EEL6935: Autonomic Computing Fall 2011
Homework 2
Monitoring and Controlling Xen VMs

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Contents

1 Introduction

The code used to run all the experiments and make the graphs is listed in Appendix A. One program "hw2.py" runs the experiments and dumps the result as a python pickle string—a serialized representation of a python dictionary. The other program "hw2_graph.py" loads the pickle string and graphs the results of the experiments. The following sections will give analysis for each section along with a graph of the CPU usage and amount of Free Memory in each experiment. The output of the program will also be given as a listing at the end of each section.

2 Experiment #1

In this experiment, no workload was introduced. The virtual machine was just monitored in an idle state for five minutes, every 10 seconds. It was found that
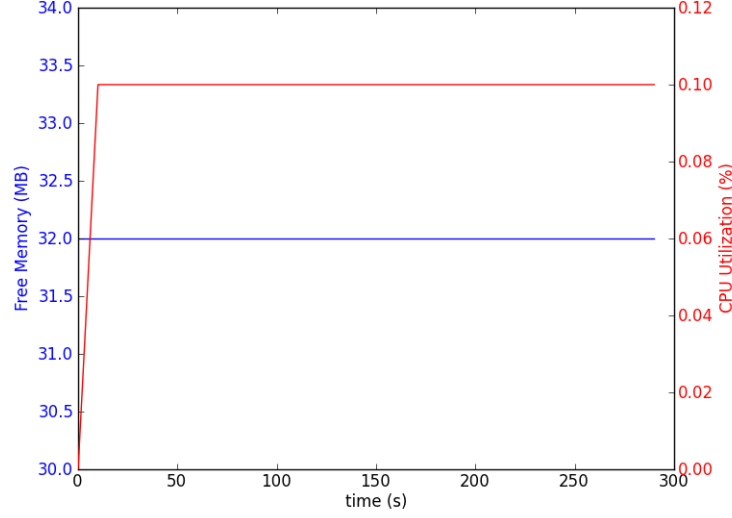
Figure 1: Results of Experiment #1 over 5 minutes

using the command xentop in a batch mode was sufficient to gather CPU usage (%) but not the free memory. Therefore, vmstat was run on the VM to get the current memory. Figure 1 shows the CPU % very low and constant around 0.1%. The free memory is also constant at around 32 MB. The output of the experiment is given in Listing 1.

Listing 1: Listing of output of Experiment #1

```
3.77029299736      CPU%:   0.1         MEM%:   32
13.7501699924      CPU%:   0.1         MEM%:   32
23.7845978737      CPU%:   0.1         MEM%:   32
33.7891039848      CPU%:   0.1         MEM%:   32
43.80001688        CPU%:   0.1         MEM%:   32
53.7508938313      CPU%:   0.1         MEM%:   32
63.8369739056      CPU%:   0.1         MEM%:   32
73.8212580681      CPU%:   0.1         MEM%:   32
83.9238488674      CPU%:   0.1         MEM%:   32
93.9054298401      CPU%:   0.1         MEM%:   32
103.777351856      CPU%:   0.1         MEM%:   32
113.948318958      CPU%:   0.1         MEM%:   32
123.823082924      CPU%:   0.1         MEM%:   32
133.748471975      CPU%:   0.1         MEM%:   32
143.781023026      CPU%:   0.1         MEM%:   32
153.990442038      CPU%:   0.1         MEM%:   32
```

2

```
164.238781929    CPU%:   0.1      MEM%:   32
174.12400794     CPU%:   0.1      MEM%:   32
184.061975002    CPU%:   0.1      MEM%:   32
193.783978939    CPU%:   0.1      MEM%:   32
203.96567297     CPU%:   0.1      MEM%:   32
213.961178064    CPU%:   0.1      MEM%:   32
223.973019838    CPU%:   0.1      MEM%:   32
234.103590965    CPU%:   0.1      MEM%:   32
243.752620935    CPU%:   0.1      MEM%:   32
253.78975606     CPU%:   0.1      MEM%:   32
264.018770933    CPU%:   0.1      MEM%:   32
274.031414986    CPU%:   0.1      MEM%:   32
283.785341978    CPU%:   0.1      MEM%:   32
293.781864882    CPU%:   0.1      MEM%:   32
```

3   Experiment #2

For the second experiment a workload was introduced. The workload performs a matrix multiplication a certain amount of times. In this experiment the workload was set to 40. It can be observed that when the workload starts, at $t = 15$ seconds, the free memory goes down from 32 MB to 27 MB and the CPU utilization goes up to 100% from 0%. The Multiplication takes 3 minutes and 12 seconds, as shown in the output, and at that time, the memory and CPU utilization go back to there idle states. Figure 2 shows the graph of CPU and memory utilization. The output of the experiment is given in Listing 2.

Listing 2: Listing of output of Experiment #2

```
3.87395596504    CPU%:   0.1      MEM%:   32
14.0029830933    CPU%:   0.1      MEM%:   32
15.0093319416    N  is  40

real     3m12.136 s
user     3m5.344 s
sys      0m0.044 s

25.0638320446    CPU%:   99.7     MEM%:   27
34.3458909988    CPU%:   99.8     MEM%:   27
43.9036641121    CPU%:   99.6     MEM%:   27
53.9584550858    CPU%:   99.7     MEM%:   27
63.8052270412    CPU%:   99.7     MEM%:   27
73.8158681393    CPU%:   99.7     MEM%:   27
84.2257289886    CPU%:   98.7     MEM%:   27
94.2589790821    CPU%:   99.7     MEM%:   27
103.835909128    CPU%:   99.9     MEM%:   27
114.191326141    CPU%:   99.7     MEM%:   27
```
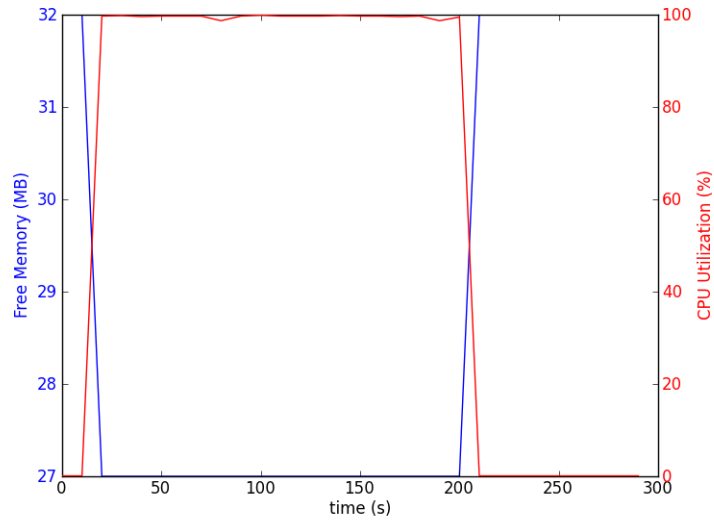
Figure 2: Results of Experiment #2 over 5 minutes with workload set to 40

```
123.943719149    CPU%:   99.7      MEM%:   27
133.788020134    CPU%:   99.7      MEM%:   27
143.864233971    CPU%:   99.8      MEM%:   27
153.943176031    CPU%:   99.7      MEM%:   27
163.994637012    CPU%:   99.7      MEM%:   27
174.560538054    CPU%:   99.6      MEM%:   27
184.09642005     CPU%:   99.7      MEM%:   27
194.439058065    CPU%:   98.7      MEM%:   27
204.016355038    CPU%:   99.5      MEM%:   27
213.823233128    CPU%:   0.1       MEM%:   32
223.80766201     CPU%:   0.1       MEM%:   32
233.783082962    CPU%:   0.1       MEM%:   32
243.910620928    CPU%:   0.1       MEM%:   32
253.801331043    CPU%:   0.1       MEM%:   32
263.919831038    CPU%:   0.1       MEM%:   32
273.780239105    CPU%:   0.1       MEM%:   32
283.920891047    CPU%:   0.1       MEM%:   32
293.954936981    CPU%:   0.1       MEM%:   32
```
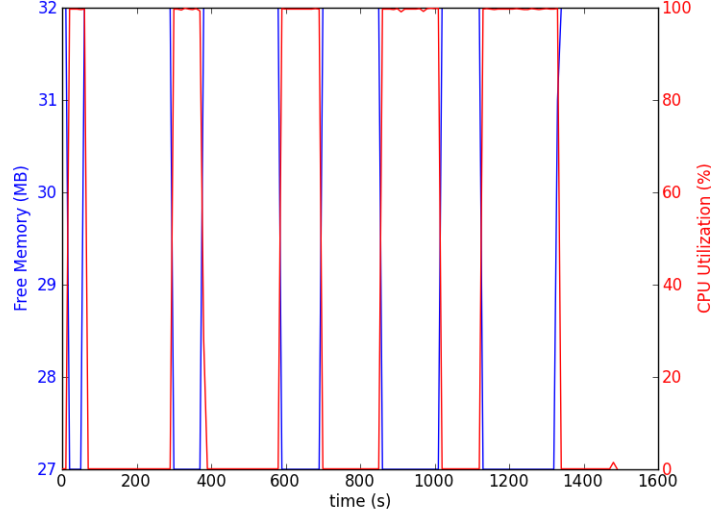
4

Figure 3: Results of Experiment #3 over 25 minutes with workload varied from 10 to 50 in increments of 10

4 Experiment #3

Experiment #3 was similar to experiment #2 except that the workload was varied in increments of 10 from 10 to 50. The experiment runs over a total of 25 minutes, as shown in Figure 3. As the workload increases, one can see that the amount of time the VM is active increases. The output of the experiment is given in Listing 3.

Listing 3: Listing of output of Experiment #3

```
3.79809308052    CPU%:  0.1        Free Mem (MB):   32
13.8875200748    CPU%:  0.1        Free Mem (MB):   32
15.0076861382    N is 10
24.7367241383    CPU%:  99.7       Free Mem (MB):   27
34.2333509922    CPU%:  99.7       Free Mem (MB):   27
44.8408432007    CPU%:  99.7       Free Mem (MB):   27
54.6706171036    CPU%:  99.6       Free Mem (MB):   27

real    0m47.611s
user    0m46.191s
sys     0m0.036s
63.9467802048    CPU%:  99.7       Free Mem (MB):   32
74.3951530457    CPU%:  0.1        Free Mem (MB):   32
83.84425807      CPU%:  0.1        Free Mem (MB):   32
```

```
94.0051760674    CPU%:   0.1       Free  Mem  (MB):   32
103.792278051    CPU%:   0.1       Free  Mem  (MB):   32
113.839336157    CPU%:   0.1       Free  Mem  (MB):   32
123.785258055    CPU%:   0.1       Free  Mem  (MB):   32
133.827678204    CPU%:   0.1       Free  Mem  (MB):   32
144.332842112    CPU%:   0.1       Free  Mem  (MB):   32
154.572579145    CPU%:   0.1       Free  Mem  (MB):   32
164.099258184    CPU%:   0.1       Free  Mem  (MB):   32
174.124778986    CPU%:   0.1       Free  Mem  (MB):   32
183.792167187    CPU%:   0.1       Free  Mem  (MB):   32
194.375648022    CPU%:   0.1       Free  Mem  (MB):   32
203.788021088    CPU%:   0.1       Free  Mem  (MB):   32
213.784555197    CPU%:   0.1       Free  Mem  (MB):   32
223.788208008    CPU%:   0.1       Free  Mem  (MB):   32
234.387079      CPU%:   0.1       Free  Mem  (MB):   32
244.359857082    CPU%:   0.1       Free  Mem  (MB):   32
253.833490133    CPU%:   0.1       Free  Mem  (MB):   32
263.895126104    CPU%:   0.1       Free  Mem  (MB):   32
273.784301043    CPU%:   0.1       Free  Mem  (MB):   32
283.809118032    CPU%:   0.1       Free  Mem  (MB):   32
293.786077023    CPU%:   0.1       Free  Mem  (MB):   32
315.010709047    N  is  20
334.090958118    CPU%:  99.7       Free  Mem  (MB):   27
343.937783003    CPU%:  99.7       Free  Mem  (MB):   27
354.004678011    CPU%:  99.5       Free  Mem  (MB):   27
364.31529808     CPU%:  99.9       Free  Mem  (MB):   27
374.095797062    CPU%:  99.7       Free  Mem  (MB):   27
383.8089571      CPU%:  99.6       Free  Mem  (MB):   27
394.055711985    CPU%:  99.8       Free  Mem  (MB):   27
403.919515133    CPU%:  99.3       Free  Mem  (MB):   27

real     1m35.238s
user     1m32.198s
sys      0m0.048s
413.801928997    CPU%:  28.2       Free  Mem  (MB):   32
423.912294149    CPU%:   0.1       Free  Mem  (MB):   32
433.750920057    CPU%:   0.1       Free  Mem  (MB):   32
444.242916107    CPU%:   0.1       Free  Mem  (MB):   32
453.993866205    CPU%:   0.1       Free  Mem  (MB):   32
463.826381207    CPU%:   0.1       Free  Mem  (MB):   32
473.791594028    CPU%:   0.1       Free  Mem  (MB):   32
483.817265987    CPU%:   0.1       Free  Mem  (MB):   32
493.782862186    CPU%:   0.1       Free  Mem  (MB):   32
503.854818106    CPU%:   0.1       Free  Mem  (MB):   32
513.784216166    CPU%:   0.1       Free  Mem  (MB):   32
523.831620216    CPU%:   0.1       Free  Mem  (MB):   32
```

```
533.857113123    CPU%:   0.1        Free  Mem  (MB):   32
543.826488018    CPU%:   0.1        Free  Mem  (MB):   32
553.754951       CPU%:   0.1        Free  Mem  (MB):   32
563.948775053    CPU%:   0.1        Free  Mem  (MB):   32
573.968418121    CPU%:   0.1        Free  Mem  (MB):   32
584.021180153    CPU%:   0.1        Free  Mem  (MB):   32
593.998157024    CPU%:   0.1        Free  Mem  (MB):   32
603.877757072    CPU%:   0.1        Free  Mem  (MB):   32
613.979189157    CPU%:   0.1        Free  Mem  (MB):   32
615.021424055    N  is  30
624.89679718     CPU%:   99.8       Free  Mem  (MB):   27
664.253035069    CPU%:   99.7       Free  Mem  (MB):   27
673.816966057    CPU%:   99.7       Free  Mem  (MB):   27
683.885106087    CPU%:   99.7       Free  Mem  (MB):   27
694.172137022    CPU%:   99.7       Free  Mem  (MB):   27
704.000138998    CPU%:   99.7       Free  Mem  (MB):   27
714.538915157    CPU%:   99.7       Free  Mem  (MB):   27
724.817816019    CPU%:   99.7       Free  Mem  (MB):   27
734.3781991      CPU%:   99.7       Free  Mem  (MB):   27
744.173650026    CPU%:   99.8       Free  Mem  (MB):   27
753.798233032    CPU%:   99.7       Free  Mem  (MB):   27


real     2m22.263s
user     2m18.409s
sys      0m0.060s
763.849694014    CPU%:   0.1        Free  Mem  (MB):   32
773.789415121    CPU%:   0.1        Free  Mem  (MB):   32
784.014249086    CPU%:   0.1        Free  Mem  (MB):   32
794.29770112     CPU%:   0.1        Free  Mem  (MB):   32
803.82319212     CPU%:   0.1        Free  Mem  (MB):   32
813.781311035    CPU%:   0.1        Free  Mem  (MB):   32
823.779935122    CPU%:   0.1        Free  Mem  (MB):   32
834.749770164    CPU%:   0.1        Free  Mem  (MB):   32
843.833389997    CPU%:   0.1        Free  Mem  (MB):   32
853.821031094    CPU%:   0.1        Free  Mem  (MB):   32
864.055639982    CPU%:   0.1        Free  Mem  (MB):   32
873.859069109    CPU%:   0.1        Free  Mem  (MB):   32
883.90241313     CPU%:   0.1        Free  Mem  (MB):   32
893.817115068    CPU%:   0.1        Free  Mem  (MB):   32
903.804824114    CPU%:   0.1        Free  Mem  (MB):   32
913.938194036    CPU%:   0.1        Free  Mem  (MB):   32
915.008661032    N  is  40
924.865731001    CPU%:   99.7       Free  Mem  (MB):   27
934.454658031    CPU%:   99.7       Free  Mem  (MB):   27
943.79186821     CPU%:   99.7       Free  Mem  (MB):   27
954.114700079    CPU%:   99.6       Free  Mem  (MB):   27
```

```
994.198443174     CPU%:   99.8      Free Mem (MB):   27
1004.05619502     CPU%:   99.1      Free Mem (MB):   27
1013.97656202     CPU%:   99.7      Free Mem (MB):   27
1023.92263317     CPU%:   99.7      Free Mem (MB):   27
1034.49425411     CPU%:   99.7      Free Mem (MB):   27
1044.28859806     CPU%:   99.7      Free Mem (MB):   27
1054.10452199     CPU%:   99.8      Free Mem (MB):   27
1063.93545818     CPU%:   99.2      Free Mem (MB):   27
1073.99083114     CPU%:   99.8      Free Mem (MB):   27
1084.55387521     CPU%:   99.9      Free Mem (MB):   27
1094.11284113     CPU%:   99.8      Free Mem (MB):   27
1104.16076303     CPU%:   99.9      Free Mem (MB):   27

real     3m10.283s
user     3m4.540s
sys      0m0.060s
1113.78529406     CPU%:   0.1       Free Mem (MB):   32
1123.78509212     CPU%:   0.1       Free Mem (MB):   32
1133.90575099     CPU%:   0.1       Free Mem (MB):   32
1143.78076315     CPU%:   0.1       Free Mem (MB):   32
1153.7784462      CPU%:   0.1       Free Mem (MB):   32
1163.79113507     CPU%:   0.1       Free Mem (MB):   32
1173.8249011      CPU%:   0.1       Free Mem (MB):   32
1184.16968107     CPU%:   0.1       Free Mem (MB):   32
1193.78419113     CPU%:   0.1       Free Mem (MB):   32
1204.05757618     CPU%:   0.1       Free Mem (MB):   32
1213.81900001     CPU%:   0.1       Free Mem (MB):   32
1215.29904819     N is  50
1224.60643721     CPU%:   99.7      Free Mem (MB):   27
1234.18040705     CPU%:   99.8      Free Mem (MB):   27
1244.00520015     CPU%:   99.7      Free Mem (MB):   27
1254.0219841      CPU%:   99.6      Free Mem (MB):   27
1264.38237214     CPU%:   99.7      Free Mem (MB):   27
1274.19884014     CPU%:   99.7      Free Mem (MB):   27
1283.98829699     CPU%:   99.7      Free Mem (MB):   27
1323.79032302     CPU%:   99.7      Free Mem (MB):   27
1333.90397406     CPU%:   99.7      Free Mem (MB):   27
1344.46774721     CPU%:   99.8      Free Mem (MB):   27
1354.013659       CPU%:   99.7      Free Mem (MB):   27
1364.07129717     CPU%:   99.6      Free Mem (MB):   27
1373.87681508     CPU%:   99.6      Free Mem (MB):   27
1384.423738       CPU%:   99.8      Free Mem (MB):   27
1394.21270299     CPU%:   99.7      Free Mem (MB):   27
1404.50360799     CPU%:   99.6      Free Mem (MB):   27
1413.81043315     CPU%:   99.7      Free Mem (MB):   27
1423.79197407     CPU%:   99.8      Free Mem (MB):   27
```

```
1433.99559808    CPU%:   99.7      Free Mem (MB):   27
1444.29419112    CPU%:   99.7      Free Mem (MB):   27

real    3m57.972s
user    3m50.710s
sys     0m0.052s
1454.10305119    CPU%:   99.8      Free Mem (MB):   31
1463.78201699    CPU%:   0.1       Free Mem (MB):   32
1473.82635021    CPU%:   0.1       Free Mem (MB):   32
1483.75951815    CPU%:   0.1       Free Mem (MB):   32
1493.78621507    CPU%:   0.1       Free Mem (MB):   32
1504.00086904    CPU%:   0.1       Free Mem (MB):   32
1513.96175313    CPU%:   0.1       Free Mem (MB):   32
1523.75341511    CPU%:   0.1       Free Mem (MB):   32
1533.794415      CPU%:   0.1       Free Mem (MB):   32
1543.97719908    CPU%:   0.1       Free Mem (MB):   32
1553.75053406    CPU%:   0.1       Free Mem (MB):   32
1563.9738152     CPU%:   0.1       Free Mem (MB):   32
1574.04178119    CPU%:   0.1       Free Mem (MB):   32
1584.027951      CPU%:   0.1       Free Mem (MB):   32
1593.7523241     CPU%:   0.1       Free Mem (MB):   32
1603.75508118    CPU%:   1.5       Free Mem (MB):   32
1613.85361409    CPU%:   0.1       Free Mem (MB):   32
```

5   Experiment #4

For the final experiment, the procedure of experiment #3 was repeated with
different settings of the VM. The CPU cap was set to 50% and 75% and the
memory allocated to the VM was set to 128 and 256 MB. The cases of 100%
CPU cap and 512 MB of allocated memory were not considered because they
are identical to the previous experiment. Figures 6, 7, 4, and 5 show the results
of the experiment #3 procedure for each of these cases. As the figures show,
limiting the CPU cycles allocated to the VM have the effect of making the work
take longer. The memory allocation had no effect though, probably due to the
small size of the matrix being computed. The output of the experiment is given
in Listing 4.

Listing 4: Listing of output of one run in Experiment #4

```
4.44317293167    CPU%:   0.1       Free Mem (MB):   38
14.1197578907    CPU%:   0.1       Free Mem (MB):   38
15.2154159546    N is 10
25.2771189213    CPU%:   50.3      Free Mem (MB):   33
35.8618359566    CPU%:   49.3      Free Mem (MB):   33
45.3964250088    CPU%:   49.5      Free Mem (MB):   33
55.3995909691    CPU%:   49.3      Free Mem (MB):   33
```
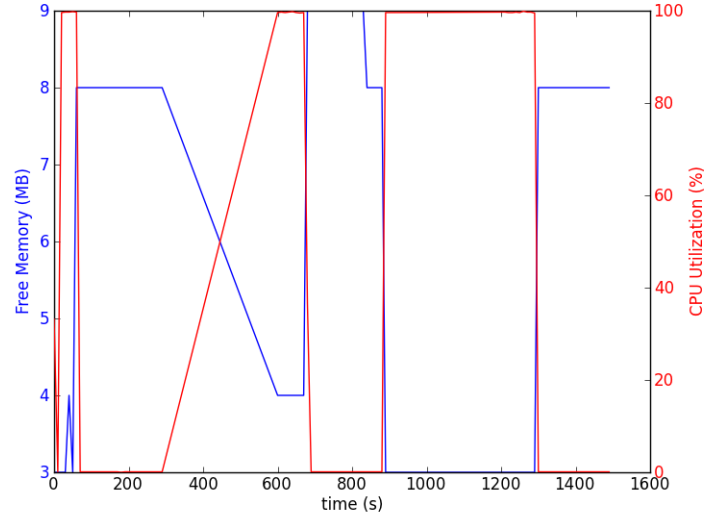
Figure 4: Results of Experiment #3 (only workload of 10, 20, and 30) with only 128 MB of memory allocated to the VM
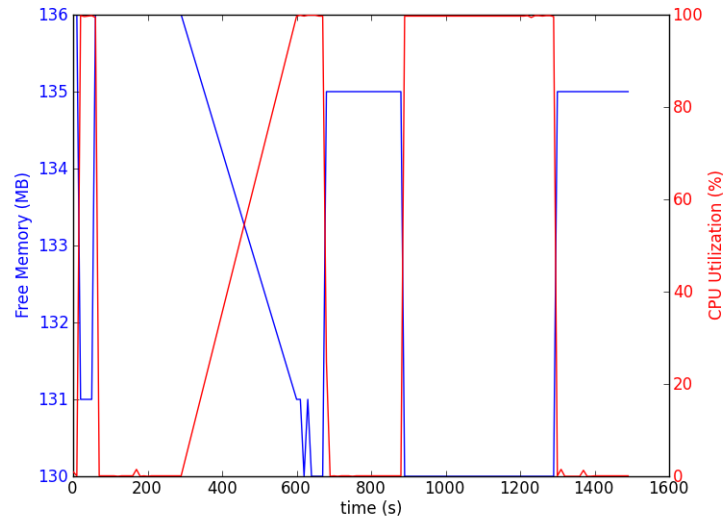

Figure 5: Results of Experiment #3 (only workload of 10, 20, and 30) with only 256 MB of memory allocated to the VM
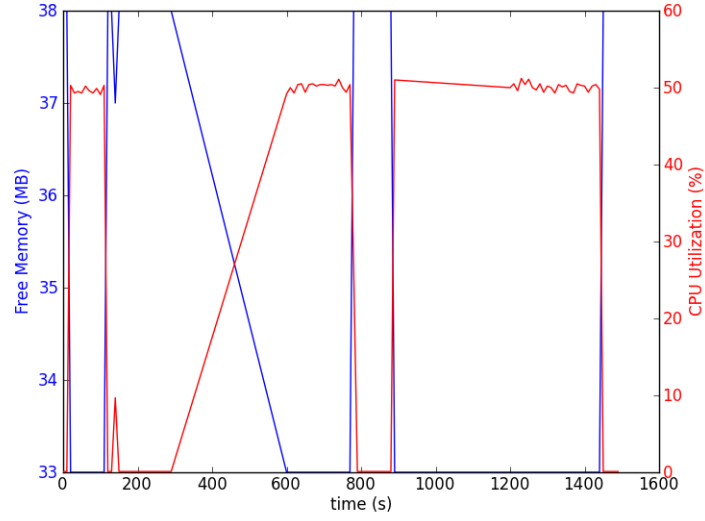
Figure 6: Results of Experiment #3 (only workload of 10, 20, and 30) with only 50% CPU time allocated to the VM
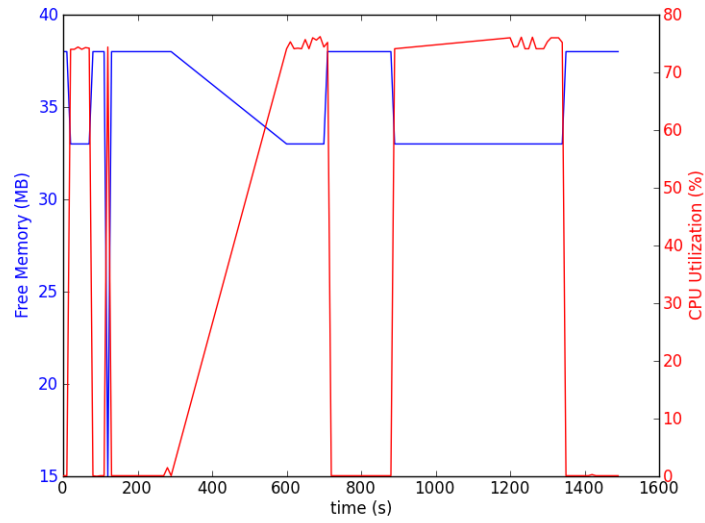

Figure 7: Results of Experiment #3 (only workload of 10, 20, and 30) with only 75% CPU time allocated to the VM

```
64.9371929169    CPU%:   50.2      Free Mem (MB):   33
74.4024200439    CPU%:   49.6      Free Mem (MB):   33
84.6587729454    CPU%:   49.3      Free Mem (MB):   33
95.3726029396    CPU%:   49.9      Free Mem (MB):   33
105.922680855    CPU%:   49.1      Free Mem (MB):   33
114.952903986    CPU%:   50.3      Free Mem (MB):   33
124.17640996     CPU%:   0.1       Free Mem (MB):   38
134.274008989    CPU%:   0.1       Free Mem (MB):   38
144.334965944    CPU%:   9.7       Free Mem (MB):   37
154.148923874    CPU%:   0.1       Free Mem (MB):   38
164.154473066    CPU%:   0.1       Free Mem (MB):   38
174.183307886    CPU%:   0.1       Free Mem (MB):   38
184.139539957    CPU%:   0.1       Free Mem (MB):   38
194.072887897    CPU%:   0.1       Free Mem (MB):   38
204.120509863    CPU%:   0.1       Free Mem (MB):   38
214.101826906    CPU%:   0.1       Free Mem (MB):   38
224.283763885    CPU%:   0.1       Free Mem (MB):   38
234.105763912    CPU%:   0.1       Free Mem (MB):   38
244.277848005    CPU%:   0.1       Free Mem (MB):   38
254.17145896     CPU%:   0.1       Free Mem (MB):   38
264.238085985    CPU%:   0.1       Free Mem (MB):   38
274.146939039    CPU%:   0.1       Free Mem (MB):   38
284.201148033    CPU%:   0.1       Free Mem (MB):   38
294.179144859    CPU%:   0.1       Free Mem (MB):   38
315.229169846    N is 20
334.267037868    CPU%:   49.2      Free Mem (MB):   33
344.322923899    CPU%:   50.0      Free Mem (MB):   33
355.301980972    CPU%:   49.3      Free Mem (MB):   33
365.816500902    CPU%:   50.4      Free Mem (MB):   33
375.393079042    CPU%:   50.5      Free Mem (MB):   33
385.393841028    CPU%:   49.4      Free Mem (MB):   33
395.429416895    CPU%:   50.4      Free Mem (MB):   33
405.454941988    CPU%:   50.5      Free Mem (MB):   33
416.379776955    CPU%:   50.2      Free Mem (MB):   33
424.913300991    CPU%:   50.4      Free Mem (MB):   33
434.999879837    CPU%:   50.4      Free Mem (MB):   33
444.971845865    CPU%:   50.3      Free Mem (MB):   33
455.516819      CPU%:   50.4      Free Mem (MB):   33
466.103028059    CPU%:   50.2      Free Mem (MB):   33
475.102149963    CPU%:   51.1      Free Mem (MB):   33
485.230326891    CPU%:   50.0      Free Mem (MB):   33
494.708127975    CPU%:   49.4      Free Mem (MB):   33
505.682692051    CPU%:   50.4      Free Mem (MB):   33
514.350955963    CPU%:   26.5      Free Mem (MB):   38
524.087517023    CPU%:   0.1       Free Mem (MB):   38
534.177162886    CPU%:   0.1       Free Mem (MB):   38
```

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544.149618864      CPU%:    0.1        Free Mem (MB):    38
554.481915951      CPU%:    0.1        Free Mem (MB):    38
564.497184038      CPU%:    0.1        Free Mem (MB):    38
574.294957876      CPU%:    0.1        Free Mem (MB):    38
584.092633963      CPU%:    0.1        Free Mem (MB):    38
594.209672928      CPU%:    0.1        Free Mem (MB):    38
604.077142954      CPU%:    0.1        Free Mem (MB):    38
614.140940905      CPU%:    0.1        Free Mem (MB):    38
615.216619968      N is 30
625.681262016      CPU%:    51.0       Free Mem (MB):    33
664.77628994       CPU%:    50.0       Free Mem (MB):    33
675.217061996      CPU%:    50.5       Free Mem (MB):    33
684.783740044      CPU%:    49.6       Free Mem (MB):    33
694.817431927      CPU%:    51.2       Free Mem (MB):    33
704.774263859      CPU%:    50.4       Free Mem (MB):    33
714.757174969      CPU%:    51.1       Free Mem (MB):    33
725.740494013      CPU%:    50.0       Free Mem (MB):    33
734.778100967      CPU%:    49.7       Free Mem (MB):    33
744.817873955      CPU%:    50.5       Free Mem (MB):    33
755.152298927      CPU%:    49.4       Free Mem (MB):    33
765.242629051      CPU%:    50.2       Free Mem (MB):    33
775.415616989      CPU%:    50.0       Free Mem (MB):    33
785.84175086       CPU%:    49.3       Free Mem (MB):    33
794.909889936      CPU%:    50.4       Free Mem (MB):    33
804.362200022      CPU%:    50.1       Free Mem (MB):    33
814.392813921      CPU%:    50.3       Free Mem (MB):    33
824.986196995      CPU%:    49.5       Free Mem (MB):    33
834.981822968      CPU%:    49.3       Free Mem (MB):    33
844.977037907      CPU%:    50.5       Free Mem (MB):    33
854.871077061      CPU%:    50.3       Free Mem (MB):    33
864.33134985       CPU%:    50.2       Free Mem (MB):    33
874.960151911      CPU%:    49.4       Free Mem (MB):    33
885.499028921      CPU%:    50.2       Free Mem (MB):    33
896.176672935      CPU%:    50.4       Free Mem (MB):    33
905.118725061      CPU%:    49.8       Free Mem (MB):    33
914.267814875      CPU%:    0.1        Free Mem (MB):    38
924.210764885      CPU%:    0.1        Free Mem (MB):    38
934.144307852      CPU%:    0.1        Free Mem (MB):    38
944.10788393       CPU%:    0.1        Free Mem (MB):    38
954.161974907      CPU%:    0.1        Free Mem (MB):    38
958.386291981      CPU%:    0.1        Free Mem (MB):    38
968.371842861      CPU%:    0.1        Free Mem (MB):    38
969.408093929      N is 10
980.177752972      CPU%:    74.0       Free Mem (MB):    33
988.706449986      CPU%:    74.0       Free Mem (MB):    33
998.249166012      CPU%:    74.4       Free Mem (MB):    33
```

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1008.93646884    CPU%:   74.0    Free Mem (MB):   33
1018.71191192    CPU%:   74.3    Free Mem (MB):   33
1028.48450184    CPU%:   74.2    Free Mem (MB):   33
1038.15546584    CPU%:   0.1     Free Mem (MB):   38
1048.22577786    CPU%:   0.0     Free Mem (MB):   38
1058.18418288    CPU%:   0.1     Free Mem (MB):   38
1068.33876705    CPU%:   0.1     Free Mem (MB):   38
1078.28282404    CPU%:   74.4    Free Mem (MB):   15
1088.22701788    CPU%:   0.1     Free Mem (MB):   38
1098.14685988    CPU%:   0.1     Free Mem (MB):   38
1108.14733005    CPU%:   0.1     Free Mem (MB):   38
1118.22318101    CPU%:   0.1     Free Mem (MB):   38
1128.38906884    CPU%:   0.1     Free Mem (MB):   38
1138.24359584    CPU%:   0.1     Free Mem (MB):   38
1148.31656504    CPU%:   0.1     Free Mem (MB):   38
1158.33736992    CPU%:   0.1     Free Mem (MB):   38
1168.53307104    CPU%:   0.1     Free Mem (MB):   38
1178.33367085    CPU%:   0.1     Free Mem (MB):   38
1188.58885503    CPU%:   0.1     Free Mem (MB):   38
1198.19339299    CPU%:   0.1     Free Mem (MB):   38
1208.17917204    CPU%:   0.1     Free Mem (MB):   38
1218.263129      CPU%:   0.1     Free Mem (MB):   38
1228.30416298    CPU%:   0.1     Free Mem (MB):   38
1238.4410789     CPU%:   1.5     Free Mem (MB):   38
1248.183851      CPU%:   0.1     Free Mem (MB):   38
1269.41108298    N is 20
1288.98315907    CPU%:   74.1    Free Mem (MB):   33
1298.24132705    CPU%:   75.3    Free Mem (MB):   33
1308.28363085    CPU%:   74.1    Free Mem (MB):   33
1318.40875101    CPU%:   74.2    Free Mem (MB):   33
1328.45654106    CPU%:   74.1    Free Mem (MB):   33
1339.11206985    CPU%:   75.7    Free Mem (MB):   33
1348.40419793    CPU%:   74.1    Free Mem (MB):   33
1358.49772406    CPU%:   76.0    Free Mem (MB):   33
1368.91051006    CPU%:   75.6    Free Mem (MB):   33
1378.59565187    CPU%:   76.2    Free Mem (MB):   33
1388.64183593    CPU%:   74.4    Free Mem (MB):   33
1398.28301692    CPU%:   75.2    Free Mem (MB):   38
1408.22518992    CPU%:   0.1     Free Mem (MB):   38
1418.21033096    CPU%:   0.1     Free Mem (MB):   38
1428.15351105    CPU%:   0.1     Free Mem (MB):   38
1438.23462391    CPU%:   0.1     Free Mem (MB):   38
1448.29549003    CPU%:   0.1     Free Mem (MB):   38
1458.27285504    CPU%:   0.1     Free Mem (MB):   38
1468.14693284    CPU%:   0.1     Free Mem (MB):   38
1478.15567994    CPU%:   0.1     Free Mem (MB):   38
```

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1488.18161988    CPU%:   0.1        Free Mem (MB):   38
1498.32727599    CPU%:   0.1        Free Mem (MB):   38
1508.1586709     CPU%:   0.1        Free Mem (MB):   38
1518.145895      CPU%:   0.1        Free Mem (MB):   38
1528.14962292    CPU%:   0.1        Free Mem (MB):   38
1538.31361985    CPU%:   0.1        Free Mem (MB):   38
1548.29197884    CPU%:   0.1        Free Mem (MB):   38
1558.16399384    CPU%:   0.1        Free Mem (MB):   38
1568.18978596    CPU%:   0.1        Free Mem (MB):   38
1569.41007805    N is  30
1579.56480885    CPU%:   74.1       Free Mem (MB):   33
1619.84805799    CPU%:   76.0       Free Mem (MB):   33
1629.16208887    CPU%:   74.4       Free Mem (MB):   33
1638.85978889    CPU%:   74.5       Free Mem (MB):   33
1648.86473799    CPU%:   76.1       Free Mem (MB):   33
1658.56876802    CPU%:   74.1       Free Mem (MB):   33
1668.57252097    CPU%:   74.1       Free Mem (MB):   33
1678.51532292    CPU%:   76.1       Free Mem (MB):   33
1688.56107783    CPU%:   74.1       Free Mem (MB):   33
1698.91642284    CPU%:   74.1       Free Mem (MB):   33
1708.46464396    CPU%:   74.1       Free Mem (MB):   33
1718.30855799    CPU%:   75.3       Free Mem (MB):   33
1729.26406598    CPU%:   76.0       Free Mem (MB):   33
1739.55903506    CPU%:   76.0       Free Mem (MB):   33
1748.87065792    CPU%:   76.0       Free Mem (MB):   33
1758.30412388    CPU%:   75.2       Free Mem (MB):   33
1768.18962383    CPU%:   0.1        Free Mem (MB):   38
1778.25282598    CPU%:   0.1        Free Mem (MB):   38
1788.23877192    CPU%:   0.1        Free Mem (MB):   38
1798.38876987    CPU%:   0.1        Free Mem (MB):   38
1808.18790793    CPU%:   0.1        Free Mem (MB):   38
1818.5129869     CPU%:   0.1        Free Mem (MB):   38
1828.15957785    CPU%:   0.1        Free Mem (MB):   38
1838.29195905    CPU%:   0.3        Free Mem (MB):   38
1848.61187792    CPU%:   0.1        Free Mem (MB):   38
1858.51032186    CPU%:   0.1        Free Mem (MB):   38
1868.22121692    CPU%:   0.1        Free Mem (MB):   38
1878.24205399    CPU%:   0.1        Free Mem (MB):   38
1888.22200894    CPU%:   0.1        Free Mem (MB):   38
1898.24024701    CPU%:   0.1        Free Mem (MB):   38
1908.26063704    CPU%:   0.1        Free Mem (MB):   38
1913.33336902    CPU%:   33.2       Free Mem (MB):   3
1922.54505587    CPU%:   0.1        Free Mem (MB):   3
1923.74573803    N is  10
1933.14103198    CPU%:   99.6       Free Mem (MB):   3
1942.69964385    CPU%:   99.7       Free Mem (MB):   3
```

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1953.02420998     CPU%:   99.7      Free Mem (MB):   4
1962.59513187     CPU%:   99.8      Free Mem (MB):   3
1972.78070402     CPU%:   99.7      Free Mem (MB):   8
1982.52716589     CPU%:   0.1       Free Mem (MB):   8
1992.52469587     CPU%:   0.1       Free Mem (MB):   8
2002.5471499      CPU%:   0.1       Free Mem (MB):   8
2012.52726293     CPU%:   0.1       Free Mem (MB):   8
2022.92136788     CPU%:   0.1       Free Mem (MB):   8
2032.69359088     CPU%:   0.1       Free Mem (MB):   8
2042.73627591     CPU%:   0.1       Free Mem (MB):   8
2052.52733588     CPU%:   0.1       Free Mem (MB):   8
2063.06400204     CPU%:   0.1       Free Mem (MB):   8
2072.52452087     CPU%:   0.1       Free Mem (MB):   8
2082.55955005     CPU%:   0.1       Free Mem (MB):   8
2092.70837903     CPU%:   0.0       Free Mem (MB):   8
2102.75168705     CPU%:   0.1       Free Mem (MB):   8
2112.60417104     CPU%:   0.1       Free Mem (MB):   8
2122.74995184     CPU%:   0.1       Free Mem (MB):   8
2132.63354087     CPU%:   0.1       Free Mem (MB):   8
2142.85240602     CPU%:   0.1       Free Mem (MB):   8
2152.54146504     CPU%:   0.1       Free Mem (MB):   8
2162.61206388     CPU%:   0.1       Free Mem (MB):   8
2172.55840397     CPU%:   0.1       Free Mem (MB):   8
2182.51089597     CPU%:   0.1       Free Mem (MB):   8
2192.89437485     CPU%:   0.1       Free Mem (MB):   8
2202.64723897     CPU%:   0.1       Free Mem (MB):   8
2224.09682584     N is  20
2242.89618492     CPU%:   99.6      Free Mem (MB):   4
2252.71316099     CPU%:   99.7      Free Mem (MB):   4
2262.75934005     CPU%:   99.6      Free Mem (MB):   4
2272.82216907     CPU%:   99.7      Free Mem (MB):   4
2282.89123201     CPU%:   99.8      Free Mem (MB):   4
2292.54353499     CPU%:   99.6      Free Mem (MB):   4
2303.02622604     CPU%:   99.5      Free Mem (MB):   4
2312.87257886     CPU%:   99.6      Free Mem (MB):   4
2322.77791405     CPU%:   36.6      Free Mem (MB):   9
2332.7044239      CPU%:   0.1       Free Mem (MB):   9
2342.52445197     CPU%:   0.1       Free Mem (MB):   9
2352.52077198     CPU%:   0.1       Free Mem (MB):   9
2362.6863029      CPU%:   0.1       Free Mem (MB):   9
2372.51976991     CPU%:   0.1       Free Mem (MB):   9
2382.52554798     CPU%:   0.1       Free Mem (MB):   9
2392.52328587     CPU%:   0.1       Free Mem (MB):   9
2402.773314       CPU%:   0.1       Free Mem (MB):   9
2412.52446103     CPU%:   0.1       Free Mem (MB):   9
2422.52797103     CPU%:   0.1       Free Mem (MB):   9
```

```
2432.56151795    CPU%:   0.1         Free Mem (MB):   9
2442.52469087    CPU%:   0.1         Free Mem (MB):   9
2454.61055088    CPU%:   0.1         Free Mem (MB):   9
2462.67835402    CPU%:   0.1         Free Mem (MB):   9
2472.51908183    CPU%:   0.1         Free Mem (MB):   9
2482.49215484    CPU%:   0.1         Free Mem (MB):   8
2492.51889491    CPU%:   0.1         Free Mem (MB):   8
2502.49275804    CPU%:   0.1         Free Mem (MB):   8
2512.65142989    CPU%:   0.1         Free Mem (MB):   8
2522.51781106    CPU%:   0.1         Free Mem (MB):   8
2523.74765801    N is  30
2533.52623606    CPU%:   99.6        Free Mem (MB):   3
2573.06208086    CPU%:   99.7        Free Mem (MB):   3
2583.11161304    CPU%:   99.7        Free Mem (MB):   3
2592.92829299    CPU%:   99.6        Free Mem (MB):   3
2602.67428684    CPU%:   99.6        Free Mem (MB):   3
2612.74448586    CPU%:   99.7        Free Mem (MB):   3
2623.11839986    CPU%:   99.6        Free Mem (MB):   3
2632.93463993    CPU%:   99.9        Free Mem (MB):   3
2642.7665329     CPU%:   99.7        Free Mem (MB):   3
2652.98084903    CPU%:   99.7        Free Mem (MB):   3
2662.53790188    CPU%:   99.5        Free Mem (MB):   3
2672.71944785    CPU%:   0.1         Free Mem (MB):   8
2682.49276304    CPU%:   0.1         Free Mem (MB):   8
2692.53028798    CPU%:   0.1         Free Mem (MB):   8
2702.55181694    CPU%:   0.1         Free Mem (MB):   8
2712.55325198    CPU%:   0.1         Free Mem (MB):   8
2722.55729604    CPU%:   0.1         Free Mem (MB):   8
2732.78679895    CPU%:   0.1         Free Mem (MB):   8
2742.56726694    CPU%:   0.1         Free Mem (MB):   8
2752.75359797    CPU%:   0.1         Free Mem (MB):   8
2762.72311997    CPU%:   0.1         Free Mem (MB):   8
2772.48856902    CPU%:   0.1         Free Mem (MB):   8
2782.48736501    CPU%:   0.1         Free Mem (MB):   8
2792.548769      CPU%:   0.1         Free Mem (MB):   8
2802.65817785    CPU%:   0.1         Free Mem (MB):   8
2812.55693984    CPU%:   0.1         Free Mem (MB):   8
2822.52414799    CPU%:   0.1         Free Mem (MB):   8
2832.74540496    CPU%:   0.1         Free Mem (MB):   8
2842.52600098    CPU%:   0.1         Free Mem (MB):   8
2852.64730096    CPU%:   0.1         Free Mem (MB):   8
2862.52716899    CPU%:   0.1         Free Mem (MB):   8
2866.58653593    CPU%:   1.0         Free Mem (MB):   136
2876.58799505    CPU%:   0.1         Free Mem (MB):   136
2877.81100583    N is  10
2888.05022001    CPU%:   99.8        Free Mem (MB):   131
```

```
2897.60745096    CPU%:  99.6      Free Mem (MB):  131
2906.94277692    CPU%:  99.7      Free Mem (MB):  131
2916.75845695    CPU%:  99.8      Free Mem (MB):  131
2926.59236789    CPU%:  99.4      Free Mem (MB):  136
2936.58789802    CPU%:  0.1       Free Mem (MB):  136
2946.74191594    CPU%:  0.1       Free Mem (MB):  136
2956.59335899    CPU%:  0.1       Free Mem (MB):  136
2966.58434486    CPU%:  0.1       Free Mem (MB):  136
2976.81710696    CPU%:  0.1       Free Mem (MB):  136
2986.594661      CPU%:  0.0       Free Mem (MB):  136
2996.55196285    CPU%:  0.1       Free Mem (MB):  136
3006.72605205    CPU%:  0.1       Free Mem (MB):  136
3016.55255294    CPU%:  0.1       Free Mem (MB):  136
3026.81090689    CPU%:  0.1       Free Mem (MB):  136
3036.93587303    CPU%:  1.5       Free Mem (MB):  136
3046.59215283    CPU%:  0.0       Free Mem (MB):  136
3056.59662485    CPU%:  0.1       Free Mem (MB):  136
3066.5882709     CPU%:  0.0       Free Mem (MB):  136
3076.58213305    CPU%:  0.1       Free Mem (MB):  136
3086.79043198    CPU%:  0.1       Free Mem (MB):  136
3096.58965492    CPU%:  0.1       Free Mem (MB):  136
3106.55192804    CPU%:  0.1       Free Mem (MB):  136
3116.55634904    CPU%:  0.1       Free Mem (MB):  136
3126.6041379     CPU%:  0.1       Free Mem (MB):  136
3136.61975598    CPU%:  0.1       Free Mem (MB):  136
3146.58420992    CPU%:  0.1       Free Mem (MB):  136
3156.58963299    CPU%:  0.1       Free Mem (MB):  136
3177.809793      N is  20
3196.79905796    CPU%:  99.7      Free Mem (MB):  131
3206.65019083    CPU%:  99.9      Free Mem (MB):  131
3216.94176793    CPU%:  99.7      Free Mem (MB):  130
3226.76166201    CPU%:  99.9      Free Mem (MB):  131
3236.84246802    CPU%:  99.9      Free Mem (MB):  130
3246.91190195    CPU%:  99.9      Free Mem (MB):  130
3256.57645988    CPU%:  99.7      Free Mem (MB):  130
3266.81834602    CPU%:  99.7      Free Mem (MB):  130
3276.6066699     CPU%:  24.8      Free Mem (MB):  135
3286.58427596    CPU%:  0.0       Free Mem (MB):  135
3296.67436886    CPU%:  0.1       Free Mem (MB):  135
3306.63561702    CPU%:  0.0       Free Mem (MB):  135
3316.58692002    CPU%:  0.1       Free Mem (MB):  135
3326.76322985    CPU%:  0.1       Free Mem (MB):  135
3336.58782196    CPU%:  0.1       Free Mem (MB):  135
3346.58309698    CPU%:  0.0       Free Mem (MB):  135
3356.58023691    CPU%:  0.1       Free Mem (MB):  135
3366.58952403    CPU%:  0.1       Free Mem (MB):  135
```

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3376.5870049     CPU%:  0.1        Free Mem (MB):  135
3386.73400187    CPU%:  0.1        Free Mem (MB):  135
3396.79500794    CPU%:  0.1        Free Mem (MB):  135
3406.5485239     CPU%:  0.1        Free Mem (MB):  135
3416.62748194    CPU%:  0.1        Free Mem (MB):  135
3426.58224392    CPU%:  0.1        Free Mem (MB):  135
3436.59411502    CPU%:  0.1        Free Mem (MB):  135
3446.76840687    CPU%:  0.1        Free Mem (MB):  135
3456.5854249     CPU%:  0.1        Free Mem (MB):  135
3466.74310994    CPU%:  0.1        Free Mem (MB):  135
3476.61817694    CPU%:  0.1        Free Mem (MB):  135
3477.81270599    N is 30
3487.64312196    CPU%:  99.7       Free Mem (MB):  130
3527.23086905    CPU%:  99.7       Free Mem (MB):  130
3537.05121183    CPU%:  99.7       Free Mem (MB):  130
3546.86772704    CPU%:  99.8       Free Mem (MB):  130
3556.95510793    CPU%:  99.4       Free Mem (MB):  130
3566.76558089    CPU%:  99.8       Free Mem (MB):  130
3576.85332799    CPU%:  99.8       Free Mem (MB):  130
3587.16855597    CPU%:  99.7       Free Mem (MB):  130
3597.22283292    CPU%:  99.8       Free Mem (MB):  130
3606.79124689    CPU%:  99.8       Free Mem (MB):  130
3616.57740903    CPU%:  99.6       Free Mem (MB):  130
3626.62029195    CPU%:  0.1        Free Mem (MB):  135
3636.60749793    CPU%:  1.5        Free Mem (MB):  135
3646.62249184    CPU%:  0.0        Free Mem (MB):  135
3656.68196392    CPU%:  0.0        Free Mem (MB):  135
3666.73624086    CPU%:  0.0        Free Mem (MB):  135
3676.62403893    CPU%:  0.0        Free Mem (MB):  135
3686.60112786    CPU%:  0.0        Free Mem (MB):  135
3696.58830094    CPU%:  1.3        Free Mem (MB):  135
3706.59427094    CPU%:  0.0        Free Mem (MB):  135
3716.6222949     CPU%:  0.0        Free Mem (MB):  135
3726.59187102    CPU%:  0.1        Free Mem (MB):  135
3736.59623003    CPU%:  0.1        Free Mem (MB):  135
3746.72003984    CPU%:  0.1        Free Mem (MB):  135
3756.7498889     CPU%:  0.1        Free Mem (MB):  135
3766.59812284    CPU%:  0.1        Free Mem (MB):  135
3776.59980702    CPU%:  0.1        Free Mem (MB):  135
3786.65264988    CPU%:  0.1        Free Mem (MB):  135
3796.71668792    CPU%:  0.1        Free Mem (MB):  135
3806.58552384    CPU%:  0.1        Free Mem (MB):  135
3816.71036386    CPU%:  0.1        Free Mem (MB):  135
```

6 Conclusions

This homework assignment helped greatly in learning how to monitor and control Xen VM systems—a lesson which I will definitely use in my professional life. Unfortunately, the last experiment didn't run perfectly and took a lot longer to complete than expected, but, with a few tweaks, the code written here should serve as a great base for future experiments. I look forward to doing more assignments in this topic.

A Code Listings

Listing 5: Python program used to gather data

```python
#!/usr/bin/python2
import sched, time, os, sys, subprocess, pickle

class Experiment(object):
  """Run experiments in HW2"""
  def __init__(self, ex, graph=False):
    self.graph = graph
    self.ex = ex
    self.startTime = time.time()
    self.memFree = []
    self.cpuPercent = []
    self.times = []
    # init the scheduler
    self.s = sched.scheduler(time.time, time.sleep)

  def get_metrics(self):
    """Get the CPU usage and free Mem of VM from xentop and vmstat"""
    ret = os.popen('/usr/bin/sudo /usr/sbin/xentop -b -i2 -d3')
    cpuPercent = ret.readlines()[-3].split()[3]
    ret = os.popen('/usr/bin/ssh acvm-04-1 vmstat -S M')
    memFree = ret.readlines()[-1].split()[3]
    print time.time() - self.startTime, "\tCPU%: ", cpuPercent, "\tFree Mem (MB)
    if self.graph:
      self.memFree.append(memFree)
      self.cpuPercent.append(cpuPercent)

  def launchWork(self,N):
    """Launch the workload application with N as matrix size"""
    subprocess.Popen('/usr/bin/ssh acvm-04-1 "time ./workload %d"' % (N), shell=
    print time.time() - self.startTime, "\tN is %d" % (N)

  def loop(self):
```

```python
    """Main program loop. Schedules the monitor and workloads."""
    self.startTime = time.time()
    if self.ex==1:
    # Monitor for 5 min with no workload
      for i in xrange(5*6):
        self.s.enter(i*10, 1, self.get_metrics, ())
        self.times.append(i*10)
      self.s.run()
    elif self.ex==2:
    # Monitor for 5 min with workload 40
      self.s.enter(15, 1, self.launchWork, ([40]))
      for i in xrange(5*6):
        self.times.append(i*10)
        self.s.enter(i*10, 1, self.get_metrics, ())
      self.s.run()
    elif self.ex==3:
    # Monitor 5 times for five minutes each with workload {10,20,..,50}
      runEx3()
    elif self.ex==4:
    # Varying cap and mem repeat ex3
      for cap in ['50','75','0']:
        os.popen('/usr/bin/sudo_/usr/sbin/xm_sched-credit_-d_acvm-04-1.acis.ufl.
        self.runEx3()
        self.dump()
        os.popen('mv_ex4ResDump.pickle_ex4ResDump_Cap='+cap+'.pickle')
      for mem in ['128','256','512']:
        os.popen('/usr/bin/sudo_/usr/sbin/xm_mem-set_acvm-04-1.acis.ufl.edu_'+mem
        self.runEx3()
        self.dump()
        os.popen('mv_ex4ResDump.pickle_ex4ResDump_Mem='+mem+'.pickle')
    else:
      print "Not_a_valid_experiment_number!\nTry_1_or_2."

def runEx3(self):
  for i in xrange(5):
    self.s.enter((i*300)+15, 1, self.launchWork, ([(i+1)*10]))
    for j in xrange(i*30,(i+1)*30):
      self.times.append(i*300+j*10)
      self.s.enter(i*30+j*10, 1, self.get_metrics, ())
  self.s.run()

def dump(self):
  """No way to install numpy, matplotlib so this just pickles the
  arrays to be graphed on my home machine."""
  dumpFileName = "ex%dResDump.pickle" % (self.ex,)
  dumpFile = open(dumpFileName, 'w')
```

```python
        pickle.dump({'ex': self.ex, 'times': self.times, 'memFree':
          self.memFree, 'cpuPercent': self.cpuPercent}, dumpFile)
        dumpFile.close()


if __name__=='__main__':
  if (len(sys.argv) < 2):
    print "Please specify experiment as: ", sys.argv[0], "<experment number>"
    sys.exit(1)
  # run the experiment specified on the command line
  if (len(sys.argv) > 2):
    exp = Experiment(int(sys.argv[1]), True)
    exp.loop()
    exp.dump()
  else:
    exp = Experiment(int(sys.argv[1]))
    exp.loop()
```

Listing 6: Python program used to make the charts

```python
#!/usr/bin/python2
import sys
import pickle

import numpy as np
import matplotlib.pyplot as plt

def getDict(dumpFileName):
  try:
    dumpFile = open(dumpFileName, 'r')
  except:
    print "Couldn't open "+dumpFileName+" file! Check experiment number."
    sys.exit(1)
  dumpDict =  pickle.load(dumpFile)
  dumpFile.close()
  return dumpDict

def plot(ex):
  if ex>0 and ex<4:
    # Get data
    dataDict = getDict("ex%dResDump.pickle" % (ex,))
    # Set up figure
    fig = plt.figure()
    # Axis one shows mem
    ax1 = fig.add_subplot(111)
    ax1.plot(dataDict['times'], dataDict['memFree'], 'b-')
    ax1.set_xlabel('time (s)')
```

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```python
        ax1.set_ylabel('Free_Memory_(MB)', color='b')
        for tl in ax1.get_yticklabels():
            tl.set_color('b')
        # Axis two shows cpu
        ax2 = ax1.twinx()
        ax2.plot(dataDict['times'], dataDict['cpuPercent'], 'r-')
        ax2.set_ylabel('CPU_Utilization_(%)', color='r')
        for tl in ax2.get_yticklabels():
            tl.set_color('r')
        # Plot and save the figure
        plt.savefig('ex%d.png' % (ex,))
        plt.show()
    elif ex==4:
        #for exp in ['Cap=50','Cap=75','Cap=0','Mem=128','Mem=256','Mem=512']:
        for exp in ['Cap=50','Cap=75','Mem=128','Mem=256']:
            dataDict = getDict("ex4ResDump_"+exp+".pickle")
            # Set up figure
            fig = plt.figure()
            # Axis one shows mem
            ax1 = fig.add_subplot(111)
            ax1.plot(dataDict['times'], dataDict['memFree'], 'b-')
            ax1.set_xlabel('time_(s)')
            ax1.set_ylabel('Free_Memory_(MB)', color='b')
            for tl in ax1.get_yticklabels():
                tl.set_color('b')
            # Axis two shows cpu
            ax2 = ax1.twinx()
            ax2.plot(dataDict['times'], dataDict['cpuPercent'], 'r-')
            ax2.set_ylabel('CPU_Utilization_(%)', color='r')
            for tl in ax2.get_yticklabels():
                tl.set_color('r')
            # Plot and save the figure
            plt.savefig('ex4'+exp+'.png')
    else:
        print "Not_a_valid_experiment_number"

if __name__=='__main__':
    if(len(sys.argv) < 2):
        print "Please_specify_experiment_as:_", sys.argv[0], "<experment_number>"
        sys.exit(1)
    else:
        plot(int(sys.argv[1]))
```