Sun microsystems

Performance Monitoring (focused on Java SE)

Topics

- What information to monitor
- What tools to use
- What level of the software stack to monitor
  - Operating system level
  - JVM level
  - Application level
- What to monitor is covered per component at a given level
  - Example. At OS level, monitor CPU usage

Tools For Monitoring

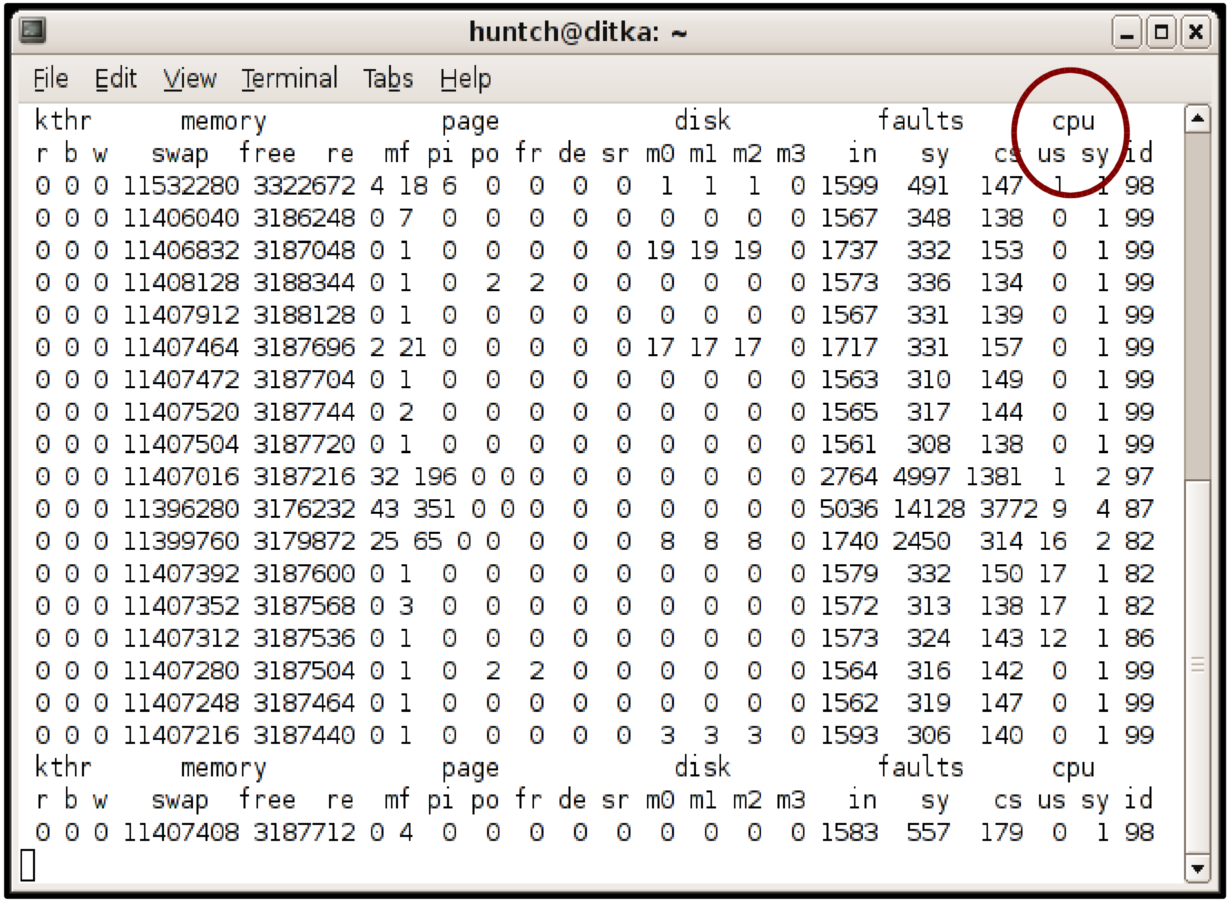
- Definition: An act of *non-intrusively* collecting or observing performance data from an operating or running application.
- What to monitor and where?
  - Operating system: cpu utilization (kernel & user), network i/o, disk i/o, memory, processes and kernel (locks).
  - JVM: garbage collection frequency and duration, heap usage, threads, lock contention, cpu usage
  - Application: throughput, responsiveness

CPU Monitoring Tools at the OS-Level

Tools For Monitoring : OS Level

- cpu
  - vmstat (Solaris & Linux)
  - mpstat (Solaris)
  - prstat (Solaris)
  - top (Linux, prefer prstat on Solaris)
  - Task Manager (Windows)
  - Performance Monitor (Windows)
  - xosview (Linux)
  - cpubar (Solaris – Performance Tools CD)
  - iobar (Solaris – Performance Tools CD)
  - dtrace (Solaris)

Tools For Monitoring : vmstat

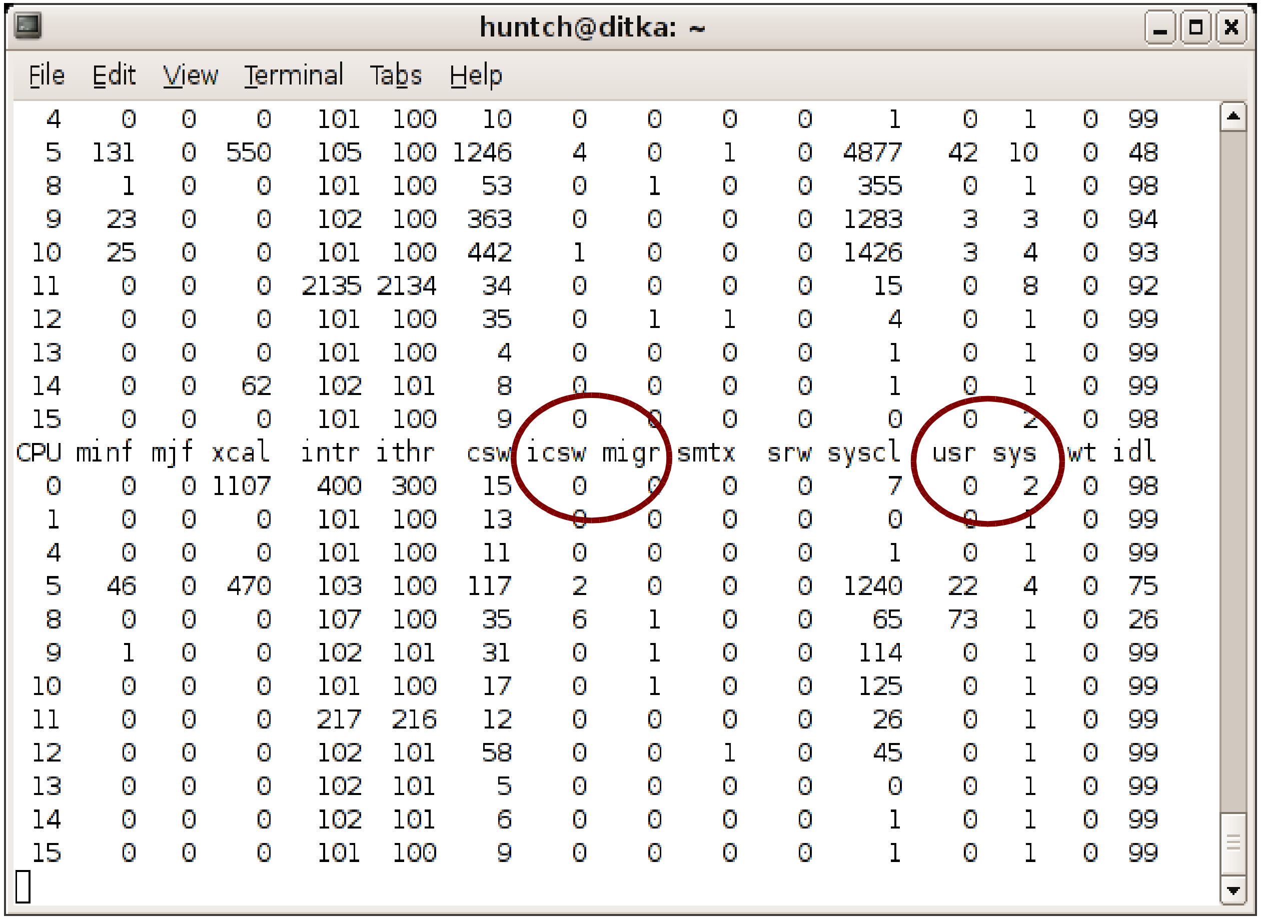


```
kthr      memory            page            disk          faults      cpu
r b w   swap  free  re  mf pi po fr de sr m0 m1 m2 m3   in   sy   cs us sy id
0 0 0 11532280 3322672 4 18 6  0  0  0  0  1  1  1  0 1599  491  147  1  1 98
0 0 0 11406040 3186248 0 7  0  0  0  0  0  0  0  0  0 1567  348  138  0  1 99
0 0 0 11406832 3187048 0 1  0  0  0  0  0 19 19 19  0 1737  332  153  0  1 99
0 0 0 11408128 3188344 0 1  0  2  2  0  0  0  0  0  0 1573  336  134  0  1 99
0 0 0 11407912 3188128 0 1  0  0  0  0  0  0  0  0  0 1567  331  139  0  1 99
0 0 0 11407464 3187696 2 21 0  0  0  0  0 17 17 17  0 1717  331  157  0  1 99
0 0 0 11407472 3187704 0 1  0  0  0  0  0  0  0  0  0 1563  310  149  0  1 99
0 0 0 11407520 3187744 0 2  0  0  0  0  0  0  0  0  0 1565  317  144  0  1 99
0 0 0 11407504 3187720 0 1  0  0  0  0  0  0  0  0  0 1561  308  138  0  1 99
0 0 0 11407016 3187216 32 196 0 0 0  0  0  0  0  0  0 2764 4997 1381  1  2 97
0 0 0 11396280 3176232 43 351 0 0 0  0  0  0  0  0  0 5036 14128 3772 9  4 87
0 0 0 11399760 3179872 25 65 0 0  0  0  0  8  8  8  0 1740 2450  314 16  2 82
0 0 0 11407392 3187600 0 1  0  0  0  0  0  0  0  0  0 1579  332  150 17  1 82
0 0 0 11407352 3187568 0 3  0  0  0  0  0  0  0  0  0 1572  313  138 17  1 82
0 0 0 11407312 3187536 0 1  0  0  0  0  0  0  0  0  0 1573  324  143 12  1 86
0 0 0 11407280 3187504 0 1  0  2  2  0  0  0  0  0  0 1564  316  142  0  1 99
0 0 0 11407248 3187464 0 1  0  0  0  0  0  0  0  0  0 1562  319  147  0  1 99
0 0 0 11407216 3187440 0 1  0  0  0  0  0  3  3  3  0 1593  306  140  0  1 99
kthr      memory            page            disk          faults      cpu
r b w   swap  free  re  mf pi po fr de sr m0 m1 m2 m3   in   sy   cs us sy id
0 0 0 11407408 3187712 0 4  0  0  0  0  0  0  0  0  0 1583  557  179  0  1 98
```

vmstat

- Virtual Memory Statistics
- reports virtual memory statistics of process, virtual memory, disk, trap, and CPU activity.
- cpu (breakdown of percentage usage of CPU time. On multiprocessors this is an a verage across all processors.)
  - > us - user time
  - > sy - system time
  - > id - idle time

Tools For Monitoring : mpstat



```
  4    0   0    0   101  100   10    0    0    0    0     1    0   1   0  99
  5  131   0  550   105  100 1246    4    0    1    0  4877   42  10   0  48
  8    1   0    0   101  100   53    0    1    0    0   355    0   1   0  98
  9   23   0    0   102  100  363    0    0    0    0  1283    3   3   0  94
 10   25   0    0   101  100  442    1    0    0    0  1426    3   4   0  93
 11    0   0    0  2135 2134   34    0    0    0    0    15    0   8   0  92
 12    0   0    0   101  100   35    0    1    1    0     4    0   1   0  99
 13    0   0    0   101  100    4    0    0    0    0     1    0   1   0  99
 14    0   0   62   102  101    8    0    0    0    0     1    0   1   0  99
 15    0   0    0   101  100    9    0    0    0    0     0    0   2   0  98
CPU minf mjf xcal  intr ithr  csw icsw migr smtx  srw syscl  usr sys  wt idl
  0    0   0 1107   400  300   15    0    0    0    0     7    0   2   0  98
  1    0   0    0   101  100   13    0    0    0    0     0    0   1   0  99
  4    0   0    0   101  100   11    0    0    0    0     1    0   1   0  99
  5   46   0  470   103  100  117    2    0    0    0  1240   22   4   0  75
  8    0   0    0   107  100   35    6    1    0    0    65   73   1   0  26
  9    1   0    0   102  101   31    0    1    0    0   114    0   1   0  99
 10    0   0    0   101  100   17    0    1    0    0   125    0   1   0  99
 11    0   0    0   217  216   12    0    0    0    0    26    0   1   0  99
 12    0   0    0   102  101   58    0    0    1    0    45    0   1   0  99
 13    0   0    0   102  101    5    0    0    0    0     0    0   1   0  99
 14    0   0    0   102  101    6    0    0    0    0     1    0   1   0  99
 15    0   0    0   101  100    9    0    0    0    0     1    0   1   0  99
```

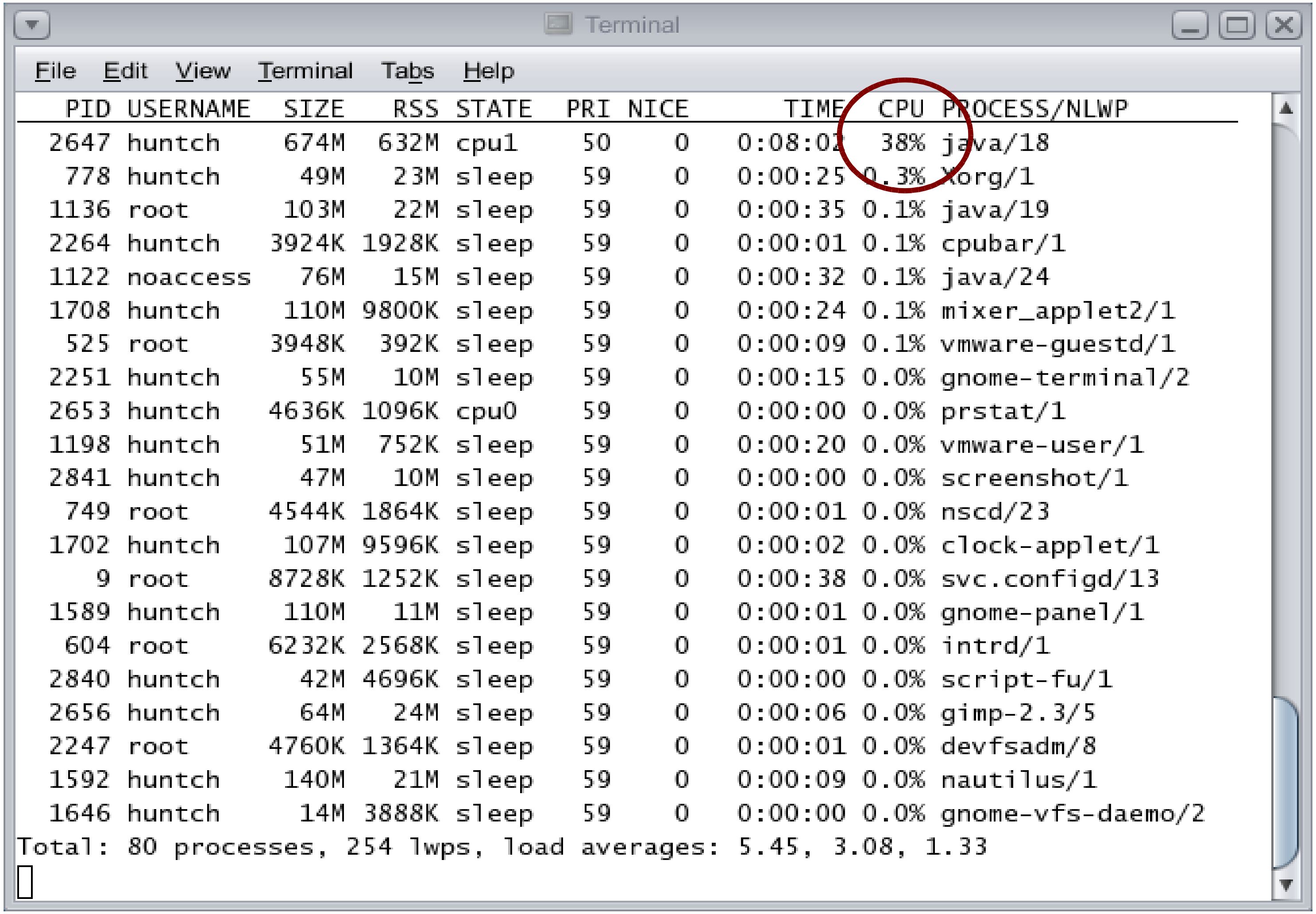
mpstat

- Multi-processor status
- Reveals the individual CPU utilization on multi-processor
- Each row of the table represents the activity of one processor.
- The first table summarizes all activity since boot
- Each subsequent table summarizes activity for the preceding interval.
- All values are rates (events per second) unless otherwise noted.

mpstat

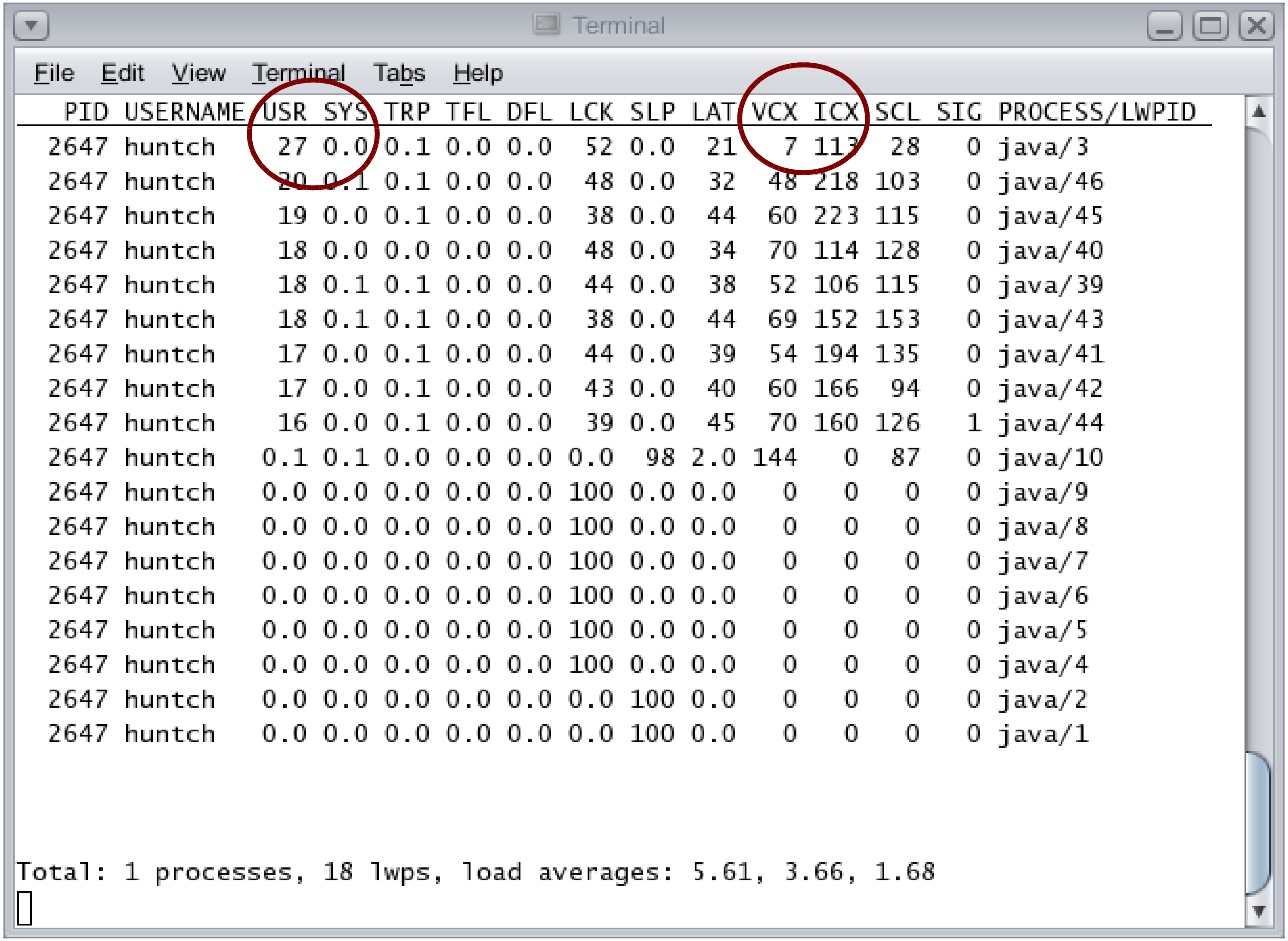
icsw	involuntary context switches
migr	thread migrations (to another processor)
usr	percent user time
sys	percent system time

Tools For Monitoring : prstat



```
   PID USERNAME  SIZE   RSS STATE  PRI NICE      TIME  CPU PROCESS/NLWP
  2647 huntch    674M  632M cpu1    50    0   0:08:02  38% java/18
   778 huntch     49M   23M sleep   59    0   0:00:25 0.3% Xorg/1
  1136 root      103M   22M sleep   59    0   0:00:35 0.1% java/19
  2264 huntch   3924K 1928K sleep   59    0   0:00:01 0.1% cpubar/1
  1122 noaccess   76M   15M sleep   59    0   0:00:32 0.1% java/24
  1708 huntch    110M 9800K sleep   59    0   0:00:24 0.1% mixer_applet2/1
   525 root     3948K  392K sleep   59    0   0:00:09 0.1% vmware-guestd/1
  2251 huntch     55M   10M sleep   59    0   0:00:15 0.0% gnome-terminal/2
  2653 huntch   4636K 1096K cpu0    59    0   0:00:00 0.0% prstat/1
  1198 huntch     51M  752K sleep   59    0   0:00:20 0.0% vmware-user/1
  2841 huntch     47M   10M sleep   59    0   0:00:00 0.0% screenshot/1
   749 root     4544K 1864K sleep   59    0   0:00:01 0.0% nscd/23
  1702 huntch    107M 9596K sleep   59    0   0:00:02 0.0% clock-applet/1
     9 root     8728K 1252K sleep   59    0   0:00:38 0.0% svc.configd/13
  1589 huntch    110M   11M sleep   59    0   0:00:01 0.0% gnome-panel/1
   604 root     6232K 2568K sleep   59    0   0:00:01 0.0% intrd/1
  2840 huntch     42M 4696K sleep   59    0   0:00:00 0.0% script-fu/1
  2656 huntch     64M   24M sleep   59    0   0:00:06 0.0% gimp-2.3/5
  2247 root     4760K 1364K sleep   59    0   0:00:01 0.0% devfsadm/8
  1592 huntch    140M   21M sleep   59    0   0:00:09 0.0% nautilus/1
  1646 huntch     14M 3888K sleep   59    0   0:00:00 0.0% gnome-vfs-daemo/2
Total: 80 processes, 254 lwps, load averages: 5.45, 3.08, 1.33
```

Tools For Monitoring : prstat -Lm

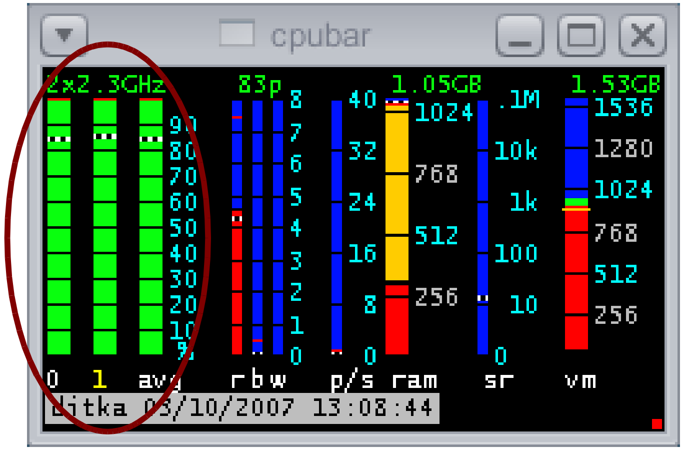


```
   PID USERNAME USR SYS TRP TFL DFL LCK SLP LAT VCX ICX SCL SIG PROCESS/LWPID
  2647 huntch    27 0.0 0.1 0.0 0.0  52 0.0  21   7 113  28   0 java/3
  2647 huntch    20 0.1 0.1 0.0 0.0  48 0.0  32  48 218 103   0 java/46
  2647 huntch    19 0.0 0.1 0.0 0.0  38 0.0  44  60 223 115   0 java/45
  2647 huntch    18 0.0 0.0 0.0 0.0  48 0.0  34  70 114 128   0 java/40
  2647 huntch    18 0.1 0.1 0.0 0.0  44 0.0  38  52 106 115   0 java/39
  2647 huntch    18 0.1 0.1 0.0 0.0  38 0.0  44  69 152 153   0 java/43
  2647 huntch    17 0.0 0.1 0.0 0.0  44 0.0  39  54 194 135   0 java/41
  2647 huntch    17 0.0 0.1 0.0 0.0  43 0.0  40  60 166  94   0 java/42
  2647 huntch    16 0.0 0.1 0.0 0.0  39 0.0  45  70 160 126   1 java/44
  2647 huntch   0.1 0.1 0.0 0.0 0.0 0.0  98 2.0 144   0  87   0 java/10
  2647 huntch   0.0 0.0 0.0 0.0 0.0 100 0.0 0.0   0   0   0   0 java/9
  2647 huntch   0.0 0.0 0.0 0.0 0.0 100 0.0 0.0   0   0   0   0 java/8
  2647 huntch   0.0 0.0 0.0 0.0 0.0 100 0.0 0.0   0   0   0   0 java/7
  2647 huntch   0.0 0.0 0.0 0.0 0.0 100 0.0 0.0   0   0   0   0 java/6
  2647 huntch   0.0 0.0 0.0 0.0 0.0 100 0.0 0.0   0   0   0   0 java/5
  2647 huntch   0.0 0.0 0.0 0.0 0.0 100 0.0 0.0   0   0   0   0 java/4
  2647 huntch   0.0 0.0 0.0 0.0 0.0 0.0 100 0.0   0   0   0   0 java/2
  2647 huntch   0.0 0.0 0.0 0.0 0.0 0.0 100 0.0   0   0   0   0 java/1



Total: 1 processes, 18 lwps, load averages: 5.61, 3.66, 1.68
```

vmstat

- CPU   The percentage of recent CPU time used by the process.
- VCX   The number of voluntary context switches.
- ICX   The number of involuntary context switches.

Tools For Monitoring : cpubar



- Available on Solaris Performance Tools 3.0 CD, or download from:

http://mediacast.sun.com/share/stefanschneider/PerformanceCD3.0.tar.gz

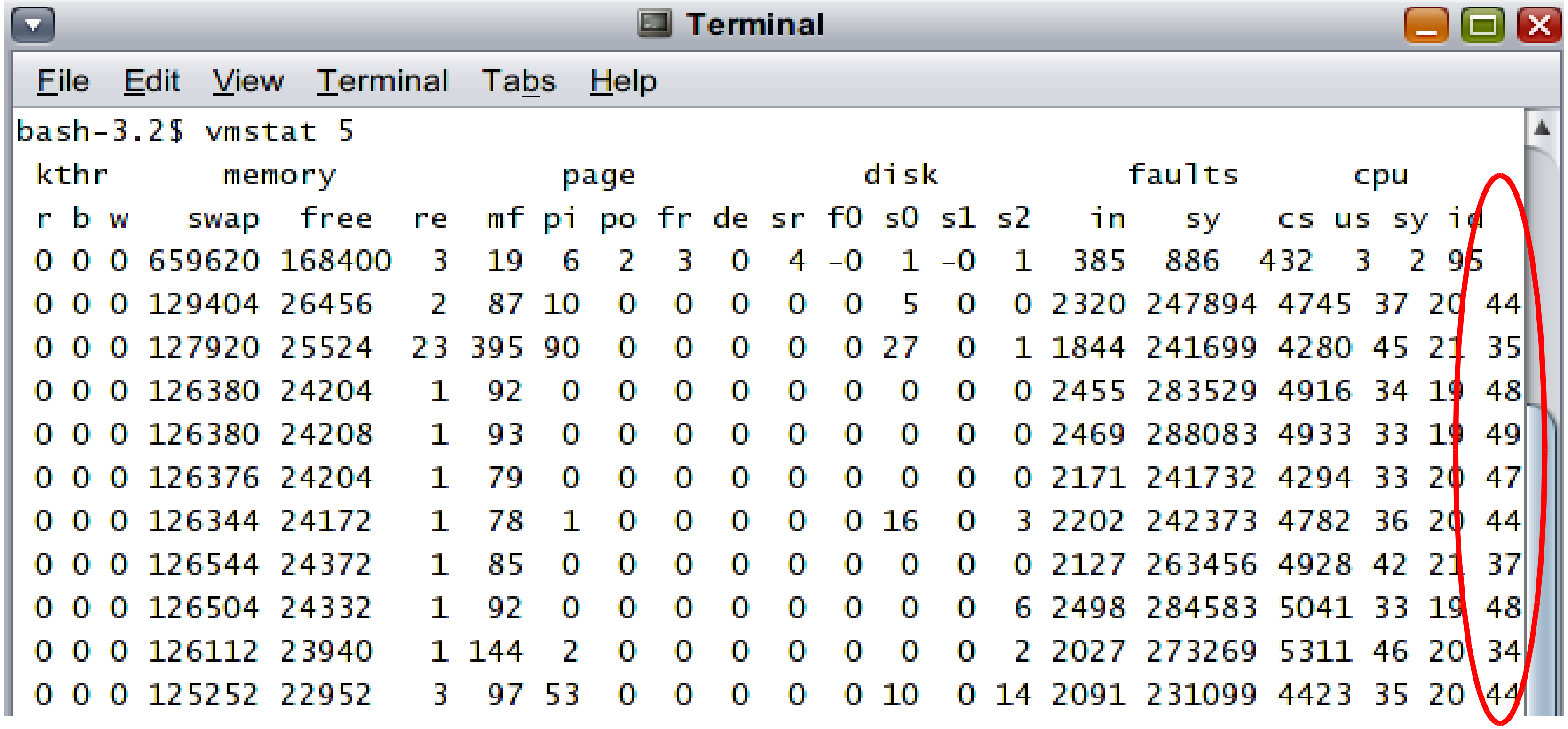
CPU monitoring : What to look for

- Using HotSpot's jps command you can find the process ids of all running Java processes on your machine.
- Using Solaris *prstat -Lm*, or *prstat -Lmp* <*pid*> to locate the LWP id(s) consuming the most cpu (usr or sys) and using HotSpot's *jstack* you can find the executing threads taking the cpu (usr and sys) time.
  - LWPID is in the far right column of prstat.
  - Look for jstack's corresponding 'tid', reported in hex.

CPU monitoring : What to look for

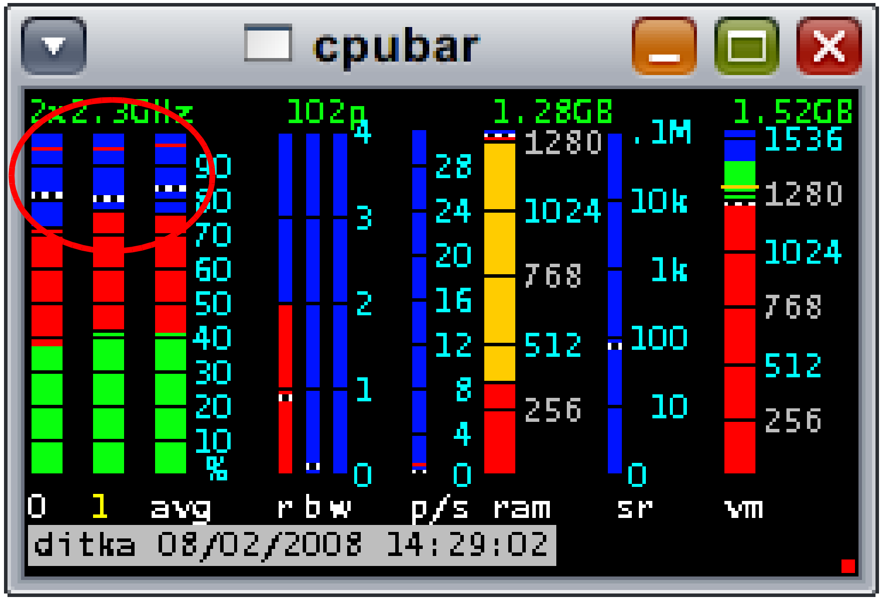
- Idle cpu
  - On multi-threaded applications and multi-core systems, idle cpu can be an indicator of an application's inability to scale.
  - Combination of high sys or kernel CPU utilization and idle CPU could indicate shared resource contention as the scalability blocker.
  - Applicable to all operating systems, i.e. Windows, Linux and Solaris

CPU monitoring : What to look for



```
bash-3.2$ vmstat 5
 kthr      memory            page            disk          faults      cpu
 r b w   swap  free  re  mf pi po fr de sr f0 s0 s1 s2   in   sy   cs us sy id
 0 0 0 659620 168400  3  19  6  2  3  0  4 -0  1 -0  1  385  886  432  3  2 95
 0 0 0 129404 26456   2  87 10  0  0  0  0  0  5  0  0 2320 247894 4745 37 20 44
 0 0 0 127920 25524  23 395 90  0  0  0  0  0 27  0  1 1844 241699 4280 45 21 35
 0 0 0 126380 24204   1  92  0  0  0  0  0  0  0  0  0 2455 283529 4916 34 19 48
 0 0 0 126380 24208   1  93  0  0  0  0  0  0  0  0  0 2469 288083 4933 33 19 49
 0 0 0 126376 24204   1  79  0  0  0  0  0  0  0  0  0 2171 241732 4294 33 20 47
 0 0 0 126344 24172   1  78  1  0  0  0  0  0 16  0  3 2202 242373 4782 36 20 44
 0 0 0 126544 24372   1  85  0  0  0  0  0  0  0  0  0 2127 263456 4928 42 21 37
 0 0 0 126504 24332   1  92  0  0  0  0  0  0  0  0  6 2498 284583 5041 33 19 48
 0 0 0 126112 23940   1 144  2  0  0  0  0  0  0  0  2 2027 273269 5311 46 20 34
 0 0 0 125252 22952   3  97 53  0  0  0  0  0 10  0 14 2091 231099 4423 35 20 44
```

CPU monitoring : What to look for



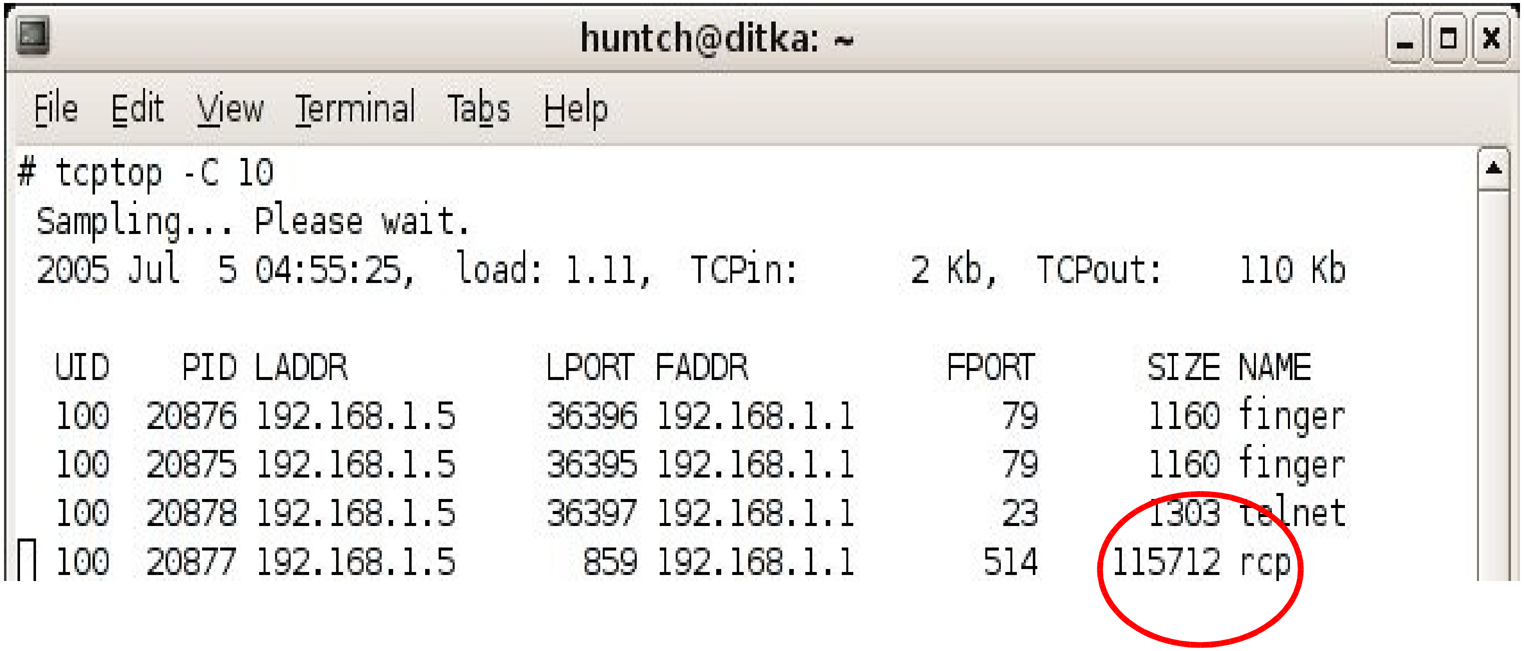
Networking I/O Monitoring at OS Level

Tools For Monitoring : OS Level

- network i/o
  - netstat (Solaris & Linux)
  - Performance Monitor (Windows)
  - dtrace (Solaris)
  - nicstat (Solaris – Performance Tools CD)
  - tcptop (Dtrace Toolkit)
- Data of interest
  - network utilization, established connections,

Network i/o : What to look for

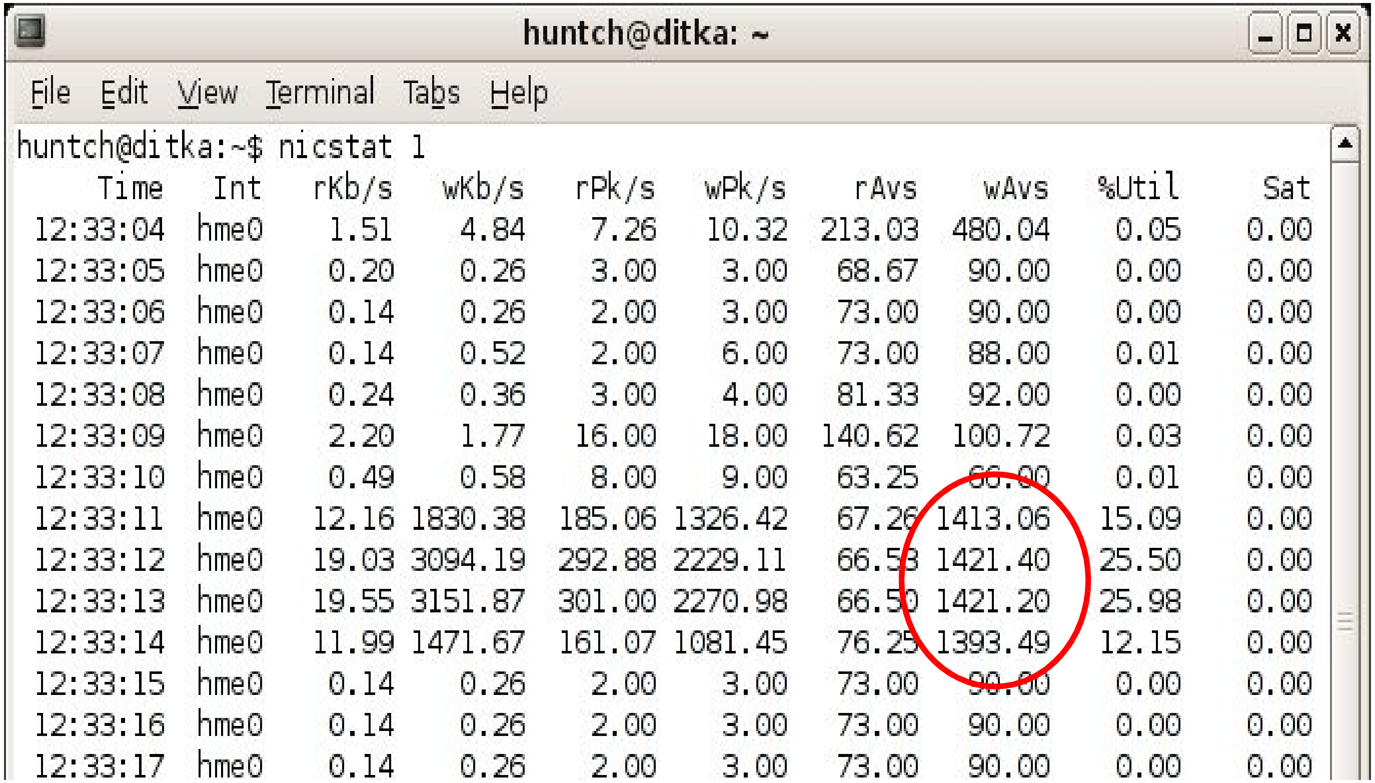
- tcptop can show per process tcp stats



```
# tcptop -C 10
 Sampling... Please wait.
 2005 Jul  5 04:55:25,  load: 1.11,  TCPin:      2 Kb,  TCPout:    110 Kb

  UID    PID LADDR           LPORT FADDR           FPORT      SIZE NAME
  100  20876 192.168.1.5     36396 192.168.1.1        79      1160 finger
  100  20875 192.168.1.5     36395 192.168.1.1        79      1160 finger
  100  20878 192.168.1.5     36397 192.168.1.1        23      1303 telnet
  100  20877 192.168.1.5       859 192.168.1.1       514    115712 rcp
```

- Here we can see 'rcp' is generating about 115 kb of traffic

Tools For Monitoring : nicstat



```
huntch@ditka:~$ nicstat 1
    Time   Int    rKb/s    wKb/s    rPk/s    wPk/s     rAvs     wAvs    %Util     Sat
12:33:04  hme0     1.51     4.84     7.26    10.32   213.03   480.04     0.05    0.00
12:33:05  hme0     0.20     0.26     3.00     3.00    68.67    90.00     0.00    0.00
12:33:06  hme0     0.14     0.26     2.00     3.00    73.00    90.00     0.00    0.00
12:33:07  hme0     0.14     0.52     2.00     6.00    73.00    88.00     0.01    0.00
12:33:08  hme0     0.24     0.36     3.00     4.00    81.33    92.00     0.00    0.00
12:33:09  hme0     2.20     1.77    16.00    18.00   140.62   100.72     0.03    0.00
12:33:10  hme0     0.49     0.58     8.00     9.00    63.25    66.00     0.01    0.00
12:33:11  hme0    12.16  1830.38   185.06  1326.42    67.26  1413.06    15.09    0.00
12:33:12  hme0    19.03  3094.19   292.88  2229.11    66.53  1421.40    25.50    0.00
12:33:13  hme0    19.55  3151.87   301.00  2270.98    66.50  1421.20    25.98    0.00
12:33:14  hme0    11.99  1471.67   161.07  1081.45    76.25  1393.49    12.15    0.00
12:33:15  hme0     0.14     0.26     2.00     3.00    73.00    90.00     0.00    0.00
12:33:16  hme0     0.14     0.26     2.00     3.00    73.00    90.00     0.00    0.00
12:33:17  hme0     0.14     0.26     2.00     3.00    73.00    90.00     0.00    0.00
```

- Notice wAvs, write average size, during four intervals is about 1420 bytes, the MTU size.

Disk I/O Monitoring at OS Level

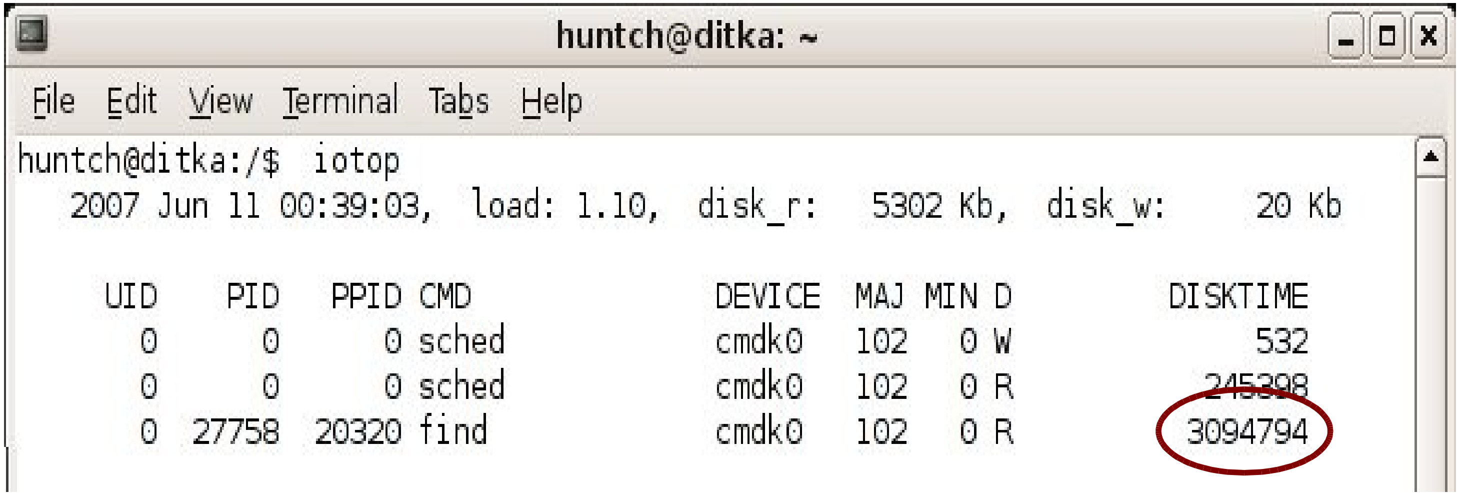
Tools For Monitoring : OS Level

- disk i/o
  - iostat (Solaris & Linux)
  - Performance Monitor (Windows)
  - dtrace (Solaris)
  - iobar (Solaris – Performance Tools CD)
  - iotop (Solaris – Performance Tools CD)
- Data of interest
  - number of disk accesses, latency, average latencies

Tools For Monitoring : iostat, iobar, iotop

- iostat reports per disk, text output
- iobar reports per disk, gui output
- iotop reports per process statistics, text output
- Data of interest
  - number of disk accesses, latency, average latencies

Tools For Monitoring : iotop example



```
huntch@ditka:/$  iotop
   2007 Jun 11 00:39:03,  load: 1.10,  disk_r:   5302 Kb,  disk_w:     20 Kb

     UID    PID   PPID CMD              DEVICE  MAJ MIN D        DISKTIME
       0      0      0 sched            cmdk0   102   0 W             532
       0      0      0 sched            cmdk0   102   0 R          245398
       0  27758  20320 find             cmdk0   102   0 R         3094794
```

- iotop reporting at a 5 second interval
- DISKTIME reported in microseconds
- CMD find is keeping disk cmdk0 busy almost 60% of time during the 5 second interval

disk i/o : What to look for

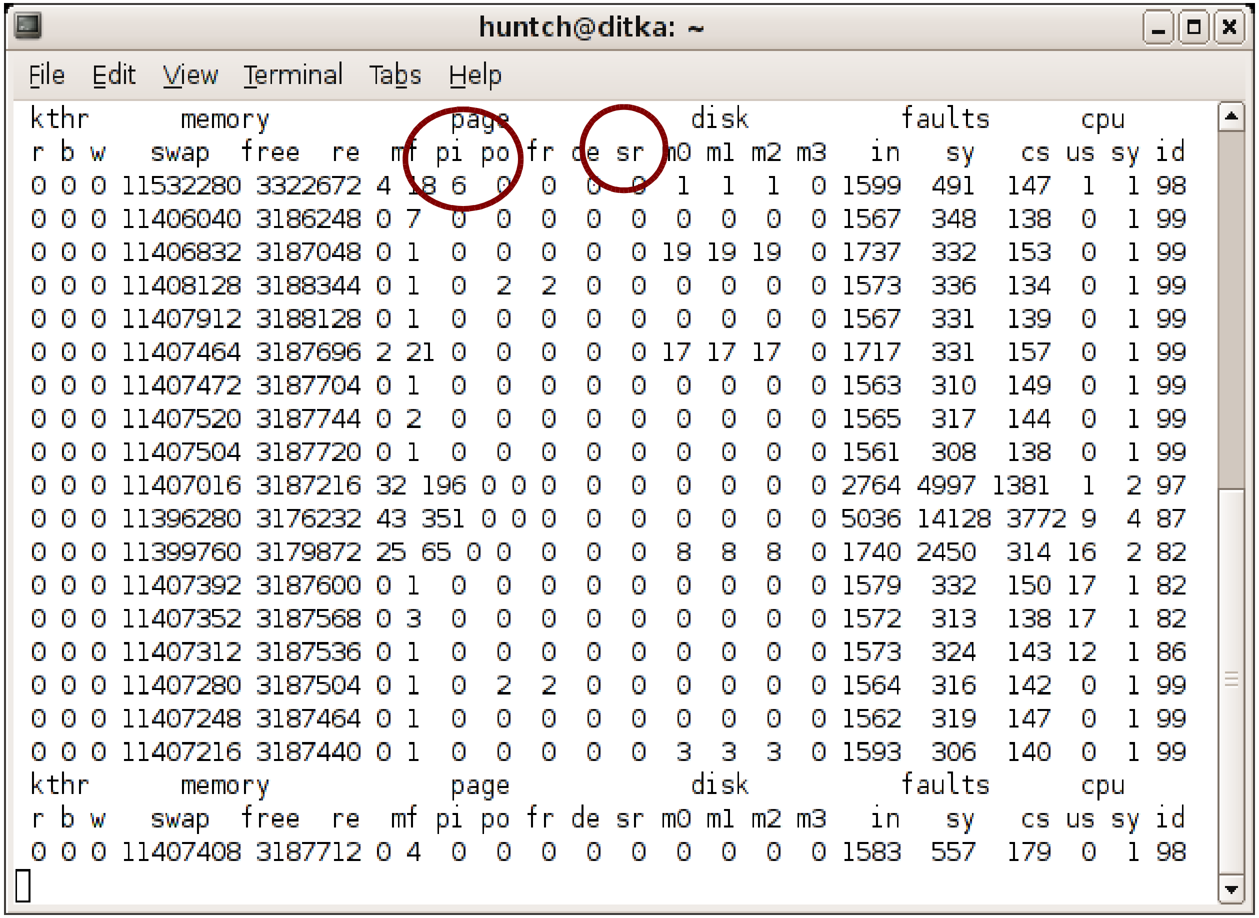
- Disk cache
  - Why not enable disk cache?
  - What's the risk?
  - On Solaris x86, disk cache may be disabled by default. Linux & Windows systems usually have it enabled.
  - Disk cache being disabled depends on the Sun branded model and how recent the model.

Memory Monitoring at OS Level

Tools For Monitoring : OS Level

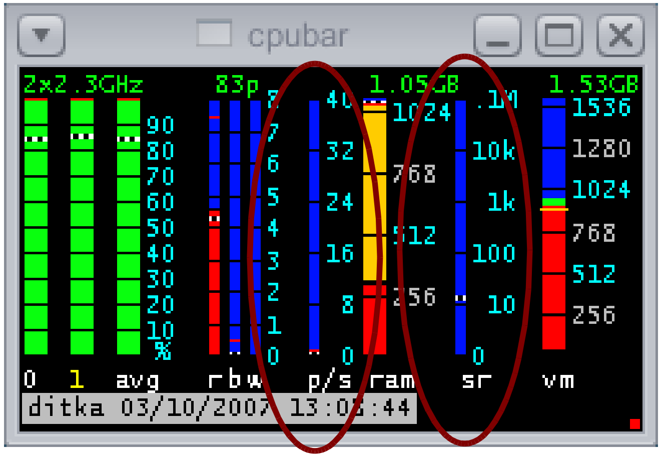
- memory
  - vmstat (Solaris & Linux)
  - prstat (Solaris)
  - top (Linux – prefer prstat on Solaris)
  - Performance Monitor (Windows)
  - dtrace (Solaris)
  - cpubar (Solaris – Performance Tools CD)
  - meminfo (Solaris – Performance Tools CD)
- Data of interest
  - paging, memory usage

Tools For Monitoring : vmstat



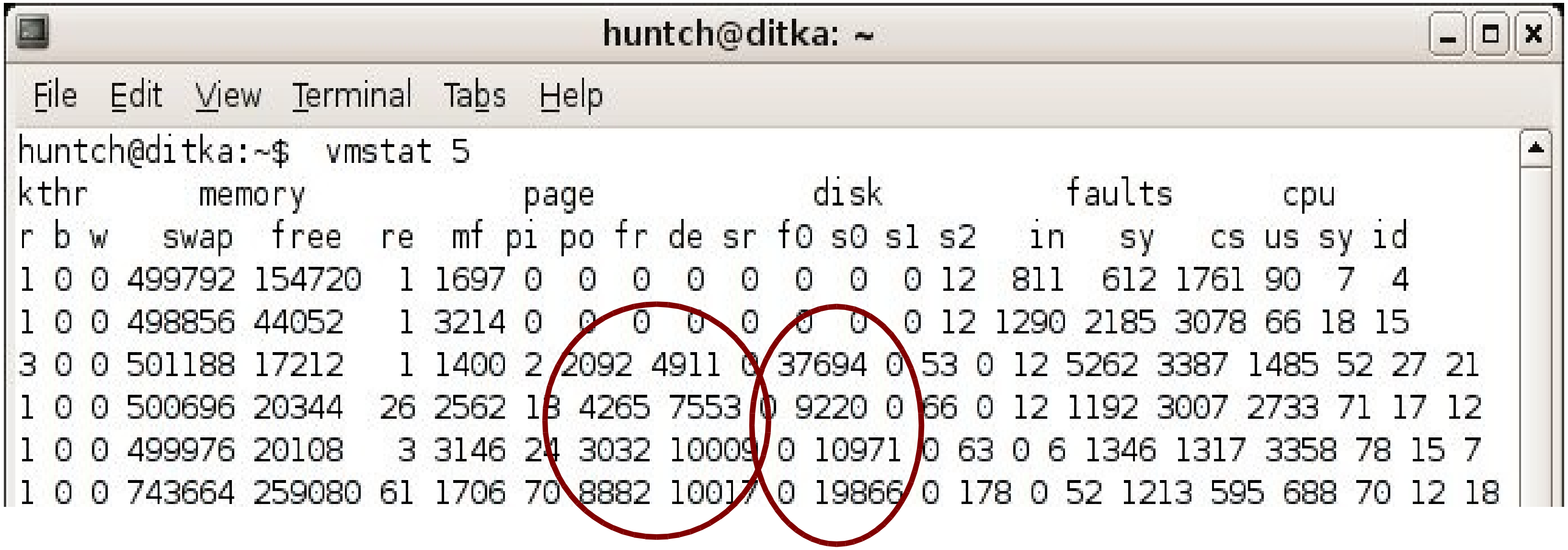
```
kthr      memory            page            disk          faults      cpu
r b w   swap  free  re  mf pi po fr de sr m0 m1 m2 m3   in   sy   cs us sy id
0 0 0 11532280 3322672 4 18 6  0  0  0  0  1  1  1  0 1599  491  147  1  1 98
0 0 0 11406040 3186248 0 7  0  0  0  0  0  0  0  0  0 1567  348  138  0  1 99
0 0 0 11406832 3187048 0 1  0  0  0  0  0 19 19 19  0 1737  332  153  0  1 99
0 0 0 11408128 3188344 0 1  0  2  2  0  0  0  0  0  0 1573  336  134  0  1 99
0 0 0 11407912 3188128 0 1  0  0  0  0  0  0  0  0  0 1567  331  139  0  1 99
0 0 0 11407464 3187696 2 21 0  0  0  0  0 17 17 17  0 1717  331  157  0  1 99
0 0 0 11407472 3187704 0 1  0  0  0  0  0  0  0  0  0 1563  310  149  0  1 99
0 0 0 11407520 3187744 0 2  0  0  0  0  0  0  0  0  0 1565  317  144  0  1 99
0 0 0 11407504 3187720 0 1  0  0  0  0  0  0  0  0  0 1561  308  138  0  1 99
0 0 0 11407016 3187216 32 196 0 0 0  0  0  0  0  0  0 2764 4997 1381  1  2 97
0 0 0 11396280 3176232 43 351 0 0 0  0  0  0  0  0  0 5036 14128 3772 9  4 87
0 0 0 11399760 3179872 25 65 0 0  0  0  0  8  8  8  0 1740 2450  314 16  2 82
0 0 0 11407392 3187600 0 1  0  0  0  0  0  0  0  0  0 1579  332  150 17  1 82
0 0 0 11407352 3187568 0 3  0  0  0  0  0  0  0  0  0 1572  313  138 17  1 82
0 0 0 11407312 3187536 0 1  0  0  0  0  0  0  0  0  0 1573  324  143 12  1 86
0 0 0 11407280 3187504 0 1  0  2  2  0  0  0  0  0  0 1564  316  142  0  1 99
0 0 0 11407248 3187464 0 1  0  0  0  0  0  0  0  0  0 1562  319  147  0  1 99
0 0 0 11407216 3187440 0 1  0  0  0  0  0  3  3  3  0 1593  306  140  0  1 99
kthr      memory            page            disk          faults      cpu
r b w   swap  free  re  mf pi po fr de sr m0 m1 m2 m3   in   sy   cs us sy id
0 0 0 11407408 3187712 0 4  0  0  0  0  0  0  0  0  0 1583  557  179  0  1 98
```

Tools For Monitoring : cpubar



- Data of interest
  - p/s - pages per second, sr - scan rate
  - Watch for high scan rate, or increasing trend. Low scan is ok if they are infrequent.

memory utilization : What to look for



```
huntch@ditka:~$  vmstat 5
kthr      memory            page            disk          faults      cpu
r b w   swap  free  re  mf pi po fr de sr f0 s0 s1 s2   in   sy   cs us sy id
1 0 0 499792 154720  1 1697 0  0  0  0  0  0  0  0 12  811  612 1761 90  7  4
1 0 0 498856 44052   1 3214 0  0  0  0  0  0  0  0 12 1290 2185 3078 66 18 15
3 0 0 501188 17212   1 1400 2 2092 4911 0 37694 0 53 0 12 5262 3387 1485 52 27 21
1 0 0 500696 20344  26 2562 13 4265 7553 0 9220 0 66 0 12 1192 3007 2733 71 17 12
1 0 0 499976 20108   3 3146 24 3032 10009 0 10971 0 63 0 6 1346 1317 3358 78 15 7
1 0 0 743664 259080 61 1706 70 8882 10017 0 19866 0 178 0 52 1213 595 688 70 12 18
```

- Why is swapping bad for a Java application?
- Anyone volunteers want to explain?

memory utilization : What to look for

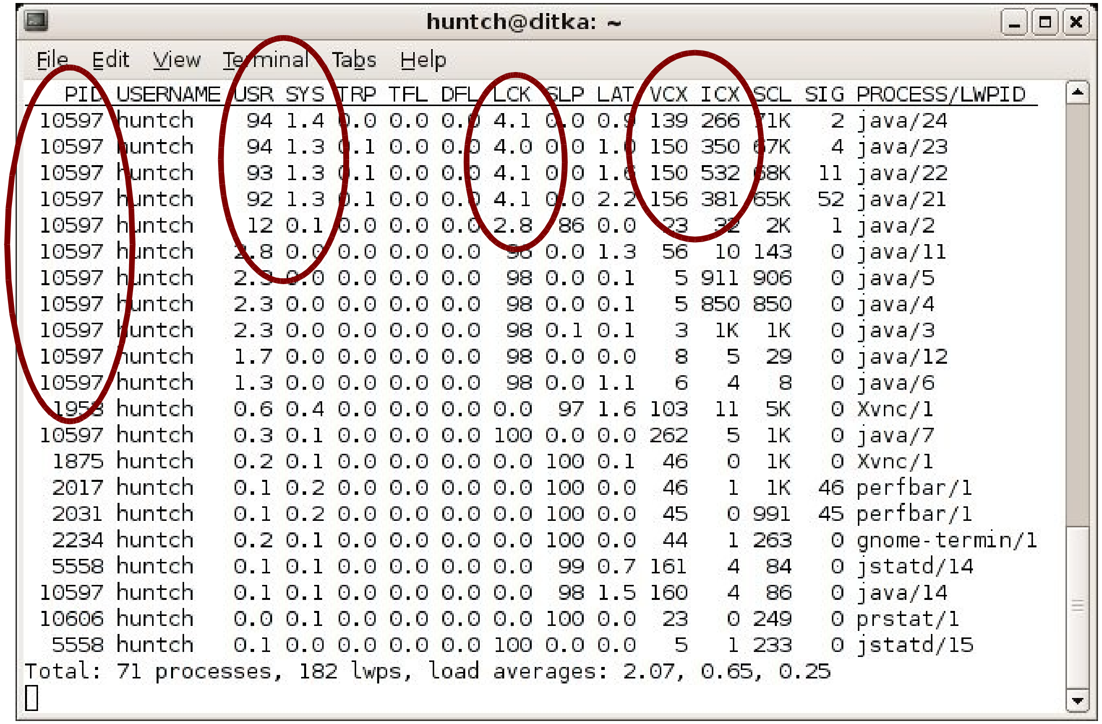
- How do you fix the swapping problem?
  - > Smaller Java heap sizes
  - > Add physical memory
  - > Reduce number of applications running on the machine
  - > Any one, or any combination of the above will help

Processes Monitoring at OS Level

Tools For Monitoring : OS Level

- processes
  - ps (Solaris & Linux)
  - vmstat (Solaris & Linux)
  - mpstat (Solaris)
  - prstat (Solaris)
  - Performance Monitor (Windows)
  - top (Linux – prefer prstat on Solaris)
  - dtrace (Solaris)
- Data of interest
  - footprint size, number of threads, thread state, cpu usage, runtime stack, context switches

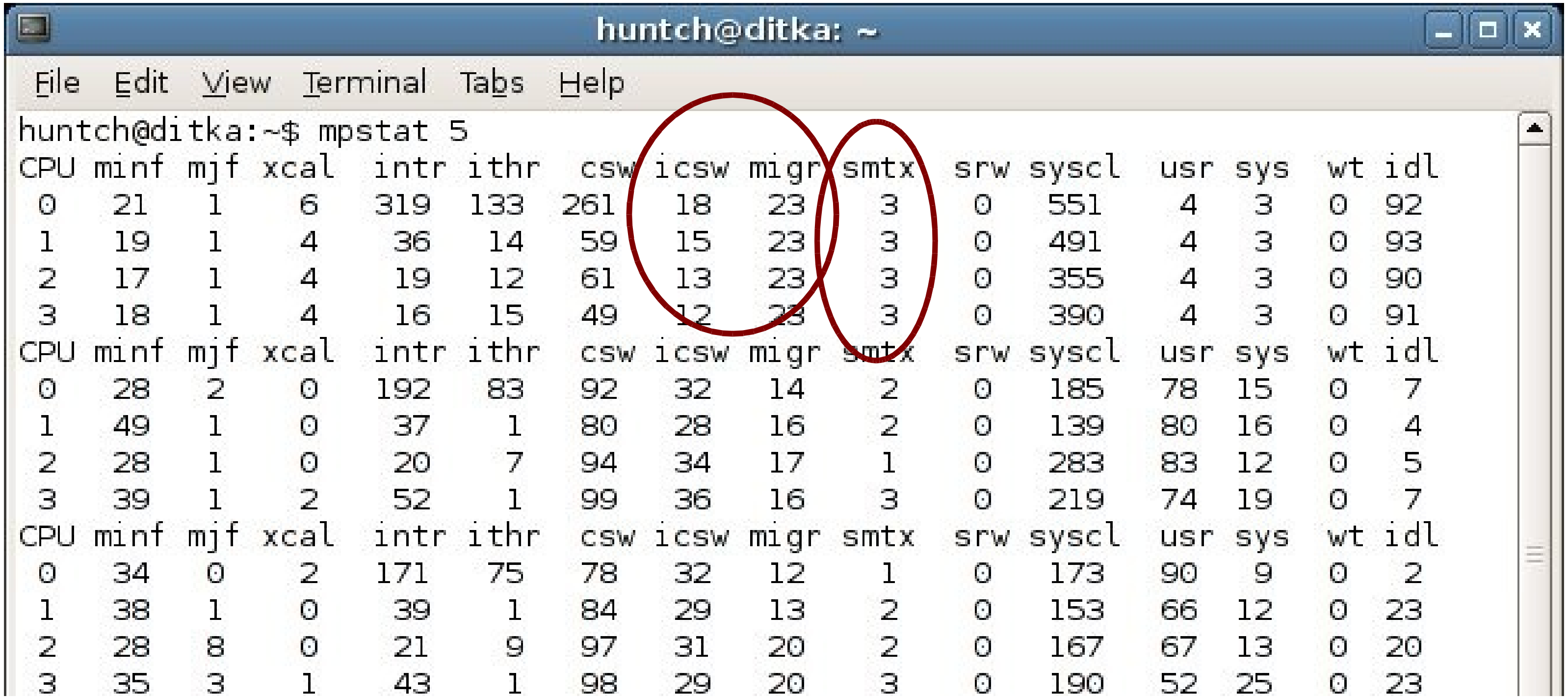
Tools For Monitoring : prstat -Lm



```
  PID USERNAME USR SYS TRP TFL DFL LCK SLP LAT VCX ICX SCL SIG PROCESS/LWPID
10597 huntch    94 1.4 0.0 0.0 0.0 4.1 0.0 0.9 139 266 71K   2 java/24
10597 huntch    94 1.3 0.1 0.0 0.0 4.0 0.0 1.0 150 350 67K   4 java/23
10597 huntch    93 1.3 0.1 0.0 0.0 4.1 0.0 1.6 150 532 68K  11 java/22
10597 huntch    92 1.3 0.1 0.0 0.0 4.1 0.0 2.2 156 381 65K  52 java/21
10597 huntch    12 0.1 0.0 0.0 0.0 2.8  86 0.0  23  32  2K   1 java/2
10597 huntch   2.8 0.0 0.0 0.0 0.0  98 0.0 1.3  56  10 143   0 java/11
10597 huntch   2.3 0.0 0.0 0.0 0.0  98 0.0 0.1   5 911 906   0 java/5
10597 huntch   2.3 0.0 0.0 0.0 0.0  98 0.0 0.1   5 850 850   0 java/4
10597 huntch   2.3 0.0 0.0 0.0 0.0  98 0.1 0.1   3  1K  1K   0 java/3
10597 huntch   1.7 0.0 0.0 0.0 0.0  98 0.0 0.0   8   5  29   0 java/12
10597 huntch   1.3 0.0 0.0 0.0 0.0  98 0.0 1.1   6   4   8   0 java/6
 1958 huntch   0.6 0.4 0.0 0.0 0.0 0.0  97 1.6 103  11  5K   0 Xvnc/1
10597 huntch   0.3 0.1 0.0 0.0 0.0 100 0.0 0.0 262   5  1K   0 java/7
 1875 huntch   0.2 0.1 0.0 0.0 0.0 0.0 100 0.1  46   0  1K   0 Xvnc/1
 2017 huntch   0.1 0.2 0.0 0.0 0.0 0.0 100 0.0  46   1  1K  46 perfbar/1
 2031 huntch   0.1 0.2 0.0 0.0 0.0 0.0 100 0.0  45   0 991  45 perfbar/1
 2234 huntch   0.2 0.1 0.0 0.0 0.0 0.0 100 0.0  44   1 263   0 gnome-termin/1
 5558 huntch   0.1 0.1 0.0 0.0 0.0 0.0  99 0.7 161   4  84   0 jstatd/14
10597 huntch   0.1 0.1 0.0 0.0 0.0 0.0  98 1.5 160   4  86   0 java/14
10606 huntch   0.0 0.1 0.0 0.0 0.0 0.0 100 0.0  23   0 249   0 prstat/1
 5558 huntch   0.1 0.0 0.0 0.0 0.0 100 0.0 0.0   5   1 233   0 jstatd/15
Total: 71 processes, 182 lwps, load averages: 2.07, 0.65, 0.25
```

- Data of interest
  - number of threads, cpu usage, locks, context switches

Tools For Monitoring : mpstat



```
huntch@ditka:~$ mpstat 5
CPU minf mjf xcal  intr ithr  csw icsw migr smtx  srw syscl  usr sys  wt idl
  0   21   1    6   319  133  261   18   23    3    0   551    4   3   0  92
  1   19   1    4    36   14   59   15   23    3    0   491    4   3   0  93
  2   17   1    4    19   12   61   13   23    3    0   355    4   3   0  90
  3   18   1    4    16   15   49   12   23    3    0   390    4   3   0  91
CPU minf mjf xcal  intr ithr  csw icsw migr smtx  srw syscl  usr sys  wt idl
  0   28   2    0   192   83   92   32   14    2    0   185   78  15   0   7
  1   49   1    0    37    1   80   28   16    2    0   139   80  16   0   4
  2   28   1    0    20    7   94   34   17    1    0   283   83  12   0   5
  3   39   1    2    52    1   99   36   16    3    0   219   74  19   0   7
CPU minf mjf xcal  intr ithr  csw icsw migr smtx  srw syscl  usr sys  wt idl
  0   34   0    2   171   75   78   32   12    1    0   173   90   9   0   2
  1   38   1    0    39    1   84   29   13    2    0   153   66  12   0  23
  2   28   8    0    21    9   97   31   20    2    0   167   67  13   0  20
  3   35   3    1    43    1   98   29   20    3    0   190   52  25   0  23
```

- Data of interest
  - > context switches, lock contention

processes : What to look for

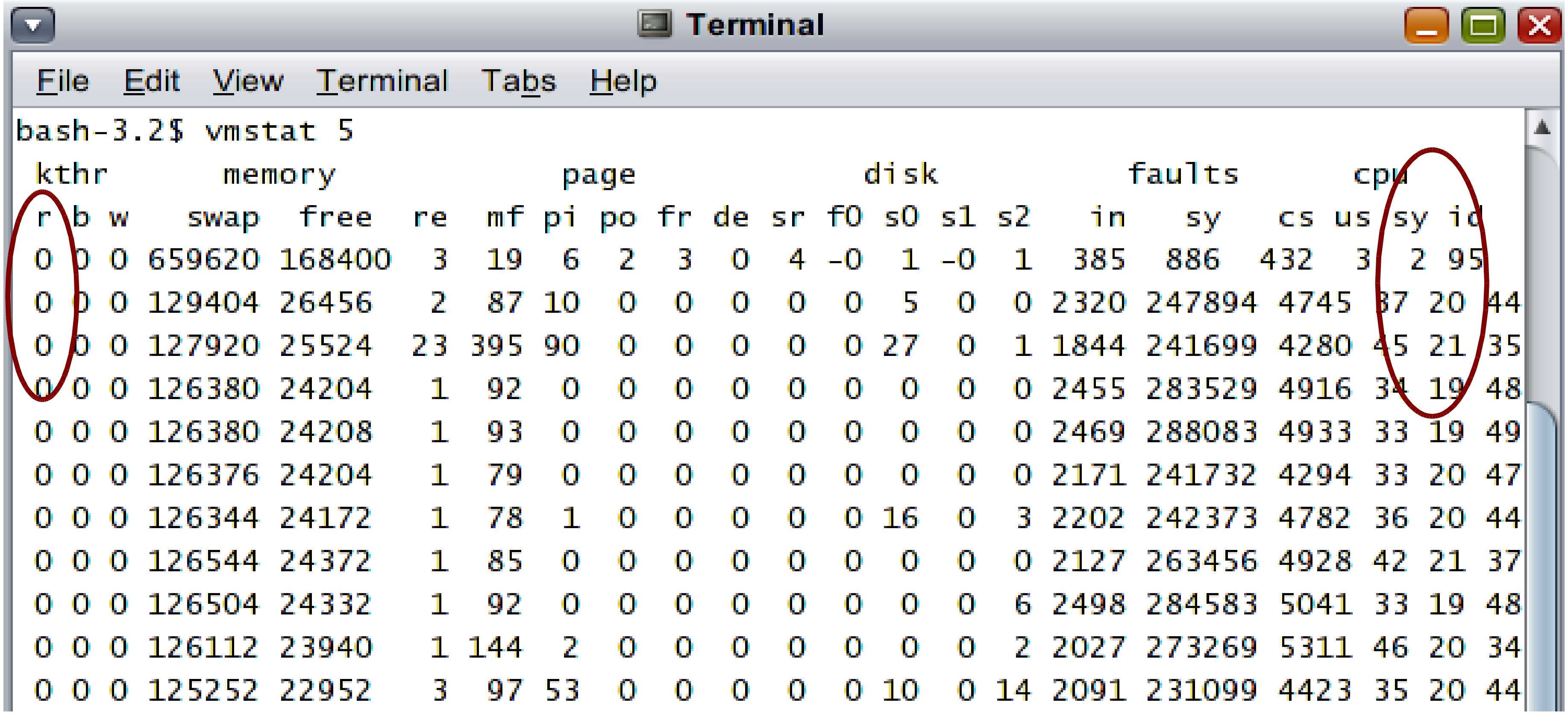
- Why footprint size, number of threads, thread state, lock contention and context switching are important to monitor?
- What does lock contention and/or context switching look like on Solaris?
- How can you find the lock or locks causing problems?
- How can you address the thread context switching problem?

Kernel Monitoring at OS Level

Tools For Monitoring : OS Level

- kernel
  - vmstat (Linux & Solaris)
  - mpstat (Solaris)
  - lockstat & plockstat (Solaris)
  - Performance Monitor (Windows)
  - dtrace (Solaris)
  - intrstat (Solaris)
- Data of interest
  - kernel cpu utilization, locks, system calls, interrupts, migrations, run queue depth

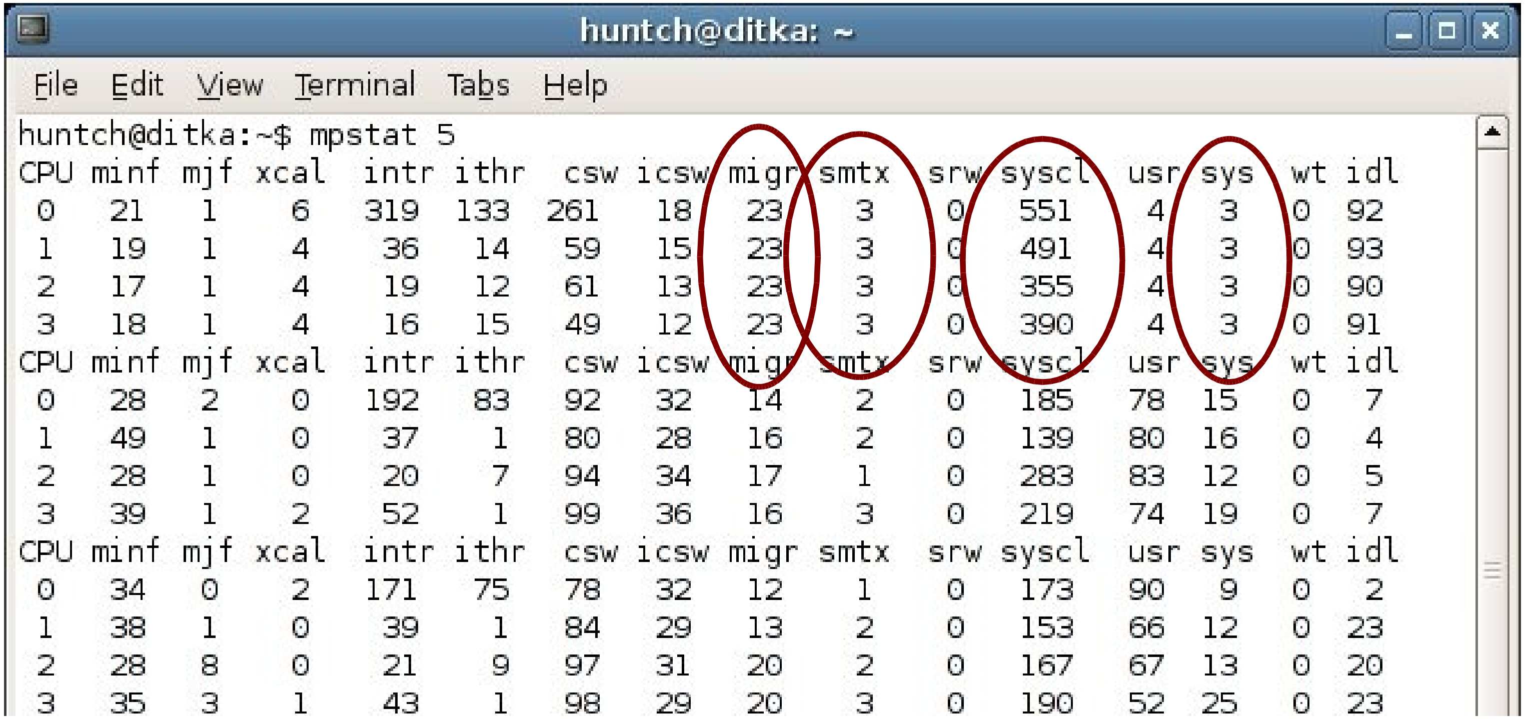
Tools For Monitoring : vmstat



```
bash-3.2$ vmstat 5
 kthr      memory            page            disk          faults      cpu
 r b w   swap  free  re  mf pi po fr de sr f0 s0 s1 s2   in   sy   cs us sy id
 0 0 0 659620 168400  3  19  6  2  3  0  4 -0  1 -0  1  385  886  432  3  2 95
 0 0 0 129404 26456   2  87 10  0  0  0  0  0  5  0  0 2320 247894 4745 37 20 44
 0 0 0 127920 25524  23 395 90  0  0  0  0  0 27  0  1 1844 241699 4280 45 21 35
 0 0 0 126380 24204   1  92  0  0  0  0  0  0  0  0  0 2455 283529 4916 34 19 48
 0 0 0 126380 24208   1  93  0  0  0  0  0  0  0  0  0 2469 288083 4933 33 19 49
 0 0 0 126376 24204   1  79  0  0  0  0  0  0  0  0  0 2171 241732 4294 33 20 47
 0 0 0 126344 24172   1  78  1  0  0  0  0  0 16  0  3 2202 242373 4782 36 20 44
 0 0 0 126544 24372   1  85  0  0  0  0  0  0  0  0  0 2127 263456 4928 42 21 37
 0 0 0 126504 24332   1  92  0  0  0  0  0  0  0  0  6 2498 284583 5041 33 19 48
 0 0 0 126112 23940   1 144  2  0  0  0  0  0  0  0  2 2027 273269 5311 46 20 34
 0 0 0 125252 22952   3  97 53  0  0  0  0  0 10  0 14 2091 231099 4423 35 20 44
```

- Data of interest
  - > kernel cpu utilization, run queue depth

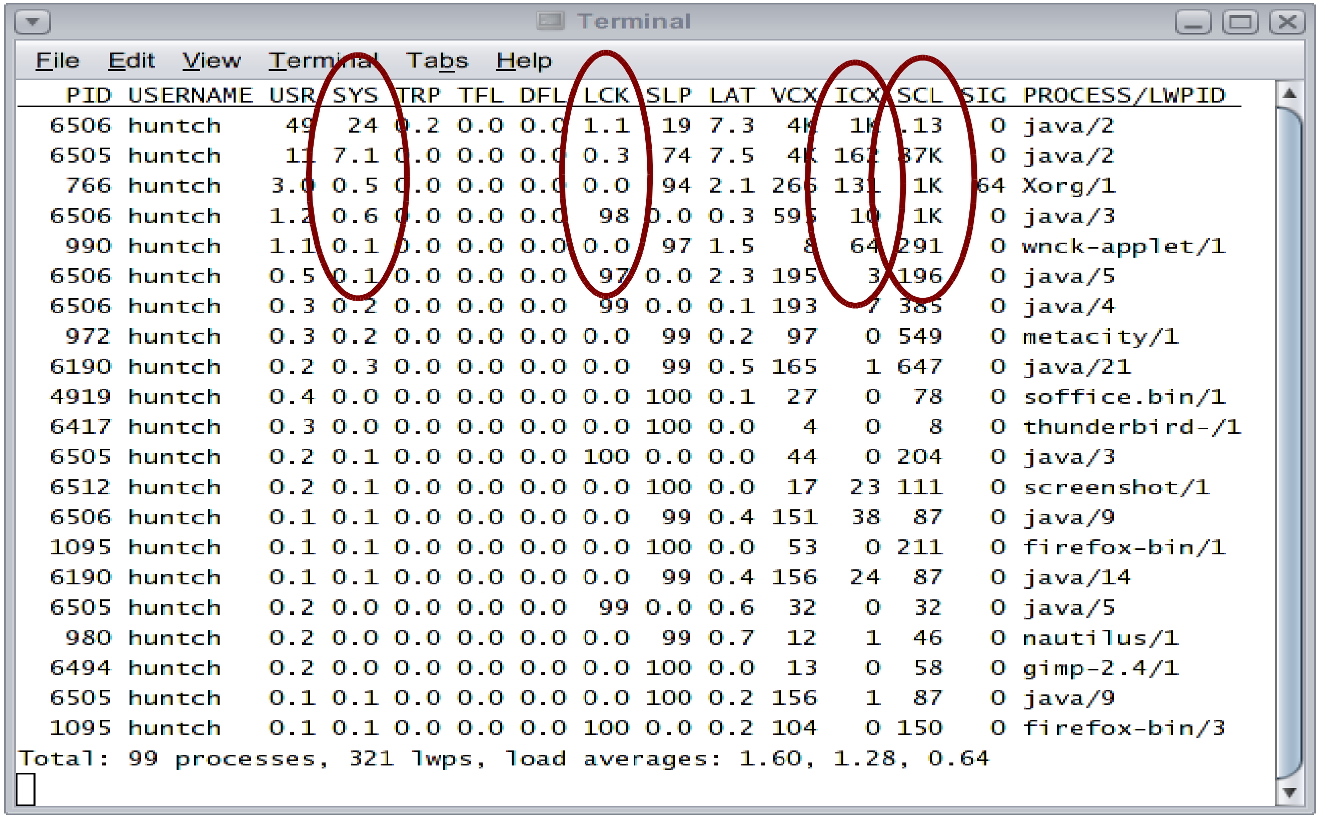
Tools For Monitoring : mpstat



```
huntch@ditka:~$ mpstat 5
CPU minf mjf xcal  intr ithr  csw icsw migr smtx  srw syscl  usr sys  wt idl
  0   21   1    6   319  133  261   18   23    3    0   551    4   3   0  92
  1   19   1    4    36   14   59   15   23    3    0   491    4   3   0  93
  2   17   1    4    19   12   61   13   23    3    0   355    4   3   0  90
  3   18   1    4    16   15   49   12   23    3    0   390    4   3   0  91
CPU minf mjf xcal  intr ithr  csw icsw migr smtx  srw syscl  usr sys  wt idl
  0   28   2    0   192   83   92   32   14    2    0   185   78  15   0   7
  1   49   1    0    37    1   80   28   16    2    0   139   80  16   0   4
  2   28   1    0    20    7   94   34   17    1    0   283   83  12   0   5
  3   39   1    2    52    1   99   36   16    3    0   219   74  19   0   7
CPU minf mjf xcal  intr ithr  csw icsw migr smtx  srw syscl  usr sys  wt idl
  0   34   0    2   171   75   78   32   12    1    0   173   90   9   0   2
  1   38   1    0    39    1   84   29   13    2    0   153   66  12   0  23
  2   28   8    0    21    9   97   31   20    2    0   167   67  13   0  20
  3   35   3    1    43    1   98   29   20    3    0   190   52  25   0  23
```

- Data of interest
  - > kernel cpu utilization, locks, system calls, interrupts, migrations

Tools For Monitoring : prstat -Lm



```
   PID USERNAME USR SYS TRP TFL DFL LCK SLP LAT VCX ICX SCL SIG PROCESS/LWPID
  6506 huntch    49  24 0.2 0.0 0.0 1.1  19 7.3  4K  1K 113   0 java/2
  6505 huntch    11 7.1 0.0 0.0 0.0 0.3  74 7.5  4K 162 87K   0 java/2
   766 huntch   3.0 0.5 0.0 0.0 0.0 0.0  94 2.1 266 131  1K  64 Xorg/1
  6506 huntch   1.2 0.6 0.0 0.0 0.0  98 0.0 0.3 595  10  1K   0 java/3
   990 huntch   1.1 0.1 0.0 0.0 0.0 0.0  97 1.5   8  64 291   0 wnck-applet/1
  6506 huntch   0.5 0.1 0.0 0.0 0.0  97 0.0 2.3 195   3 196   0 java/5
  6506 huntch   0.3 0.2 0.0 0.0 0.0  99 0.0 0.1 193   7 385   0 java/4
   972 huntch   0.3 0.2 0.0 0.0 0.0 0.0  99 0.2  97   0 549   0 metacity/1
  6190 huntch   0.2 0.3 0.0 0.0 0.0 0.0  99 0.5 165   1 647   0 java/21
  4919 huntch   0.4 0.0 0.0 0.0 0.0 0.0 100 0.1  27   0  78   0 soffice.bin/1
  6417 huntch   0.3 0.0 0.0 0.0 0.0 0.0 100 0.0   4   0   8   0 thunderbird-/1
  6505 huntch   0.2 0.1 0.0 0.0 0.0 100 0.0 0.0  44   0 204   0 java/3
  6512 huntch   0.2 0.1 0.0 0.0 0.0 0.0 100 0.0  17  23 111   0 screenshot/1
  6506 huntch   0.1 0.1 0.0 0.0 0.0 0.0  99 0.4 151  38  87   0 java/9
  1095 huntch   0.1 0.1 0.0 0.0 0.0 0.0 100 0.0  53   0 211   0 firefox-bin/1
  6190 huntch   0.1 0.1 0.0 0.0 0.0 0.0  99 0.4 156  24  87   0 java/14
  6505 huntch   0.2 0.0 0.0 0.0 0.0  99 0.0 0.6  32   0  32   0 java/5
   980 huntch   0.2 0.0 0.0 0.0 0.0 0.0  99 0.7  12   1  46   0 nautilus/1
  6494 huntch   0.2 0.0 0.0 0.0 0.0 0.0 100 0.0  13   0  58   0 gimp-2.4/1
  6505 huntch   0.1 0.1 0.0 0.0 0.0 0.0 100 0.2 156   1  87   0 java/9
  1095 huntch   0.1 0.1 0.0 0.0 0.0 100 0.0 0.2 104   0 150   0 firefox-bin/3
Total: 99 processes, 321 lwps, load averages: 1.60, 1.28, 0.64
```

- Data of interest
  - > kernel cpu utilization, locks, system calls, involuntary context switches

kernel : What to look for

- Why are high sys / kernel cpu, run queue depth, lock contention, migrations and context switching are important to monitor?
  - > Discussion
- What do they indicate when each is observed?
  - > Discussion
- How to do you address each of these problems?
  - > Discussion

Monitoring Tools at the JVM-Level

Tools For Monitoring: JVM

- Garbage Collection
  - -verbose:gc
  - -XX:+PrintGCTimeStamps
  - -XX:+PrintGCDetails
  - -XX:+PrintGCApplicationStoppedTime
  - -XX:+PrintGCApplicationConcurrentTime
  - jstat, jps
  - Jconsole
  - VisualVM
  - VisualGC
  - dtrace (HotSpot JDK 6 contains samples)

Tools For Monitoring: JVM

- Garbage Collection Data of Interest
  - Frequency and duration of collections
  - Java heap usage
  - Number of application threads
  - Lock contention
  - CPU usage

Tools For Monitoring : -verbose:gc

- -verbose:gc
  - > [GC 1884K->1299K(5056K), 0.0031820 secs]
- With -XX:+PrintGCTimeStamps
  - > 3.791: [GC 1884K->1299K(5056K), 0.0031820 secs]
- Data of interest
  - > frequency and duration, heap usage
- Explain what pattern(s) indicate potential problems.
  - > Quick demo

Tools For Monitoring : GCDetails

- -XX:+PrintGCDetails
- [GC [DefNew: 490K->64K(960K), 0.0032800 secs] 5470K->5151K(7884K), 0.0033270 secs] [Times: user=0.00 sys=0.00, real=0.00 secs]
- [Full GC (System) [Tenured: 5087K->5151K(6924K), 0.0971070 secs] 6047K->5151K(7884K), [Perm : 11178K->11178K(16384K)], 0.0972120 secs] [Times: user=0.10 sys=0.01, real=0.10 secs]
- Data of interest
  - frequency and duration, heap usage

Tools For Monitoring : pause time

- -XX:+PrintGCApplicationStoppedTime
- -XX:+PrintGCApplicationConcurrentTime
- Helpful when tuning pause time sensitive applications
- Useful for identifying odd pause time issues when combined with gc timestamps and gc duration.

Tools For Monitoring : jps

- jps
  - included in the HotSpot JDK.
  - command line utility to find running java processes.
  - jps [-q] [-mlvV] [<hostid> where <hostid> = <hostname>[:<port>]

Tools For Monitoring : jstat

- jstat
  - included in the HotSpot JDK.
  - command line utility.
  - jstat -<option> [-t] [-h<lines>] <vmid> [<internal> [<count>]]
  - Garbage collection option(s):
    - -gc, -gccapacity, -gccause, -gcnew, -gcnewcapacity, -gcold, -gcoldcapacity, -gcpermcapacity, -gcutil

Tools For Monitoring : jstat

- *Beware*: When using the concurrent collector (CMS), jstat reports two full gc events per CMS cycle, obviously misleading.
- But, young generation stats are accurate with CMS.

Tools For Monitoring : jconsole

- jconsole
  - Monitoring and management GUI console.
  - Included in the HotSpot JDK.
  - Attach local or remote.
  - Monitor internals of a target JVM.
  - Monitor multiple JVMs.
  - Explain what patterns indicate potential problems.

Tools For Monitoring : jconsole

- Endless observability
  - MBean support for
    - JVM memory usage by memory pool / spaces
    - Class loading, JIT compilation, garbage collector, runtime, threading and logging
    - Thread monitor contention
  - Graphical view of heap memory, threads, cpu usage and class loading

Tools For Monitoring : VisualVM

- VisualVM
  - Open source project at https://visualvm.dev.java.net
  - Integrates several existing JDK software tools, lightweight memory and CPU profiling capabilities.
    - JConsole
    - Subset of NetBeans Profiler
  - Includes performance analysis and troubleshooting abilities.
    - Thread deadlock detection
    - Thread monitor contention

Tools For Monitoring : VisualVM

- VisualVM
  - Can be further extended with specific functionality for target application via additional plug-in or extending an existing plug-in.
    - Possibilities include; GlassFish performance monitoring plug-in, JavaDB performance monitoring plug-in and external vendors such as WebSphere performance monitoring plug-in.
  - Plugins, enhancements and updates delivered through VisualVM plug-in center.

Tools For Monitoring : VisualVM

- VisualVM
  - Explain what patterns indicate potential performance issues.

Tools For Monitoring : VisualGC

- VisualGC
  - Standalone GUI or VisualVM plug-in.
  - Not included in HotSpot JDK. Separate download.
  - Visually observe garbage collection behavior. (A picture is worth a thousand words).
  - Also includes classloading and JIT compilation information.

Tools For Monitoring : JVM

- JIT Compilation
  - jstat
  - Jconsole
  - VisualVM
  - VisualGC
  - -XX:+PrintCompilation (can be intrusive)
  - -XX:+LogCompilation (can be intrusive)
  - DTrace (HotSpot JDK 6 contains samples)
- Data of interest
  - frequency, duration, possible opt / de-opt cycles, failed compilations

Tools For Monitoring : JIT

- -XX:+PrintCompilation
- 1   java.util.Properties$LineReader::readLine (452 bytes)
- 2   java.lang.String::hashCode (60 bytes)
- 3   java.lang.String::equals (88 bytes)
- 3   made not entrant (2) java.lang.String::equals (88 bytes)
- 4   java.lang.Object::<init> (1 bytes)
- 5   java.lang.String::indexOf (151 bytes)
- Data of interest
  - > frequency, duration, possible opt / de-opt cycles, (explain the patterns which indicate trouble)

Tools For Monitoring : JIT

- -XX:+LogCompilation
  - Beware, it can be intrusive
- Will probably need someone from JIT compiler team to analyze it.
- Data of interest
  - frequency, duration, possible opt / de-opt cycles

Tools For Monitoring : JIT

- Using .hotspot_compiler file
- When & why to use it?
  - JIT compiler in an endless loop attempting a “heroic” optimization which will not converge
  - JIT compiler in a de-optimization – re-optimization cycle
  - JIT compiler producing 'bad' code resulting in a core dump or other severe problem

Tools For Monitoring : JIT

- Using .hotspot_compiler file, continued ...
- What is the format?
  - exclude A/B/C/D methodName where
  - A.B.C.D is the fully qualified package and class name and methodName is the method name.
  - To exclude java.util.HashMap.clear(), specify:
    - exclude java/util/HashMap clear

Monitoring Tools at the Application-Level

Tools For Monitoring : Application

- Application throughput and / or responsiveness
  - JConsole (application Mbeans)
  - Extend VisualVM with a plug-in to gather Java application data of interest and monitor the application with VisualVM
  - Application log
  - Specialized DTrace scripts
- Data of interest
  - critical application information and instrumentation

Performance Monitoring (focused on Java SE)