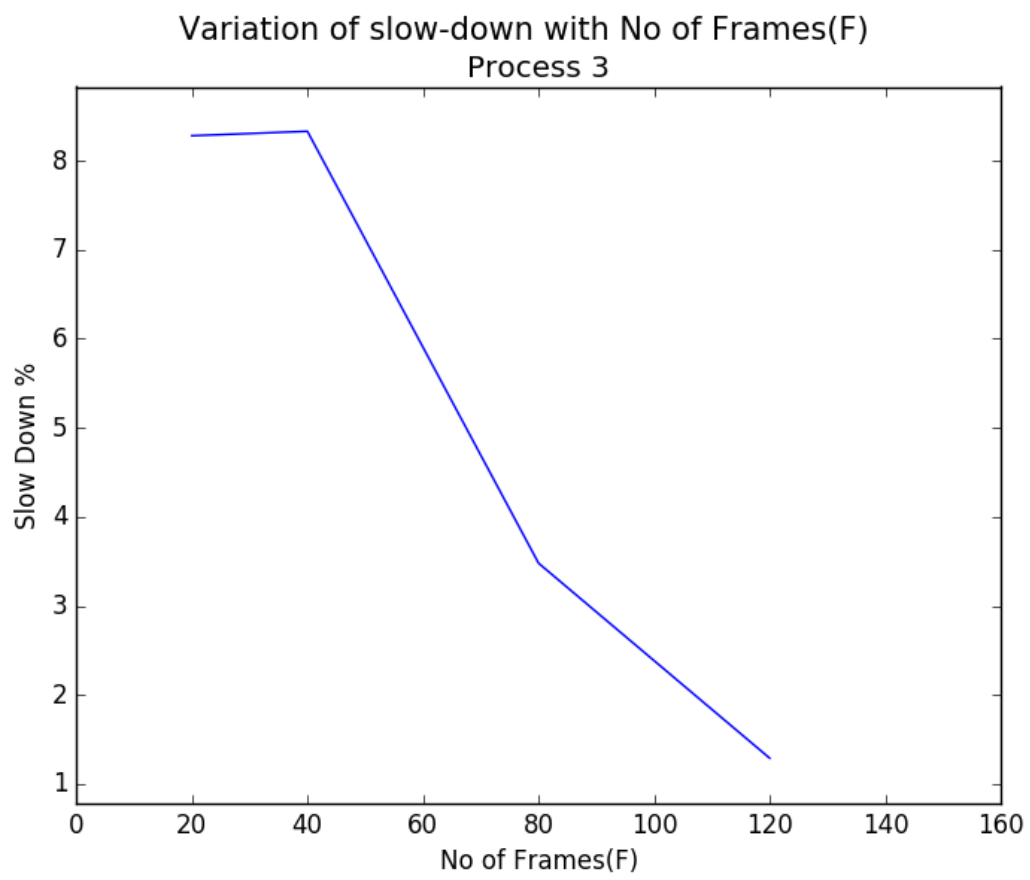


Figure 3: Slow-down vs Frames (Process 3)

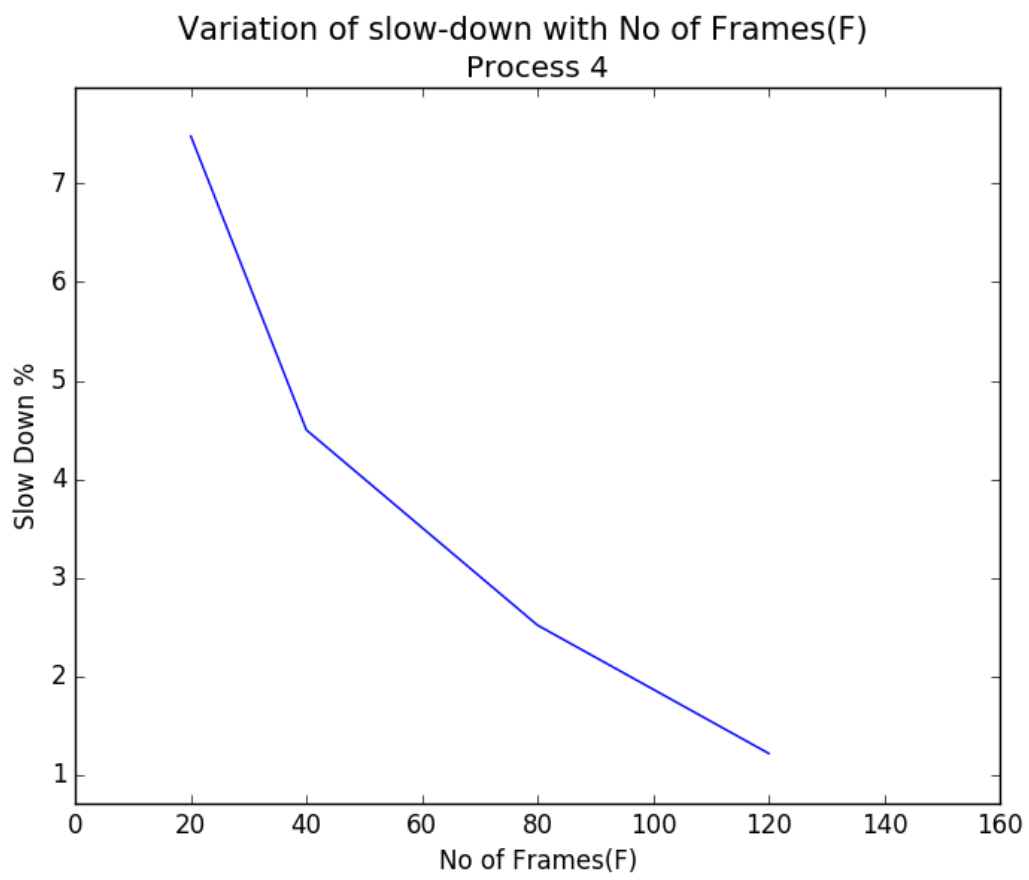


Figure 4: Slow-down vs Frames (Process 4)

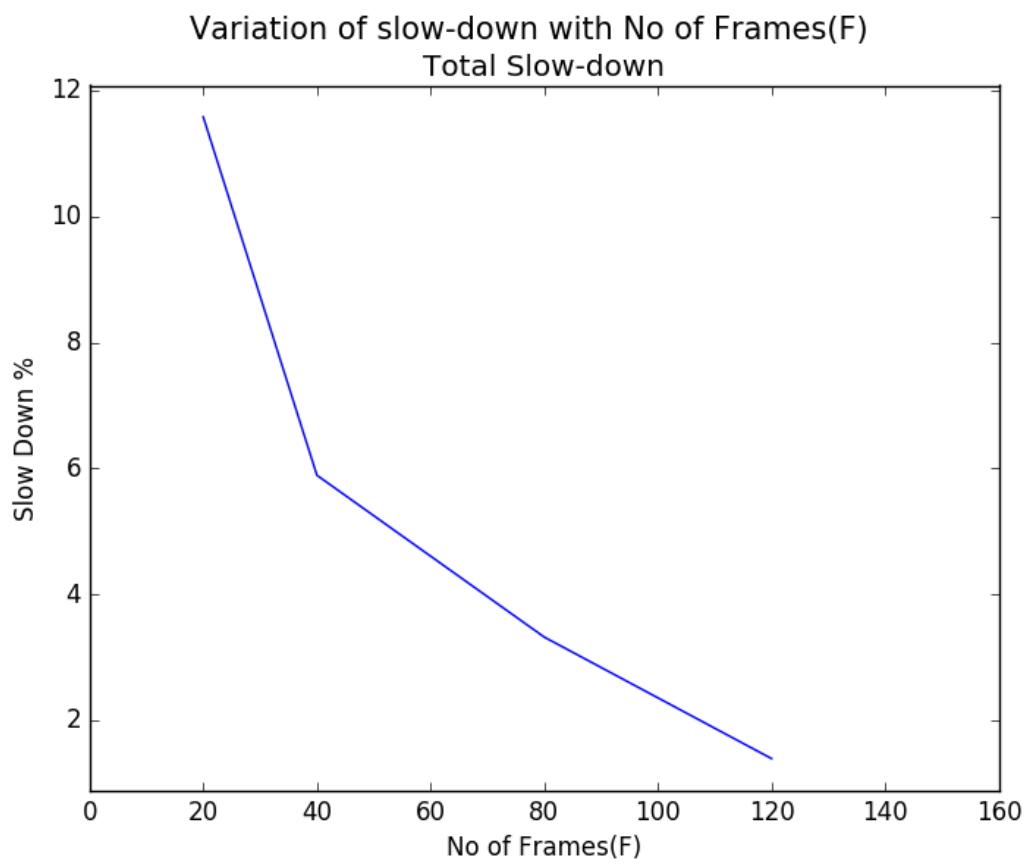


Figure 5: Slow-down vs Frames (Total)

Observations:

Slow-down for global is always less than slow-down of local page replacement algorithms.

In some graphs, which I have plotted between slow-down and no. of frames, the curve is similar to exponential decay. And one more graph has an almost linear curve with a negative slope.

I have observed that if CPU follows a local page replacement algorithm, then there will be an increase in the slow-down rate. **Conclusion:** A Low value for the number of frames and local page replacement will bring down the efficiency of the process.

case 5 (a) Global

When the number of frames are set to $3N/4$ ($N = 160$), each process have pages around 40 (on an average) with Global page-replacement algorithm. There are five processes chosen with a sigma values of 1, 2, 3, 4, 5.

Average Slow-down is: 1.83 %

PID	Slow-down
1	1.51 %
2	1.59 %
3	1.63 %
4	2.24 %
5	2.14 %

Table 5: Global page-replacement, $3N/4$

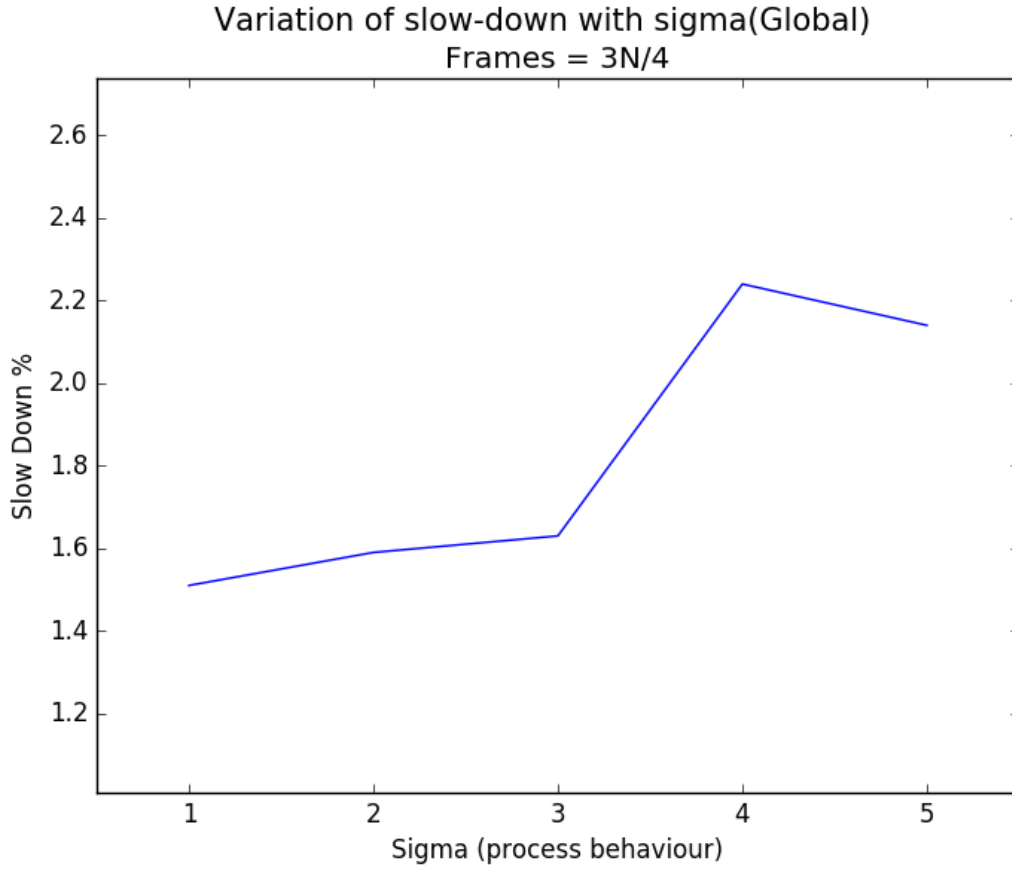


Figure 6: Slow-down vs Sigma (Global)

(b) Local

When the number of frames are set to $3N/4$ ($N = 160$), each process have pages around 40 (on an average) with Local page-replacement algorithm. There are five processes chosen with a sigma values of 1, 2, 3, 4, 5. Average Slow-down is: 6.07 %

PID	Slow-down
1	5.40 %
2	5.67 %
3	5.64 %
4	6.81 %
5	6.82 %

Table 6: Local page-replacement, $3N/4$

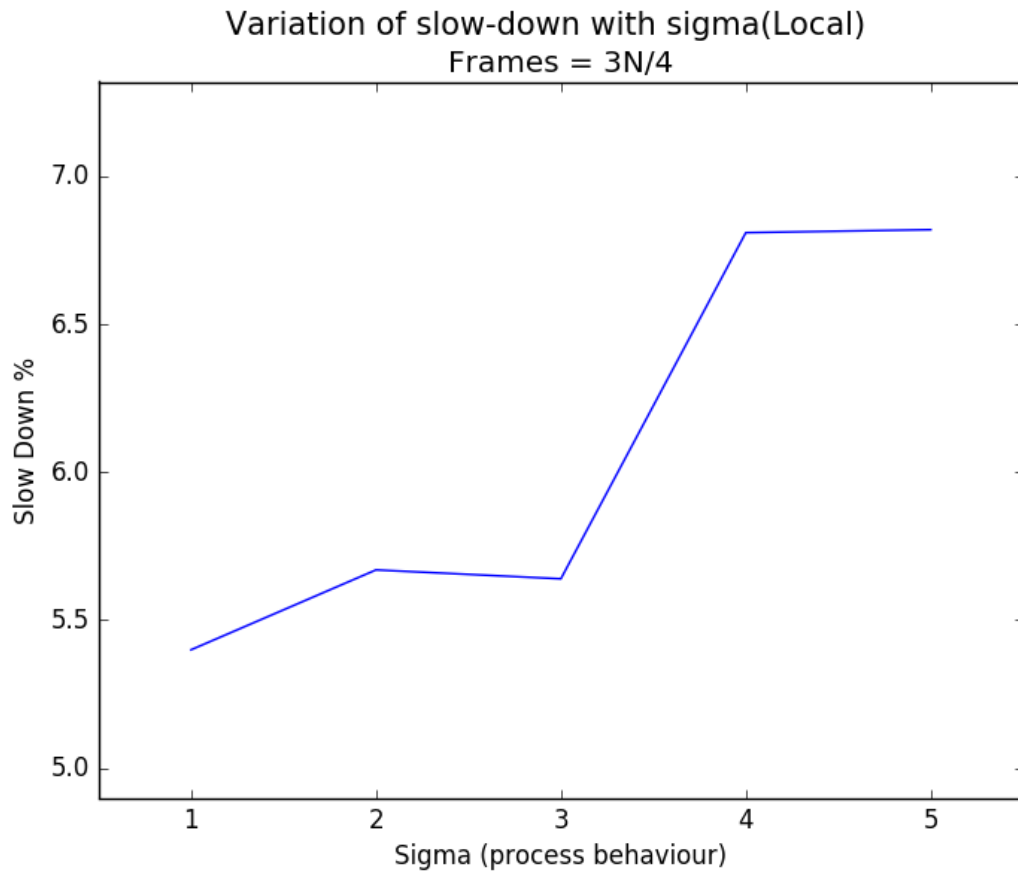


Figure 7: Slow-down vs Sigma (Local)

Observations: Sigma value is directly proportional to the slow-down rate. As sigma becomes larger and larger, the range of address references is widely spread, which leads to an increase in the number of page replacements and slow-down rate.

2 Question 2

Given: Block Size: 1KB, File Pointer: 4B. Three files each of size 100B, 10KB, 10MB.

File System:

Contiguous:

As the memory is allocated in contiguous blocks, we need only two access to read the first and last bytes of the file. One read from a file descriptor to File pointer, and the other from file pointer to the starting block of the file where the data is stored.

Block pointers in contiguous disk blocks:

In this case, the file pointers which store the addresses of the file blocks are contiguous, so if there are n file pointers for a file, then we need to read n pointers to read the file.

In the given question, we are asked to read the first and last bytes of the file, so we need to get the first and the last block addresses which are assigned to the file. So, we need two read accesses one from file descriptor to file pointer other from file pointer to the first block. For the last byte, continue the above process till getting the first file pointer, then add the file size to get the last file pointer from their to the last block, which is the last disk read. In total, we need 4 read accesses to read the first and last byte.

UNIX inode hybrid system:

In this system, the file descriptor contains 11 block addresses in which the first eight blocks are direct accesses, and the next two blocks are single index block; the last one is a double index block. The amount which is accessible by the first eight blocks is $8 * \text{Blocksize}(1\text{KB}) = 8\text{KB}$. Next two bits stores the addresses of another 512 file pointer which has holds $512 * \text{Blocksize}(1\text{KB}) = 512\text{KB}$ amount of data Finally, the last bit, which is double index block, stores the addresses of 256 single index blocks, which in turn stores 256 file pointers, which holds $256 * 256 * \text{Blocksize}(1\text{KB}) = 64\text{MB}$.

100B File: This file is pointed by the first block of the file descriptor. So the number of disk reads is required to read first, and the last byte is 1.

10KB File: The first Block has the information about the first byte, and the 9th block has info about the next 256 blocks, which is 1 level indexing, and one of the 256 blocks contains the last byte, So the number of disk reads are 2.

10MB File: The first Block contains the information about the first byte,

and the 11th block leads to another 256 single index blocks and each of which leads to another 256 file pointer, which is 2 level indexing, So the number of disk reads are 3.

Inverted FAT:

In this system, a certain number of blocks are allocated for storing file pointers in the disk, and the file descriptor is stored in memory. In our case, the largest file which we are storing is 10MB(10240 KB), which needs 10240 file pointers, which can need to be stored in 40 blocks. So the first 40 disk blocks contain all the next-block pointers for all the blocks on the disk.

100B: The number of blocks occupied by the file is 1, so we need only two disk reads one from file descriptor to first block and the other from file pointer to data block of the file. So, to get the first and last byte of the file.

10KB: A single block can store up to 256 file pointers. But the file needs only ten file pointers, so all the file pointers which are needed for the file are present in the first block Totally we need two read accesses for reading each first as well as last byte.

10MB: To store this big file, we need a total of 10240 file pointers, which requires 40 disk blocks of memory. For reading first byte, we need 2 read access one from file descriptor to file pointer and other from file pointer to first disk block of the file. For reading the last byte, we need 41(1+39+1) read access one from file descriptor to file pointer, next 39 reads from first disk block, which contains the file pointer to the last one and the last one from last file pointer in the block to a data disk block.

3 Question 3

Read of a device is broadly divided into 4 levels. They are:

1. Process Level
2. Logical file system
3. Physical file system
4. I/O system

Process Level Here, the read function takes the file identifier (like file-pointer), buffer, and length of the buffer and produces a file descriptor.

Logical file system File identifier is stored in the process descriptor. The file system uses the file identifier to check the existence of the file. then it picks the logical byte number which is in the file (this is kept in the open file structure). Then after that it calculates the logical block number which are required and reads them one by one.

Physical file system Now the logical block number which we obtained from the logical file system is converted to a device number and physical block number on that device. This translation uses the information on the file block locations found in the file descriptor.

I/O System Now the task is to get the required disk block into a system disk buffer. The system disk buffers are actually a disk cache. First, the module checks to see if the required disk block is already in the cache. If it is, then the address of the disk buffer is passed immediately, and no disk I/O is done. If it is not, then a disk cache buffer is allocated to this block, and the device driver is called to transfer the block from the disk to memory.

Major & Minor Numbers Major number is used to identify the type of device driver and minor number is used to identify the specific device for the corresponding driver. In Linux System all the device drivers information is stored in a directory named /dev. As linux treats every thing as files, even these device drivers are also treated as files. There are two types of devices in linux, they are character and block devices the command 'ls -l /dev' gives a long listing of all the device drivers in the directory. Each line displays some details about a device driver, the first character of each line specifies whether the device is character or block device.

```
anurag@anurag-HP-Pavilion-Laptop-15-cc1xx: ~/courses/os/assign2
crw-r----- 1 root kmem      1,   1 Nov 11 22:42 mem
crw-r----- 1 root root     10,  56 Nov 11 22:42 memory_bandwidth
drwxrwxrwt   2 root root     40,  40 Nov 11 22:42 /tmp
drwxr-xr-x   2 root root     60,  60 Nov 11 22:42 net
crw-r----- 1 root root     10,  58 Nov 11 22:42 network_latency
crw-r----- 1 root root     10,  57 Nov 11 22:42 network_throughput
crw-rw-rw-   1 root root      1,   3 Nov 11 22:42 null
crw-r----- 1 root kmem    10, 144 Nov 11 22:43 nvram
crw-r----- 1 root kmem      1,   4 Nov 11 22:42 port
crw-r----- 1 root root    108,   0 Nov 11 22:42 ppp
crw-r----- 1 root root     10,   1 Nov 11 22:42 psaux
crw-rw-rw-   1 root tty       5,   2 Nov 12 07:22 ptmx
drwxr-xr-x   2 root root      0,   0 Nov 11 22:42 pts
crw-rw-rw-   1 root root      1,   8 Nov 11 22:42 random
crw-rw-rw-   1 root netdev   10,  62 Nov 11 22:42 rfkill
lrwxrwxrwx   1 root root      4,   4 Nov 11 22:42 rtc -> rtc0
crw-r----- 1 root root    251,   0 Nov 11 22:42 rtc0
brw-rw-rw-   1 root disk      8,   0 Nov 11 22:42 sda
brw-rw-rw-   1 root disk      8,   1 Nov 11 22:42 sda1
brw-rw-rw-   1 root disk      8,  10 Nov 12 04:25 sda10
brw-rw-rw-   1 root disk      8,  11 Nov 11 22:42 sda11
brw-rw-rw-   1 root disk      8,  12 Nov 11 22:42 sda12
brw-rw-rw-   1 root disk      8,   2 Nov 11 22:42 sda2
brw-rw-rw-   1 root disk      8,   3 Nov 11 22:42 sda3
brw-rw-rw-   1 root disk      8,   4 Nov 11 22:42 sda4
brw-rw-rw-   1 root disk      8,   5 Nov 11 22:42 sda5
brw-rw-rw-   1 root disk      8,   6 Nov 11 22:42 sda6
brw-rw-rw-   1 root disk      8,   7 Nov 11 22:42 sda7
brw-rw-rw-   1 root disk      8,   8 Nov 11 22:42 sda8
brw-rw-rw-   1 root disk      8,   9 Nov 11 22:42 sda9
crw-rw-rw-   1 root disk     21,   0 Nov 11 22:42 sg0
drwxrwxrwt   2 root root    400,  40 Nov 12 07:06 /var
crw-r----- 1 root root     10, 231 Nov 11 22:42 snapshot
drwxr-xr-x   3 root root    260, 260 Nov 11 22:42 snd
crw-rw-rw-   1 root root     15,  15 Nov 11 22:42 stderr -> /proc/self/fd/2
crw-rw-rw-   1 root root     15,  15 Nov 11 22:42 stdin -> /proc/self/fd/0
crw-rw-rw-   1 root root     15,  15 Nov 11 22:42 stdout -> /proc/self/fd/1
crw-r----- 1 root root     10, 224 Nov 11 22:42 tpm0
crw-rw-rw-   1 root tty       5,   0 Nov 12 04:59 tty
```

Figure 8: `ls -l /dev`

Generally minor number is used only by the driver specified by the major number, other parts of kernel just pass them to the device driver. The range of minor number is $[0, 255]$ inclusive. `cat /proc/devices` shows all the registered devices in the system along with their major numbers.

Raw Data:
Images for the Case when No. of Frames(F) is $3N/4$

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	32	0	62373
2	28	0	68240
3	26	0	66534
4	23	0	61416
Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	62373 ms	63941 ms	2.513908 %
2	68240 ms	69612 ms	2.010551 %
3	66534 ms	67808 ms	1.914810 %
4	61416 ms	62543 ms	1.835027 %
Total Slow down 2.07 %			

Figure 9: Case 1

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	31	0	127336
2	27	0	142280
3	22	0	138723
4	24	0	128052
Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	127336 ms	128855 ms	1.192907 %
2	142280 ms	143603 ms	0.929857 %
3	138723 ms	139801 ms	0.777088 %
4	128052 ms	129228 ms	0.918377 %
Total Slow down 0.95 %			

Figure 10: Case 2

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	33	0	95924
2	28	0	108640
3	32	0	105924
4	21	0	97776
Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	95924 ms	97541 ms	1.685710 %
2	108640 ms	110012 ms	1.262887 %
3	105924 ms	107492 ms	1.480307 %
4	97776 ms	98805 ms	1.052405 %
Total Slow down 1.37 %			

Figure 11: Case 3

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	35	0	94725
2	24	0	105400
3	28	0	102765
4	23	0	94860
Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	94725 ms	96440 ms	1.810504 %
2	105400 ms	106576 ms	1.115750 %
3	102765 ms	104137 ms	1.335085 %
4	94860 ms	95987 ms	1.188067 %
Total Slow down 1.36 %			

Figure 12: Case 4

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	31	0	143799
2	28	0	161720
3	23	0	157677
4	24	0	145548

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	143799 ms	145318 ms	1.056336 %
2	161720 ms	163092 ms	0.848380 %
3	157677 ms	158804 ms	0.714752 %
4	145548 ms	146724 ms	0.807981 %

Total Slow down 0.85 %

Figure 13: Case 5

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	35	0	120921
2	23	0	137240
3	24	0	133809
4	22	0	123516

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	120921 ms	122636 ms	1.418281 %
2	137240 ms	138367 ms	0.821189 %
3	133809 ms	134985 ms	0.878865 %
4	123516 ms	124594 ms	0.872761 %

Total Slow down 0.99 %

Figure 14: Case 6

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	36	0	47720
2	27	0	51600
3	26	0	50310
4	23	0	46440

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	47720 ms	49484 ms	3.696563 %
2	51600 ms	52923 ms	2.563953 %
3	50310 ms	51584 ms	2.532300 %
4	46440 ms	47567 ms	2.426787 %

Total Slow down 2.80 %			
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Figure 15: Case 7

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	32	0	146058
2	25	0	162400
3	24	0	158340
4	21	0	146160

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	146058 ms	147626 ms	1.073546 %
2	162400 ms	163625 ms	0.754310 %
3	158340 ms	159516 ms	0.742706 %
4	146160 ms	147189 ms	0.704023 %
Total Slow down 0.82 %			

Figure 16: Case 8

Images for the Case when No. of Frames(F) is N/2

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	52	29	71224
2	44	20	77720
3	45	25	69948
4	35	22	79663

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	71224 ms	75222 ms	5.613276 %
2	77720 ms	80876 ms	4.060731 %
3	69948 ms	73403 ms	4.939384 %
4	79663 ms	82478 ms	3.533635 %

Total Slow down 4.50 %

Figure 17: Case 1

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	39	15	99895
2	52	33	108000
3	50	28	97200
4	29	14	110700

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	99895 ms	102556 ms	2.663797 %
2	108000 ms	112198 ms	3.887037 %
3	97200 ms	101050 ms	3.960905 %
4	110700 ms	112821 ms	1.915989 %

Total Slow down 3.09 %

Figure 18: Case 2

Page-Fault table				
Pid	Page-fault	Page-replacement	Page-references	
1	38	16	70093	
2	42	20	75280	
3	39	15	67752	
4	30	18	77162	

Final Slow-down table				
PID	Expected time	Observed time	% Slow down	
1	70093 ms	72755 ms	3.797811 %	
2	75280 ms	78338 ms	4.062168 %	
3	67752 ms	70413 ms	3.927559 %	
4	77162 ms	79532 ms	3.071460 %	

Total Slow down 3.70 %				
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Figure 19: Case 3

Page-Fault table				
Pid	Page-fault	Page-replacement	Page-references	
1	46	22	79251	
2	50	29	86800	
3	35	15	78120	
4	32	17	88970	

Final Slow-down table				
PID	Expected time	Observed time	% Slow down	
1	79251 ms	82605 ms	4.232123 %	
2	86800 ms	90700 ms	4.493088 %	
3	78120 ms	80585 ms	3.155402 %	
4	88970 ms	91388 ms	2.717770 %	
Total Slow down 3.64 %				

Figure 20: Case 4

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	41	21	140320
2	53	30	153800
3	38	17	138420
4	31	15	157645

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	140320 ms	143379 ms	2.180017 %
2	153800 ms	157897 ms	2.663849 %
3	138420 ms	141132 ms	1.959254 %
4	157645 ms	159914 ms	1.439310 %

Total Slow down 2.06 %

Figure 21: Case 5

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	47	26	97504
2	41	16	105680
3	40	18	95112
4	33	21	108322

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	97504 ms	101107 ms	3.695233 %
2	105680 ms	108489 ms	2.658024 %
3	95112 ms	97972 ms	3.006981 %
4	108322 ms	110989 ms	2.462104 %

Total Slow down 2.94 %

Figure 22: Case 6

Images for the Case when No. of Frames(F) is N/4

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	44	37	82534
2	32	22	68256
3	70	56	81528
4	33	24	75840
Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	82534 ms	86540 ms	4.853757 %
2	68256 ms	70924 ms	3.908814 %
3	81528 ms	87758 ms	7.641546 %
4	75840 ms	78657 ms	3.714399 %
Total Slow down 5.10 %			

Figure 23: Case 1

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	41	35	49663
2	29	18	41616
3	67	56	49708
4	32	20	46240
Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	49663 ms	53422 ms	7.569015 %
2	41616 ms	43937 ms	5.577182 %
3	49708 ms	55791 ms	12.237467 %
4	46240 ms	48808 ms	5.553633 %
Total Slow down 7.87 %			

Figure 24: Case 2

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	39	31	46219
2	30	21	37944
3	60	44	71726
4	36	29	79880

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	46219 ms	49680 ms	7.488262 %
2	37944 ms	40464 ms	6.641366 %
3	71726 ms	76866 ms	7.166160 %
4	79880 ms	83094 ms	4.023535 %
Total Slow down 6.08 %			

Figure 25: Case 3

Page-Fault table				
Pid	Page-fault	Page-replacement	Page-references	
1	38	30	85142	
2	36	29	69588	
3	67	53	83119	
4	35	24	77320	

Final Slow-down table				
PID	Expected time	Observed time	% Slow down	
1	85142 ms	88504 ms	3.948697 %	
2	69588 ms	72802 ms	4.618612 %	
3	83119 ms	89052 ms	7.137959 %	
4	77320 ms	80235 ms	3.770047 %	

Total Slow down 4.89 %				
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Figure 26: Case 4

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	45	39	75042
2	27	17	61416
3	62	48	73358
4	40	30	68240

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	75042 ms	79197 ms	5.536899 %
2	61416 ms	63589 ms	3.538166 %
3	73358 ms	78796 ms	7.412961 %
4	68240 ms	71700 ms	5.070340 %

Total Slow down 5.48 %			
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Figure 27: Case 5

Page-Fault table				
Pid	Page-fault	Page-replacement	Page-references	
1	44	35	73743	
2	35	27	61200	
3	69	55	73100	
4	38	29	68000	

Final Slow-down table				
PID	Expected time	Observed time	% Slow down	
1	73743 ms	77649 ms	5.296774 %	
2	61200 ms	64265 ms	5.008170 %	
3	73100 ms	79231 ms	8.387141 %	
4	68000 ms	71312 ms	4.870588 %	

Total Slow down 5.95 %				
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Figure 28: Case 6

Images for the Case when No. of Frames(F) is N/8

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	91	85	75021
2	99	94	77880
3	54	50	77880
4	40	35	70800
Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	75021 ms	83730 ms	11.608750 %
2	77880 ms	87431 ms	12.263739 %
3	77880 ms	83026 ms	6.607601 %
4	70800 ms	74510 ms	5.240113 %
Total Slow down 8.99 %			

Figure 29: Case 1

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	95	90	88211
2	91	84	92268
3	54	51	92268
4	38	33	83880
Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	88211 ms	97366 ms	10.378524 %
2	92268 ms	100927 ms	9.384619 %
3	92268 ms	97464 ms	5.631422 %
4	83880 ms	87392 ms	4.186934 %
Total Slow down 7.44 %			

Figure 30: Case 2

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	98	95	44882
2	93	86	46508
3	52	47	46508
4	41	36	42280
Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	44882 ms	54434 ms	21.282474 %
2	46508 ms	55365 ms	19.044035 %
3	46508 ms	51406 ms	10.531521 %
4	42280 ms	46089 ms	9.008988 %
Total Slow down 15.05 %			

Figure 31: Case 3

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	92	88	62246
2	96	91	65648
3	44	38	65648
4	42	37	59680
Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	62246 ms	71154 ms	14.310960 %
2	65648 ms	74902 ms	14.096393 %
3	65648 ms	69704 ms	6.178406 %
4	59680 ms	63588 ms	6.548257 %
Total Slow down 10.32 %			

Figure 32: Case 4

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	82	74	48497
2	90	85	50644
3	56	53	50644
4	47	43	46040

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	48497 ms	56215 ms	15.914386 %
2	50644 ms	59304 ms	17.099755 %
3	50644 ms	56038 ms	10.650817 %
4	46040 ms	50493 ms	9.672024 %

Total Slow down	13.39 %
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Figure 33: Case 5

Page-Fault table				
Pid	Page-fault	Page-replacement	Page-references	
1	99	96	47684	
2	85	76	48884	
3	52	48	48884	
4	48	44	44440	
Final Slow-down table				
PID	Expected time	Observed time	% Slow down	
1	47684 ms	57335 ms	20.239493 %	
2	48884 ms	56849 ms	16.293675 %	
3	48884 ms	53832 ms	10.121921 %	
4	44440 ms	48992 ms	10.243024 %	
Total Slow down 14.28 %				

Figure 34: Case 6

Images for comparison between slow-down and sigma (Global)

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	26	5	79344
2	23	3	77774
3	25	7	79876
4	37	7	81978
5	36	5	81978

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	79344 ms	80868 ms	1.920750 %
2	77774 ms	79051 ms	1.641937 %
3	79876 ms	81451 ms	1.971806 %
4	81978 ms	84141 ms	2.638513 %
5	81978 ms	83992 ms	2.456757 %

Total Slow down 2.13 %

Figure 35: Case 1

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	26	3	108904
2	29	8	109716
3	23	5	107040
4	33	5	104364
5	38	8	115068

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	108904 ms	110328 ms	1.307574 %
2	109716 ms	111537 ms	1.659740 %
3	107040 ms	108417 ms	1.286435 %
4	104364 ms	106231 ms	1.788931 %
5	115068 ms	117330 ms	1.965794 %

Total Slow down 1.61 %

Figure 36: Case 2

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	24	5	102347
2	31	9	124399
3	29	11	121506
4	40	13	112827
5	40	6	118613

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	102347 ms	103773 ms	1.393299 %
2	124399 ms	126368 ms	1.582810 %
3	121506 ms	123477 ms	1.622142 %
4	112827 ms	115437 ms	2.313276 %
5	118613 ms	120873 ms	1.905356 %

Total Slow down 1.77 %

Figure 37: Case 3

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	23	5	115026
2	28	7	141372
3	30	6	134946
4	43	13	138159
5	39	12	134946

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	115026 ms	116403 ms	1.197121 %
2	141372 ms	143094 ms	1.218063 %
3	134946 ms	136716 ms	1.311636 %
4	138159 ms	140916 ms	1.995527 %
5	134946 ms	137457 ms	1.860744 %

Total Slow down 1.53 %

Figure 38: Case 4

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	25	5	68086
2	28	8	79120
3	30	9	75440
4	42	12	77280
5	39	10	75440

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	68086 ms	69561 ms	2.166378 %
2	79120 ms	80892 ms	2.239636 %
3	75440 ms	77360 ms	2.545069 %
4	77280 ms	79938 ms	3.439441 %
5	75440 ms	77851 ms	3.195917 %

Total Slow down 2.73 %

Figure 39: Case 5

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	28	9	164271
2	31	10	165102
3	25	6	149378
4	35	5	153309
5	38	7	149378

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	164271 ms	166093 ms	1.109143 %
2	165102 ms	167121 ms	1.222880 %
3	149378 ms	150903 ms	1.020900 %
4	153309 ms	155274 ms	1.281725 %
5	149378 ms	151590 ms	1.480807 %

Total Slow down 1.22 %

Figure 40: Case 6

Images for comparison between slow-down and sigma (Local)

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	25	7	51364
2	29	6	47397
3	27	11	48678
4	44	15	49959
5	40	6	49959

Final Slow-down table				
PID	Expected time	Observed time	% Slow down	
1	51364 ms	52939 ms	3.066350	%
2	47397 ms	49118 ms	3.631031	%
3	48678 ms	50551 ms	3.847734	%
4	49959 ms	52865 ms	5.816770	%
5	49959 ms	52219 ms	4.523709	%

Total Slow down 4.18 %

Figure 41: Case 1

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	31	15	30783
2	31	13	27593
3	23	1	26920
4	35	2	26247
5	39	8	28939

Final Slow-down table				
PID	Expected time	Observed time	% Slow down	
1	30783 ms	33052 ms	7.370951	%
2	27593 ms	29762 ms	7.860689	%
3	26920 ms	28097 ms	4.372214	%
4	26247 ms	28062 ms	6.915076	%
5	28939 ms	31250 ms	7.985763	%

Total Slow down 6.93 %

Figure 42: Case 2

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	32	15	40280
2	36	16	46053
3	34	12	44982
4	36	5	41769
5	42	12	43911
Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	40280 ms	42598 ms	5.754717 %
2	46053 ms	48617 ms	5.567498 %
3	44982 ms	47248 ms	5.037571 %
4	41769 ms	43783 ms	4.821758 %
5	43911 ms	46569 ms	6.053153 %
Total Slow down 5.45 %			

Figure 43: Case 3

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	28	9	40833
2	30	13	47388
3	28	9	45234
4	37	5	46311
5	41	8	45234
Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	40833 ms	42655 ms	4.462077 %
2	47388 ms	49508 ms	4.473706 %
3	45234 ms	47056 ms	4.027944 %
4	46311 ms	48374 ms	4.454665 %
5	45234 ms	47643 ms	5.325640 %
Total Slow down 4.55 %			

Figure 44: Case 4

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	26	4	20960
2	28	8	24940
3	33	15	23780
4	45	18	24360
5	38	5	23780

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	20960 ms	22434 ms	7.032443 %
2	24940 ms	26712 ms	7.105052 %
3	23780 ms	26147 ms	9.953743 %
4	24360 ms	27465 ms	12.746305 %
5	23780 ms	25892 ms	8.881413 %

Total Slow down 9.19 %			
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Figure 45: Case 5

Page-Fault table			
Pid	Page-fault	Page-replacement	Page-references
1	28	7	35899
2	29	7	32844
3	29	11	29716
4	36	2	30498
5	37	12	29716

Final Slow-down table			
PID	Expected time	Observed time	% Slow down
1	35899 ms	37621 ms	4.796791 %
2	32844 ms	34615 ms	5.392157 %
3	29716 ms	31687 ms	6.632790 %
4	30498 ms	32362 ms	6.111876 %
5	29716 ms	32129 ms	8.120205 %
Total Slow down 6.14 %			

Figure 46: Case 6