Solaris Performance: Introduction

Brendan Gregg

Sun Microsystems

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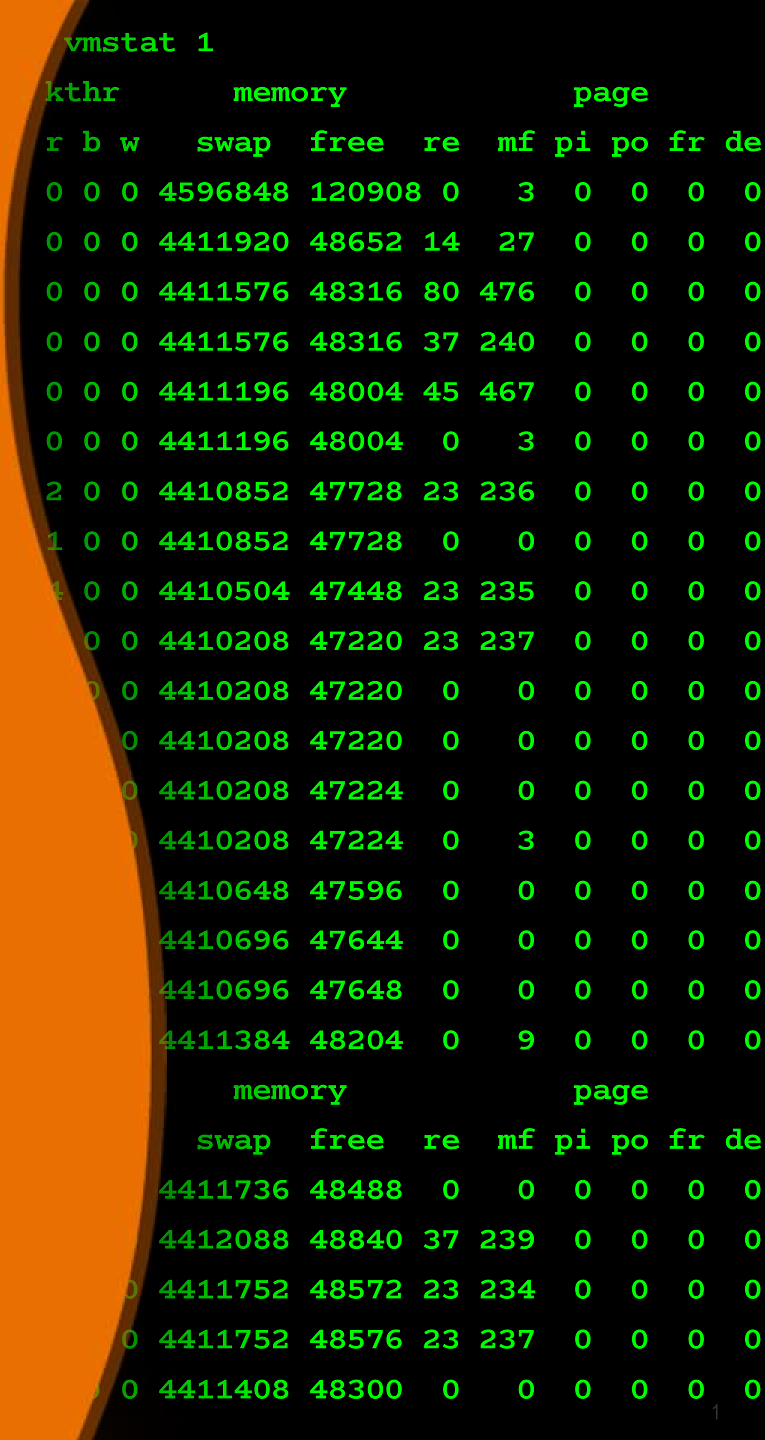


```
 vmstat 1
kthr      memory            page
r b w   swap  free  re  mf pi po fr de
0 0 0 4596848 120908 0   3  0  0  0  0
0 0 0 4411920 48652 14  27  0  0  0  0
0 0 0 4411576 48316 80 476  0  0  0  0
0 0 0 4411576 48316 37 240  0  0  0  0
0 0 0 4411196 48004 45 467  0  0  0  0
0 0 0 4411196 48004  0   3  0  0  0  0
2 0 0 4410852 47728 23 236  0  0  0  0
1 0 0 4410852 47728  0   0  0  0  0  0
4 0 0 4410504 47448 23 235  0  0  0  0
  0 0 4410208 47220 23 237  0  0  0  0
  0 0 4410208 47220  0   0  0  0  0  0
    0 4410208 47220  0   0  0  0  0  0
    0 4410208 47224  0   0  0  0  0  0
    0 4410208 47224  0   3  0  0  0  0
      4410648 47596  0   0  0  0  0  0
      4410696 47644  0   0  0  0  0  0
      4410696 47648  0   0  0  0  0  0
      4411384 48204  0   9  0  0  0  0
          memory            page
        swap  free  re  mf pi po fr de
      4411736 48488  0   0  0  0  0  0
      4412088 48840 37 239  0  0  0  0
    0 4411752 48572 23 234  0  0  0  0
    0 4411752 48576 23 237  0  0  0  0
  0 0 4411408 48300  0   0  0  0  0  0
```

Solaris Performance: Introduction

- This presentation is an introduction to the field of Solaris performance.
- These slides cover:
  - Solaris Performance Features
    - Top Features
    - Solaris
    - Solaris 10
  - Solaris Performance Observability
    - By-Layer Strategy
    - 3-Metric Strategy
    - System Components

Performance Matters

- How performance helps *you*:
  1. Shipped performance features
     - Solaris can do more with less
  2. Tune performance features
     - Solaris tunables, library features, compiler optimisation, ...
  3. Manage resources
     - Get the best ROI
  4. Solve performance issues
     - Solaris has outstanding performance observability

Solaris Performance Features

- Solaris is a mature operating system with numerous performance features
- Top performance features are,
  - > CPU and Memory Scaleability
  - > 64-bit Support
  - > Fully Preemptive Kernel
  - > Resource Management
  - > Compiler Technology
  - > Observability

CPU and Memory Scaleability

- Sun bet on SMP in early 90's
  - Symmetric Multi Processing: user and kernel work distributed across all CPUs - best scaleability
- Per-CPU dispatcher queues
- Thread CPU affinity
- Processor sets and interrupt masking
- CMP and CMT support and optimisations
- Memory locality aware
- Kernel page relocation - for hot plug and DR

64-Bit Support

- Since Solaris 7 (October 1998)
- Originally for SPARC, now also AMD64 and IA-64

Fully Preemptive Kernel

- Allows Real Time scheduling class

Resource Management

- Standard tools: pbind, ulimit
- Processor sets, pools
- IPQoS - IP Quality of Service (network priorities)
- SRM - Solaris Resource Manager
- Zones + SRM = Containers
- FSS - Fair Share Schedular
- Resource Controls
  - > CPU shares
  - > Max threads, CPU time, file descriptors, ...

Compiler Technology

- Sun Studio compiler optimises for SPARC, x86
- Both gcc and cc can be used (try both and see)
- Java VM - hotspot compiler

Observability

- DTrace
- Microstate Accounting - prstat -mL
- kstat - vmstat, mpstat, ...
- procfs - ps, prstat, truss, ...
- PICs - cpustat/cputrack, busstat

Solaris Performance Feature List

- Scaleability
- Reliability
- Fully preemptive kernel
- Real-Time scheduling class
- Cyclic page cache
- Inode cache
- UFS buffer cache
- DNLC
- 64-bit support
- direct I/O
- cpustat/cputrack
- truss/apptrace
- libumem
- lgroups
- TCP MDT
- cyclics
- processor sets
- kstat
- procfs
- SNMP
- DISM
- NCA
- MPSS
- MPO
- rcapd
- SRM

Solaris 10 Performance Feature List

- DTrace
- ZFS
- Zones
- FireEngine - faster TCP/IP
- SMF - faster boot
- CMT, Niagara
- Numerous performance improvements (many found using DTrace)

Status

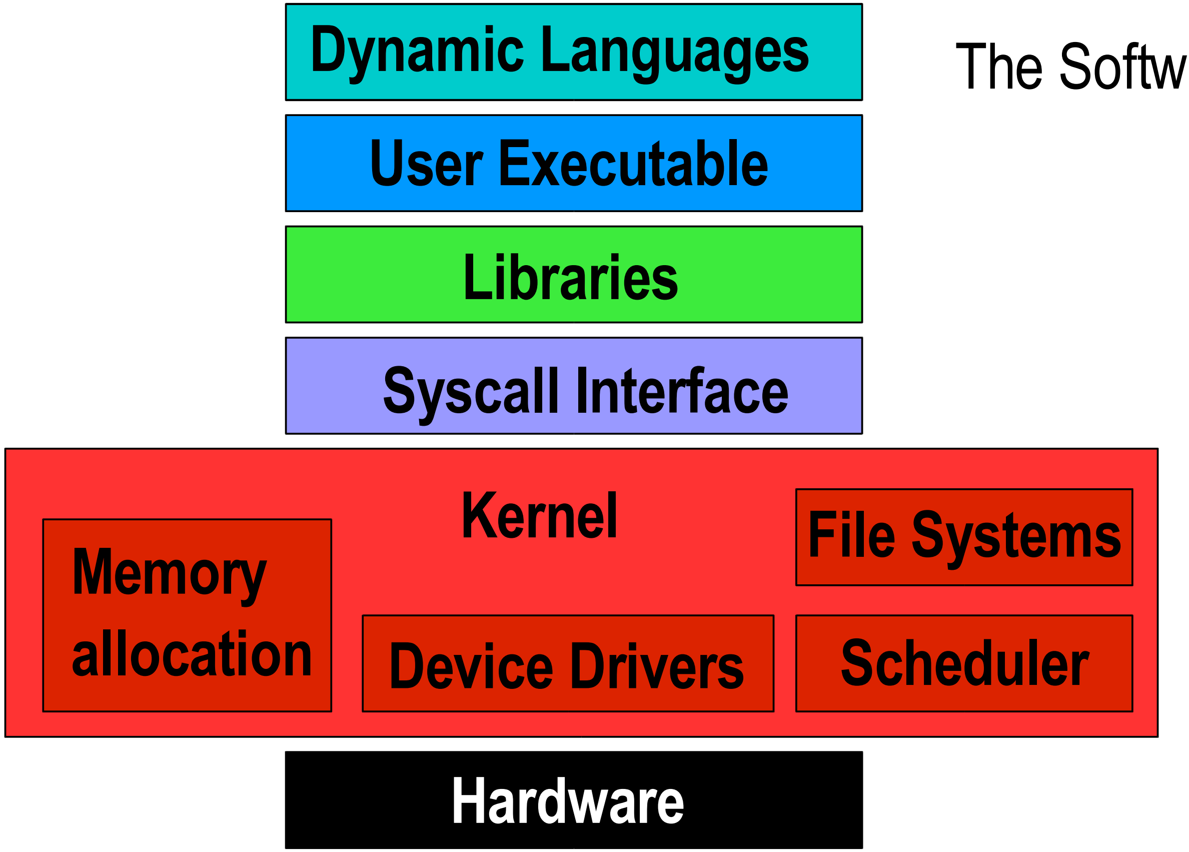
- Just Covered,
  - > *Solaris Performance Features*
    - – *Top features*
    - – *Solaris*
    - – *Solaris 10*
- Next up,
  - > Solaris Performance Observability
    - – By-Layer Strategy
    - – 3-Metric Strategy
    - – System Components

Solaris Performance Observability

- Solaris provides numerous performance tools; the trick is knowing what questions to ask - *performance analysis strategy*

By-Layer Strategy

- All software stack layers are observable
  - locate latency regardless of location



The Software Stack

By-Layer Strategy

- For an application transaction, is the latency,
  - > In the application code?
    - – e.g., bad scaleability architecture
  - > In library code?
    - – e.g., synchronisation locks
  - > In syscalls?
    - – e.g., disk or network I/O
  - > In devices?
    - – e.g., memory bus latency
- Solaris observability tools can provide the answers
  - > especially DTrace

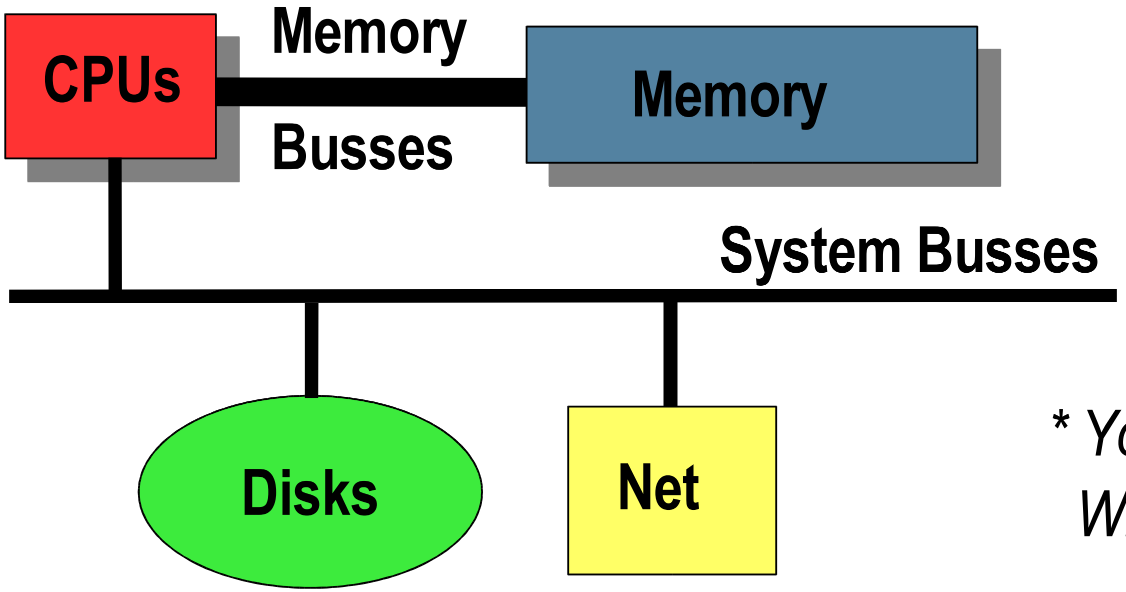
3-Metric Strategy

- For every system component, look for,

1. Utilisation
2. Saturation
3. Errors

System Components

How do you measure utilisation, saturation and errors for these?



** Your Architecture Will Vary*

Simple diagram, simple question, this should be easy to answer.

System CPU

- Load average = overall **utilisation** + **saturation**

```
$ uptime
  2:30pm  up 39 day(s), 12:40,  5 users,  load average: 0.07, 0.07, 0.11
```

> printed by `uptime`, `prstat`

> 1, 5 and 15 minute averages.

> Divide load average by CPU count,
  – value < 1.0   suggests idle, and value = utilisation
  – value == 1.0   suggests 100% utilisation
  – value > 1.0   suggests saturation

> Useful for an initial impression, then move onto other tools like `vmstat` and `mpstat`

System CPU

- `vmstat` - **utilisation** and **saturation** as metrics

```
$ vmstat 1
   kthr      memory            page            disk          faults      cpu
 r b w   swap  free  re  mf pi po fr de sr cd s0 -- --   in   sy   cs us sy id
 0 0 0 4592308 120572 0   3  0  0  0  0  5 30 -1  0  0 967 5343  861  2  1 97
 2 0 0 4349740 48280 10  28  0  0  0  0  0  0  0  0  0 602 1253  791 55  0 45
 0 0 0 4349756 48320  0   0  0  0  0  0  0  0  0  0  0 608 1059  723 50  1 49
[...]
```

  - first line is summary since boot
  - kthr:r = saturation, total threads on the run queues (but sampled at a low rate)
  - cpu:us + cpu:sy = utilisation, CPU user and system time

System CPU

- `mpstat` - **utilisation** by-CPU

```
$ mpstat 1
CPU minf mjf xcal  intr ithr  csw icsw migr smtx  srw syscl  usr sys  wt idl
  0    2   0  108   607  338  434   33   18   22    0  2580    2   1   0  96
  1    2   0   80   360   61  427   24   18   22    0  2762    2   1   0  97
CPU minf mjf xcal  intr ithr  csw icsw migr smtx  srw syscl  usr sys  wt idl
  0    0   0    8   451  323  203   74   24    5    0   261   85   1   0  14
  1    6   0    5   137    1  503   44   25    0    0   727   14   0   0  86
CPU minf mjf xcal  intr ithr  csw icsw migr smtx  srw syscl  usr sys  wt idl
  0    0   0    6   620  328  279   51   34    9    0   238   84   0   0  16
  1    0   0  175   143    1  450   62   19    5    0   685   17   1   0  82
[...]
```

- Classic performance problem - under utilised CPUs due to poor threading architecture

System CPU

- Solaris 10 FMA detects and can automatically respond to CPU **errors**
- `fmadm faulty` - what faults currently exist
- `fmstat -m cpumem-retire` - raw statistics

```
$ fmstat -m cpumem-retire
                NAME VALUE            DESCRIPTION
           auto_flts 0                auto-close faults received
            bad_flts 0                invalid fault events received
         cpu_blfails 0                failed cpu blacklists
          cpu_blsupp 0                cpu blacklists suppressed
           cpu_fails 0                cpu faults unresolveable
            cpu_flts 0                cpu faults resolved
            cpu_supp 0                cpu offlines suppressed
            nop_flts 0                inapplicable fault events received
[...]
```

System Memory

- `vmstat` - swap and physical memory **utilisation** and **saturation**

```
$ vmstat 1
 kthr      memory            page            disk          faults      cpu
 r b w   swap  free  re  mf pi po fr de sr cd s0 -- --   in   sy   cs us sy id
 0 0 0 4592236 120548 0   3  0  0  0  0  5 30 -1  0  0  967 5342  861  2  1 97
 0 0 0 4350572 48096 18  30  0  0  0  0  0  0  0  0  0  687 1114  781  0  1 99
 0 0 0 4350572 48124  0   0  0  0  0  0  0  0  0  0  0 6206 37271 11979 3 12 85
[...]
```

  > swap - free virtual memory (RAM + disk based swap)

  > free - available physical memory (RAM)

  > page:sr - values suggest physical memory saturation

- `mdb -k` - provides breakdown with ::memstat

System Memory

- Solaris 10 FMA detects and can automatically respond to memory **errors**
- For example, blacklisting a page of RAM that has had too many (correctable) ECC errors
- `fmadm faulty` - what is currently faulted
- `fmstat -m cpumem-retire` - raw statistics

System Disks

- iostat - disk **utilisation**, **saturation**, **errors**

```
$ iostat -xnmpz 5
                        extended device statistics
    r/s    w/s   kr/s   kw/s wait actv wsvc_t asvc_t  %w  %b device
    0.0    0.0    0.0    0.0  0.0  0.0    0.0    1.1   0   0 c0t0d0
    0.0    0.0    0.0    0.0  0.0  0.0    0.0   11.3   0   0 c1t0d0s0
    0.0    0.0    0.0    0.1  0.0  0.0    0.0    8.8   0   0 c1t0d0s1
    0.7    1.9    7.3   21.8  0.0  0.0    0.0   15.7   0   1 c1t0d0s3 (/)
    0.0    0.0    0.0    0.0  0.0  0.0    0.0   13.6   0   0 c1t0d0s4
[...]
```

  > first output is summary since boot
  >
  > %b - percent busy, a measure of utilisation
  >
  > wait - transactions waiting, a measure of saturation

- iostat -E - error summaries

System Network

- `kstat` - network **utilisation**, **saturation**, **errors**

```
$ kstat -n nge0 10
module: nge                             instance: 0
name:   nge0                            class:    net
        brdcstrcv                       0
        brdcstxmt                       0
        collisions                      0
        crtime                          61.227502261
        ierrors                         0
        ifspeed                         100000000
        ipackets                        145866056
[...]
```

  - > output includes byte counts, various errors

- `netstat` and `nicstat` (opensource) provide useful summaries of network stats

System Busses

- Measuring **utilisation**, **saturation** and **errors** is hard, but usually still possible with some effort
  - `cpustat` - measure CPU Performance Instrumentation Counters (PICs)
    - PICs for cache activity, memory bus activity, instruction events
  - `cputrack` - CPU PICs for a process
  - `busstat` - On some SPARC systems, provides hardware bus PICs

Processes

- Apart from performance observability *by-system*, also examine performance observability *by-process*.
- `prstat -mL` - useful microstates by thread

```
$ prstat -mL
   PID USERNAME USR SYS TRP TFL DFL LCK SLP LAT VCX ICX SCL SIG PROCESS/LWPID
   557 brendan  7.9 0.3 0.0 0.0 0.0 0.0  91 0.5 579 141  2K  96 Xorg/1
   828 brendan  0.6 0.4 0.0 0.0 0.0 0.0  95 4.1 434 299  2K   0 ssh/1
   830 brendan  0.2 0.0 0.0 0.0 0.0 0.0  99 0.3  36  11 160   0 gnome-termin/1
   788 brendan  0.1 0.1 0.0 0.0 0.0 0.0 100 0.0  58   0 910   0 dtwm/1
  1437 brendan  0.0 0.1 0.0 0.0 0.0 0.0 100 0.0  44   2 297   0 prstat/1
   791 brendan  0.0 0.0 0.0 0.0 0.0 0.0 100 0.3   7  11 129   0 dtterm/1
[...]
```

- DTrace - measure custom microstates
  - > in terms of application activity, across all software layers

Further Observability

- Much more can be observed and analysed on Solaris
  - > DTrace is its own field of study
- “You don't miss what you never had”
  - > Once you start exploring Solaris observability, other OSes won't feel the same again

References

- http://www.solarisinternals.com
  - Latest Solaris Performance Slides
  - Performance wiki
- The “Solaris Performance and Tools” book, http://www.sun.com/books/catalog/solaris_perf_tools.xml
- Performance Community, http://www.opensolaris.org/os/community/performance

Ctrl-D

Brendan Gregg
brendan@sun.com