DTrace Workshop

Context-Switch presents,

DTrace on Solaris 10

London, June, 2006

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This document was NOT written by Sun Microsystems, and opinions expressed are not those of Sun Microsystems unless by coincidence.

This Workshop

DAY 1

- Solaris 9 Performance Monitoring
- Introducing DTrace

DAY 2

- Programming in D
- The DTrace Mentality

DAY 3

- Fixing DTrace Faults

Chapters

References

Some topics presented are based on,

- **Solaris Performance and Tools**: DTrace and MDB Techniques for Solaris 10 and OpenSolaris (McDougall/Mauro/Gregg)

Slides

- These slides cover key topics
- I will cover many side topics, elaborate further, answer questions, run demos, ...
- as such, when I deviate from the slides – don't panic! It's part of the course.

Chapter 1

Solaris 9 Performance Monitoring

- What can be observed
- What *can't* be observed
- Key DTrace wins
- Start here

Example Fault

- Where has my CPU gone?

  using Solaris 9 tools

  ... *interactive demo* ...

The Solaris Toolkit

Consists of many, many tools

- ps, prstat, ptree, pstack, pmap
- vmstat, mpstat, iostat, netstat
- sar
- kstat, ndd, mdb
- truss, sotruss, apptrace, prex
- cpustat, trapstat, lockstat
- ...

These is no single tool to rule them all
(not even DTrace)

I have *tried*

sysperfstat

```
$ sysperfstat 1
             ------ Utilisation ------     ------ Saturation ------
     Time    %CPU   %Mem  %Disk   %Net     CPU    Mem   Disk    Net
 23:27:41    0.85  44.11   2.40   0.19    0.01   0.00   0.00   0.00
 23:27:42    3.00  80.98   0.00   0.00    0.00   0.00   0.00   0.00
 23:27:43    2.00  80.98   0.00   0.00    0.00   0.00   0.00   0.00
 23:27:44   17.00  80.98   0.00   0.00    0.00   0.00   0.00   0.00
 23:27:45   46.00  80.49  22.05  54.20    1.00   0.00   0.00   0.00
 23:27:46   50.00  79.83  14.19  78.18    0.00   0.00   0.00   0.00
 23:27:47   48.00  79.39   8.04  80.94    0.00   0.00   0.00   0.00
 23:27:48   54.00  79.62   3.06  70.89    4.00   0.00   0.00   0.00
 23:27:49   39.00  79.43   6.78  74.52    0.00   0.00   0.00   0.00
```

Such a tool serves one role but not all.
In this case, it provides the “view from 20,000 feet”.

Coping With Many Tools

- Categorise by Approach
- Categorise by Resource Type
- Checklists of tools (these slides)
- Study some, be aware what else exists

  just remembering that something is doable is valuable!

Categorise by Approach

1. **Monitoring**
   Monitoring multiple hosts
   Gathering long term data

2. **Identification**
   Examining system-wide health

3. **Analysis**
   Focusing on details

Examples

1. **Monitoring**
   SNMP, sar, SunMC

2. **Identification**
   kstat (vmstat, mpstat, iostat)
   procfs (ps, prstat)
   mnttab (df)

3. **Analysis**
   truss, apptrace, prex, lockstat, ...

Hints

- Be careful when using sar:
  - sar has sampling issues
  - the default configuration needs tuning
  - try **`truss -ft ioctl sar -u 1 5`** (yes, sar reads everything. compare to mpstat)

- Solaris 10 now uses Net-SNMP
  - USM – usernames, passwords, encryption
  - VACM – restricting views

(these greatly improve security)

Categorise by Resource Type

- **CPU**

  vmstat, mpstat, sar, prstat, ps
- **Memory**

  vmstat, swap, ::memstat, prstat, ps, pmap
- **Disk**

  iostat, *taztool*, *iosnoop*, *iotop*
- **Network**

  netstat, kstat, ndd, *nx.se*, *nicstat*
- **...**

Tools Checklist

The following list of tools serves to:

- provide a checklist
- show what is doable – you'll remember later
- show what *can* be done – the right tool for the job
- show what *can't* be done – where DTrace can help
- provide starting points for using DTrace

Tools Checklist

- uptime
- ps
- /usr/ucb/ps
- prstat
- prstat -m
- vmstat
- mpstat
- iostat
- prex/tnf*
- psio
- netstat -i
- nx.se
- nicstat
- netstat -rn
- sar
- sar -u
- sar -q
- kstat
- K9Toolkit
- ndd
- checkcable
- cpustat
- CacheKit
- busstat
- trapstat
- lockstat
- lockstat -I
- truss
- sotruss
- apptrace
- truss -ua.out
- adb
- mdb -k
- mdb -p
- lastcomm
- BSM auditing
- snmpwalk

uptime

```
$ uptime
  2:38am  up 347 day(s),  9:08,  5 users,  load average: 0.01, 0.02, 0.03
```

- load average: 1, 5 and 15 minute averages.
  - These were once the average length of the combined dispatcher queues + currently running threads, sampled during clock().
  - It is now microstate accounting based, and is all the threads usr + sys + CPU latency times.
  - load averages tend to over-simplify CPU issues.
- *Can't customise the interval*
- *DTrace can trace scheduler activity*
- BTW – 347 days is nothing; I maintain the “Sun Book of Records” (search google), where the current record is 2001 days!

ps

```
$ ps -ef
     UID   PID  PPID  C    STIME TTY        TIME CMD
    root     0     0  0   May 28 ?          0:08 sched
    root     1     0  0   May 28 ?          0:48 /etc/init -
    root     2     0  0   May 28 ?          0:02 pageout
    root     3     0  0   May 28 ?         89:39 fsflush
    root  2316     1  0   May 28 ?          0:00 /usr/lib/saf/sac -t 300
  nobody 22112 22111  0   Feb 15 ?         231:44 (squid)
    root  2061     1  0   May 28 ?          0:12 /usr/sbin/rpcbind
    root    73     1  0   May 28 ?          0:00 /usr/lib/sysevent/syseventd
    root    78     1  0   May 28 ?          0:01 /usr/lib/picl/picld
...
```

- Useful to check long-term processes
- *Default fields not hugely useful, use -o*
- *DTrace can access similar procfs statistics, and gather many additional statistics*

/usr/ucb/ps

```
$ /usr/ucb/ps auxww
USER       PID %CPU %MEM   SZ  RSS TT       S    START  TIME COMMAND
root      3768  3.0  0.8 3216 2856 pts/2    O 16:24:40  0:00 /usr/ucb/ps -auxww
root      3453  0.2  0.8 4544 2904 ?        S 15:59:10  0:01 /usr/lib/ssh/sshd
root       498  0.1  0.8 4680 2944 ?        S   May 03  0:29 /usr/lib/ssh/sshd
brendan  17545  0.1  0.6 2648 2080 pts/2    S   May 08  0:04 /bin/bash
brendan   3769  0.1  0.3  984  808 pts/2    S 16:24:40  0:00 head
brendan   2408  0.1  1.4 6800 5112 ?        S   May 28 92:28 SCREEN
root      2037  0.1  0.3 2024  800 ?        S   May 28 168:21 /usr/sbin/in.routed
root      3765  0.1  0.3 1016  816 ?        S 16:24:28  0:00 sleep 15
nobody   22112  0.1 22.79150484352 ?        S   Feb 15 231:44 (squid)
```

- Sorting by %CPU is nice
- *Fields colliding is not nice*
- **`pargs`** is better at viewing full arg listings

prstat

```
$ prstat
   PID USERNAME  SIZE   RSS STATE  PRI NICE      TIME  CPU PROCESS/NLWP
  3453 root     4544K 2904K sleep   59    0   0:00:01 0.7% sshd/1
  2408 brendan  6800K 5112K sleep   59    0   1:32:29 0.7% screen-3.9.8/1
  5558 irc      8152K 3832K sleep   59    0   0:15:41 0.4% irssi/1
  3944 brendan  4584K 4224K cpu0    39    0   0:00:00 0.4% prstat/1
 25442 brendan  2312K  296K sleep   59    0   0:05:05 0.1% telnet/1
  3939 root     1016K  816K sleep   59    0   0:00:00 0.0% sleep/1
 17545 brendan  2648K 2080K sleep   49    0   0:00:04 0.0% bash/1
  2037 root     2024K  800K sleep   59    0   2:48:21 0.0% in.routed/1
Total: 114 processes, 197 lwps, load averages: 0.04, 0.02, 0.03
```

- Great summary view
- Doesn't wallop the CPU
- *DTrace can also provide updating summaries, of a simple nature*

prstat -m

```
$ prstat -m
   PID USERNAME USR SYS TRP TFL DFL LCK SLP LAT VCX ICX SCL SIG PROCESS/NLWP
  3999 brendan  0.4 1.3 0.0 0.0 0.0 0.0  98 0.0   9   0 259   0 prstat/1
  2408 brendan  0.7 0.1 0.0 0.0 0.0 0.0  99 0.0   6   0  30   0 screen-3.9.8/1
 19763 brendan  0.0 0.0 0.0 0.0 0.0 0.0 100 0.0   5   0  13   0 sdtperfmeter/1
  2150 root     0.0 0.0  -   -   -   -  100  -    8   0  26   0 nscd/25
    78 root     0.0 0.0  -   -   -   -  100  -    0   0   0   0 picld/4
    73 root     0.0 0.0  -   -   -   -  100  -    0   0   0   0 syseventd/14
  2061 root     0.0 0.0  -   -   -   -  100  -    0   0   0   0 rpcbind/1
 22112 root     0.0 0.0  -   -   -   -  100  -    2   0   2   0 squid/1
Total: 114 processes, 197 lwps, load averages: 0.00, 0.02, 0.02
```

- Microstate accounting – great breakdown of process time (very useful!)
- *Restricted to pre-determined accounting states*
- *DTrace can measure custom states*

vmstat

```
$ vmstat 1 3
 kthr      memory            page            disk          faults      cpu
 r b w   swap  free  re  mf pi po fr de sr dd dd f0 s3   in  sy    cs us sy id
 0 0 21 422864 68800  3  16  5  0  0  0  0  0  0  0  0  126  106  135  1  0 98
 0 0 51 434616 55560 32 174  0  0  0  0  0  0  0  0  0  403  442  123  1  3 96
 0 0 51 434616 55560  0   0  0  0  0  0  0  0  0  0  0  401  250  116  0  0 100

$ vmstat -p 1 3
     memory           page          executable      anonymous      filesystem
   swap  free  re  mf  fr  de  sr  epi  epo  epf  api  apo  apf  fpi  fpo  fpf
 422864 68800   3  16   0   0   0    0    0    0    0    0    0    5    0    0
 434616 55560   0   6   0   0   0    0    0    0    0    0    0    0    0    0
 434616 55560   0   0   0   0   0    0    0    0    0    0    0    0    0    0
```

- Best system-wide view
- *Can't view statistics by-process, by-zone, ...*
- *DTrace can!*

mpstat

```
$ mpstat 5
CPU minf mjf xcal  intr ithr  csw icsw migr smtx  srw syscl  usr sys  wt idl
  0   16   0    0   127   26  135    1    0    0    0   106    1   0   0  98
  1   19   0    0   149   29  155    2    0    0    0   123    3   1   0  96
  2   13   0    0    98   17  112    0    0    0    0    94    1   0   0  98
  3   15   0    0   104   23  144    1    0    0    0   112    2   0   0  97
...
```

- Good by-CPU summary
- *DTrace can also measure by-CPU*

iostat

```
$ iostat -xnmPz 1
                    extended device statistics
    r/s    w/s   kr/s   kw/s wait actv wsvc_t asvc_t  %w  %b device
    0.0    0.0    0.1    0.1  0.0  0.0   19.4   11.6   0   0 c0t0d0s0
    0.0    0.0    0.0    0.0  0.0  0.0   56.4   11.4   0   0 c0t0d0s1
    0.0    0.0    0.0    0.0  0.0  0.0   94.9   15.6   0   0 c0t0d0s3
    0.0    0.0    0.0    0.0  0.0  0.0   92.4   14.6   0   0 c0t0d0s4
    0.0    0.0    0.0    0.0  0.0  0.0   37.7   10.0   0   0 c0t0d0s5
    0.0    0.0    0.0    0.0  0.0  0.0   15.8   12.1   0   0 c0t0d0s7 (/data)
    0.0    0.1    0.4    0.4  0.0  0.0    1.8    4.3   0   0 c0t2d0s0 (/)
    0.1    0.2    4.1    3.1  0.0  0.0   37.4    6.7   0   0 c0t2d0s1 (/export/home)
    0.1    0.0    0.2    0.5  0.0  0.0    3.3   12.7   0   0 c0t2d0s3 (/squidcache)
    0.0    0.0    0.0    0.0  0.0  0.0    0.0    4.4   0   0 mars:vold(pid2295)
...
```

- Excellent per-disk/partition/controller summary
- *No by-process summary, or event details*
- *DTrace solves both*

prex/tnfxtract/tnfdump

- prex: enables static probes to record event details to a buffer
- tnfxtract: extracts buffer contents
- tnfdump: converts buffer contents to text
- *DTrace has this exact functionality, and more (dynamic)*

prex/tnfxtract/tnfdump

```
# tnfdump out1.tnf
probe    tnf_name: "pagein" tnf_string: "keys vm pageio io;file ../../
   common/os/
bio.c;line 1333;"
probe    tnf_name: "strategy" tnf_string: "keys io blockio;file ../../
   common/os/
driver.c;line 411;"
probe    tnf_name: "biodone" tnf_string: "keys io blockio;file ../../
   common/os/b
io.c;line 1222;"
---------------- ---------------- ----- ----- ---------- ---
   -------------------
------ ------------------------
    Elapsed (ms)       Delta (ms)    PID LWPID    TID     CPU Probe Name
       Data / Description . . .
---------------- ---------------- ----- ----- ---------- ---
   -------------------
------ ------------------------
        0.000000         0.000000  5926     1 0xd423fe00   0 pagein
       vnode: 0xd678de40 offset: 0 size: 8192
        0.029433         0.029433  5926     1 0xd423fe00   0 strategy
       device: 26738688 block: 1616 size: 8192 buf: 0xd7c32aa8 flags: 34078801
       12.298443        12.269010     0     0 0xd3a00de0   0 biodone
       device: 26738688 block: 1616 buf: 0xd7c32aa8
```

psio

```
# ./psio 1
     UID   PID  PPID %I/O    STIME TTY      TIME CMD
 brendan 13271 10093 65.4 23:20:16 pts/20   0:01 grep brendan contents
    root     0     0  0.0   Mar 16 ?        0:16 sched
    root     1     0  0.0   Mar 16 ?        0:10 /etc/init -
    root     2     0  0.0   Mar 16 ?        0:00 pageout
...
```

- http://www.brendangregg.com/psio.html
- Solved %Disk I/O by-process
- *Could only run for short intervals*
- *DTrace takes this much further – tracing events, by-process info, ...*

netstat -i

```
$ netstat -i 1 5
    input   hme0      output           input  (Total)    output
packets errs  packets errs  colls  packets errs  packets errs  colls
206999694 32    223490272 0     0      326931321 32    343421899 0     0
4       0     4       0     0      6       0     6       0     0
8       0     9       0     0      10      0     11      0     0
28      0     35      0     0      30      0     37      0     0
50      0     54      0     0      52      0     56      0     0
```

- An approximation of activity
- *No further details for analysis*
- *Packets are not bytes*
- *Both kstat and DTrace provide more info*

nx.se

```
$ se nx.se 1
Current tcp RtoMin is 400, interval 1, start Thu May 11 18:22:37 2006

18:22:38 Iseg/s Oseg/s InKB/s OuKB/s Rst/s  Atf/s  Ret%  Icn/s  Ocn/s
tcp        2.0    2.0   0.06   0.13   0.00   0.00   0.0   0.00   0.00
Name    Ipkt/s Opkt/s InKB/s OuKB/s IErr/s OErr/s Coll% NoCP/s Defr/s
hme0       3.0    3.9   0.22   0.34  0.000  0.000   0.0   0.00   0.00

18:22:39 Iseg/s Oseg/s InKB/s OuKB/s Rst/s  Atf/s  Ret%  Icn/s  Ocn/s
tcp        1.0    1.0   0.04   0.32   0.00   0.00   0.0   0.00   0.00
Name    Ipkt/s Opkt/s InKB/s OuKB/s IErr/s OErr/s Coll% NoCP/s Defr/s
hme0       3.0    3.9   0.22   0.34  0.000  0.000   0.0   0.00   0.00
^C
```

- From the SE Toolkit
- Provides many more useful details

nicstat

```
$ nicstat 1
    Time   Int   rKb/s   wKb/s   rPk/s   wPk/s    rAvs    wAvs   %Util     Sat
18:23:49  hme0    4.12    4.69    6.88    7.43  613.61  645.92    0.07    0.00
18:23:50  hme0    0.19    0.23    2.01    2.01   98.00  116.00    0.00    0.00
18:23:51  hme0    1.41    4.45   13.00   17.00  111.38  267.88    0.05    0.00
18:23:52  hme0    0.99    3.64    9.00   11.00  112.89  339.09    0.04    0.00
18:23:53  hme0    0.10    0.23    1.00    2.00   98.00  116.00    0.00    0.00
```

- http://www.brendangregg.com/k9toolkit.html
- Uses kstat, written in both C and Perl
- Provides bytes, %Utilisation

netstat -rn

```
$ netstat -rn

Routing Table: IPv4
  Destination           Gateway           Flags  Ref   Use   Interface
-------------------- -------------------- ----- ----- ------ ---------
220.244.170.56       220.244.170.58        U        1   18146  hme0:1
192.168.0.0          192.168.0.2           U        1   12537  hme0:2
192.168.1.0          192.168.1.1           U        1   32151  hme0
224.0.0.0            192.168.1.1           U        1       0  hme0
default              220.244.170.57        UG       1 326156
127.0.0.1            127.0.0.1             UH       9116268837  lo0
```

- Check for unexpected routes
- *You discover problems after the fact*
- *DTrace can snoop route changes live*

sar

```
$ sar -u 1 5

SunOS mars 5.9 Generic_118558-05 sun4u    05/11/2006

18:33:46    %usr    %sys    %wio   %idle
18:33:47       2       2       0      96
18:33:48       4       1       0      95
18:33:49       3       4       5      88
18:33:50       0       2       0      98
18:33:51       4       3       3      90
```

- System Activity Reporter
- Prints a variety of kstats
- Can collect historic data, to identify long term patterns
- *Has several issues*

sar -u

```
$ sar -u

SunOS mars 5.9 Generic_118558-05 sun4u    05/11/2006

00:00:01    %usr    %sys    %wio   %idle
01:00:01       1       1       0      98
02:00:01       2       1       0      98
03:00:01       1       1       0      98
04:00:00       1       1       0      98
05:00:01       0       0       0      99
...
```

- This shows historic data from sar -u
- %wio is always zero in Solaris 10
- Note that the system is idle

sar -q

```
$ sar -q

SunOS mars 5.9 Generic_118558-05 sun4u    05/11/2006

00:00:01 runq-sz %runocc swpq-sz %swpocc
01:00:01     1.4       0    51.0     100
02:00:01     1.0       1    51.0     100
03:00:01     1.2       0    51.0     100
04:00:00     1.4       0    51.0     100
05:00:01     1.3       0    51.0     100
...
```

- sar -q shows run queue sizes
- This is the same period as before, and shows a > 1.0 run queue size. huh?

kstat

```
$ kstat -pm cpu_info
cpu_info:0:cpu_info0:chip_id    0
cpu_info:0:cpu_info0:class      misc
cpu_info:0:cpu_info0:clock_MHz  333
cpu_info:0:cpu_info0:cpu_type   sparcv9
cpu_info:0:cpu_info0:crtime     4.553718221
cpu_info:0:cpu_info0:device_ID  0
cpu_info:0:cpu_info0:fpu_type   sparcv9
cpu_info:0:cpu_info0:implementation     UltraSPARC-IIi
...
```

- Great resource
- libkstat, Sun::Solaris::Kstat, or /usr/bin/kstat
    - netstat -k is now deprecated
- *Many kstats are not documented*
- *kstat finds problems, DTrace analyses them*

K9Toolkit

- http://www.brendangregg.com/k9toolkit.html
- A Perl kstat collection
- Contains
    - sysperfstat
    - checkcable
    - nicstat
    - prtdevs
    - ...

ndd

```
# ndd /dev/hme link_speed
1

# ndd /dev/rtls link_speed
operation failed: Invalid argument
```

- Accesses read/write settings for network related drivers
- *consistancy issues between interface types*

checkcable

```
# checkcable
Interface    Link Duplex  Speed  AutoNEG
hme0           UP   FULL    100       ON
hme1           UP   HALF     10       ON
```

- http://www.brendangregg.com
- Translates both ndd and kstats
- *May not be needed in the long term (interface kstats are getting better)*

cpustat

```
# cpustat -c pic0=EC_ref,pic1=EC_hit 1 5
   time cpu event      pic0      pic1
  1.008   0  tick     77992     63504
  2.008   0  tick     81972     65364
  3.008   0  tick     76869     62250
  4.008   0  tick     77347     62518
  5.008   0  tick     76023     62405
  5.008   1 total    390203    316041
```

- Examine CPU PICs
- Observe I$, D$, E$ performance
- Use cputrack for per-process info
- *Info available is CPU-type dependant*

CacheKit

```
# ccachestat 5 5

       --- I-Cache ---          --- D-Cache ---          --- E-Cache ---
   total    miss    %hit     total    miss    %hit     total    miss    %hit
   7424k    107k   98.55     2476k     39k   98.39      879k    200k   77.20
   7941k    107k   98.65     3502k     53k   98.46      860k    211k   75.43
  39082k    504k   98.71    15243k    293k   98.08     3420k    487k   85.75
  19926k    248k   98.75     4985k    103k   97.92     1531k    277k   81.89
  11028k    146k   98.67     5340k     95k   98.21     1856k    326k   82.42
```

- http://www.brendangregg.com/cachekit.html
- Digs out useful info, calculates hit ratios
- *Needs updates to measure newer CPUs*

busstat

```
# busstat -w ac,pic0=clock_cycles,pic1=mem_bank0_rds 2 100
time   dev     event0          pic0            event1          pic1
2      ac0     clock_cycles    167242902       mem_bank0_rds   3144
2      ac1     clock_cycles    167254476       mem_bank0_rds   1392
4      ac0     clock_cycles    168025190       mem_bank0_rds   40302
...
```

- Measures bus PICs
- *No public PIC documentation (yet)*

Anyone actually used this outside of Sun?

trapstat

```
# trapstat -t 10 1
cpu m| itlb-miss %tim itsb-miss %tim | dtlb-miss %tim dtsb-miss %tim |%tim
-----+-------------------------------+-------------------------------+----
  0 u|      2393  0.1      3950  0.7 |     11926  0.6      4205  0.8 | 2.2
  0 k|       105  0.0         0  0.0 |     96358  5.2       214  0.1 | 5.3
=====+===============================+===============================+====
 ttl |      2498  0.2      3950  0.7 |    108284  5.7      4419  0.9 | 7.5

# trapstat
trapstat: not implemented on i86pc
```

- MMU statistics
- Check this to see if MPSS needs tuning

lockstat

```
# lockstat -k sleep 5

Adaptive mutex block: 6 events in 5.638 seconds (1 events/sec)

Count indv cuml rcnt     nsec Lock                   Caller
-------------------------------------------------------------------------------
    2  33%  33% 0.00    71995 0x30000e723c0          clock
    1  17%  50% 0.00    85133 0x300055ffcb0          rctl_test_entity
    1  17%  67% 0.00    77176 0x300040b2888          rctl_test_entity
    1  17%  83% 0.00    70159 0x30000e72280          clock
    1  17% 100% 0.00    73192 0x30000e722c0          clock
-------------------------------------------------------------------------------
```

- Kernel lock statistics

lockstat -I

```
# lockstat -kIi 997 sleep 5

Profiling interrupt: 5199 events in 5.208 seconds (998 events/sec)

Count indv cuml rcnt     nsec CPU+PIL                 Caller
----------------------------------------------------------------------
   ---------
 1962  38%  38% 0.00     6751 cpu[0]                  (usermode)
  264   5%  43% 0.00     7605 cpu[0]                  mutex_enter
  187   4%  46% 0.00     7970 cpu[0]                  dnlc_lookup
  170   3%  50% 0.00     7271 cpu[0]                  utl0
  142   3%  52% 0.00     6866 cpu[0]                  lookuppnvp
  119   2%  55% 0.00     6476 cpu[0]                  syscall_mstate
  112   2%  57% 0.00     7142 cpu[0]                  ufs_lookup
   99   2%  59% 0.00     2041 cpu[0]                  idle
...
```

- `-I` samples the kernel
- *DTrace can both sample and trace*

truss

```
$ truss date
execve("/usr/bin/date", 0xFFBFF754, 0xFFBFF75C)  argc = 1
resolvepath("/usr/bin/date", "/usr/bin/date", 1023) = 13
resolvepath("/usr/lib/ld.so.1", "/usr/lib/ld.so.1", 1023) = 16
stat("/usr/bin/date", 0xFFBFF528)               = 0
open("/var/ld/ld.config", O_RDONLY)             Err#2 ENOENT
stat("/usr/lib/libc.so.1", 0xFFBFF030)          = 0
resolvepath("/usr/lib/libc.so.1", "/usr/lib/libc.so.1", 1023) = 18
...
```

- Trace syscalls and signals
- truss is “violent”. can slow target by 70%
- *Can't trace all processes at the same time*
- *truss behaves synchronously to syscalls*
- *DTrace buffers system-wide syscall details and reads the buffer asynchronously. slows target < 1%*

sotruss

```
$ sotruss date
date                ->        libc.so.1:*atexit(0xff3bfaac, 0x21800, 0x0)
date                ->        libc.so.1:*atexit(0x11654, 0x21800, 0x0)
date                ->        libc.so.1:*setlocale(0x6, 0x116dc, 0xff3509e0)
date                ->        libc.so.1:*textdomain(0x116e0, 0x116dc, 0xff3509e0)
date                ->        libc.so.1:*getopt(0x1, 0xffbff684, 0x116f0)
date                ->        libc.so.1:*time(0x21d98, 0xffbff684, 0x116f0)
date                ->        libc.so.1:*nl_langinfo(0x3a, 0xffbff684, 0x21d98)
date                ->        libc.so.1:*localtime(0x21d98, 0x3a, 0x21d98)
date                ->    libc_psr.so.1:*memcpy(0xffbff5f4, 0xff2427b0, 0x24)
date                ->        libc.so.1:*strftime(0x21d9c, 0x400, 0xff22b094)
...
```

- Shared library tracing
- Added in Solaris 2.6
- *Not so clever with function arguments*

apptrace

```
$ apptrace date
date     -> libc.so.1:atexit(func = 0xff3bfaac) = 0x0
date     -> libc.so.1:atexit(func = 0x11654) = 0x0
date     -> libc.so.1:setlocale(category = 0x6, locale = "") = "C"
date     -> libc.so.1:textdomain(domainname = "SUNW_OST_OSCMD") =
   "SUNW_OST_OSCMD"
date     -> libc.so.1:getopt(argc = 0x1, argv = 0xffbff67c, optstring = "a:u")
   = 0xffffffff errno = 0 (Error 0)
...
date     -> libc.so.1:strftime(s = "Fri May 12 17:16:12 ", maxsize = 0x400,
   format = "%a %b %e %T %Z %Y", timeptr = 0xffbff5ec) = 0x1c
...
```

- Shared library tracing
- Added in Solaris 8
- Evaluates arguments
- *DTrace has this functionality*

truss -ua.out

```
$ truss -ua.out banner hello
...
-> _init(0x20f84, 0x21000, 0x0, 0x0)
<- _init() = 0x20f84
-> main(0x2, 0xffbff744, 0xffbff750, 0x21000)
brk(0x000216A0)                                 = 0
brk(0x000236A0)                                 = 0
  -> banner(0xffbff84b, 0x2144c, 0x0, 0x0)
    -> banset(0x20, 0x2144c, 0x0, 0x0)
    <- banset() = 32
    -> convert(0x68, 0x2144c, 0x0, 0x2164a)
    <- convert() = 104
...
```

- Traces user functions
- -u can also trace library calls

adb/mdb

- Perform core dump analysis – processes
- Perform clash dump analysis – kernel
- mdb was added in Solaris 8

mdb -k

```
# mdb -k
Loading modules: [ unix krtld genunix specfs dtrace ufs ip sctp usba
   random fctl nca cpc nfs sppp sd audiosup crypto ]
> ::mappings
            BASE            LIMIT              SIZE NAME
         1000000          18f4000            8f4000 ktextseg
         18f4000          1c80000            38c000 kvalloc
        70000000         80000000          10000000 kvseg32
        edd00000         f0000000           2300000 kdebugseg
     2a100000000      2a13ead8000           3ead8000 kpseg
     2a750000000      2a753adc000           3adc000 kmapseg
     30000000000      70000000000       40000000000 kvseg
     70000000000      70000916000            916000 kmem64
fffffa0000000000 fffffe0000000000       40000000000 kpmseg
>
```

- Visit kernel-land,

mdb -k

```
> ::pgrep syslog | ::print proc_t
{
    p_exec = 0x30002a822c0
    p_as = 0x300011326c8
    p_lockp = 0x30000e72780
    p_crlock = {
        _opaque = [ 0 ]
    }
    p_cred = 0x3000034ebe8
    p_swapcnt = 0
    p_stat = '\002'
    p_wcode = '\0'
    p_pidflag = 0
...
```

- ... walk kernel structures
- *DTrace does this too*

mdb -p

```
# mdb -p `pgrep -o syslogd`
Loading modules: [ ld.so.1 libc.so.1 ]
> ::mappings
    BASE    LIMIT      SIZE NAME
   10000    22000     12000 /usr/sbin/syslogd
   32000    34000      2000 /usr/sbin/syslogd
   34000    64000     30000 /usr/sbin/syslogd
fe87a000 fe87c000      2000 [ anon ]
fe97a000 fe97c000      2000 [ anon ]
fe980000 fe982000      2000 [ anon ]
fe982000 fe99c000     1a000 [ anon ]
fe99c000 fe99e000      2000 [ anon ]
fe99e000 fe9b8000     1a000 [ anon ]
...
```

- Visit user-land
- *DTrace does this too (copyin/copyout)*

process accounting

```
# lastcomm
man         root     term/a         0.02 secs Fri May 12 18:25
sh          root     term/a         0.00 secs Fri May 12 18:25
more        root     term/a         0.01 secs Fri May 12 18:25
sh          root     term/a         0.00 secs Fri May 12 18:25
mv          root     term/a         0.01 secs Fri May 12 18:25
sh          root     term/a         0.00 secs Fri May 12 18:25
...
```

- Log process creation
- Extended accounting adds task and flow
- *Limited details, no process args*
- *DTrace does this much better for short intervals*

BSM auditing

- Logs plenty of details
- Should be customised
- *Not really an as-needed troubleshooting tool*
- *DTrace serves this role*

Net-SNMP

```
$ snmpwalk -v1 -c public localhost|more
SNMPv2-MIB::sysDescr.0 = STRING: SunOS jupiter 5.10 Generic i86pc
SNMPv2-MIB::sysObjectID.0 = OID: NET-SNMP-MIB::netSnmpAgentOIDs.3
DISMAN-EVENT-MIB::sysUpTimeInstance = Timeticks: (774102766) 89 days,
   14:17:07.66
SNMPv2-MIB::sysContact.0 = STRING: "System administrator"
SNMPv2-MIB::sysName.0 = STRING: jupiter
SNMPv2-MIB::sysLocation.0 = STRING: "System administrators office"
SNMPv2-MIB::sysServices.0 = INTEGER: 72
SNMPv2-MIB::sysORLastChange.0 = Timeticks: (90) 0:00:00.90
SNMPv2-MIB::sysORID.1 = OID: IF-MIB::ifMIB
SNMPv2-MIB::sysORID.2 = OID: SNMPv2-MIB::snmpMIB
SNMPv2-MIB::sysORID.3 = OID: TCP-MIB::tcpMIB
SNMPv2-MIB::sysORID.4 = OID: IP-MIB::ip
SNMPv2-MIB::sysORID.5 = OID: UDP-MIB::udpMIB
...
```

- Added to Solaris 10

... *Unanswered Questions*

- disk I/O by process. easily.
- network I/O by process.
- short-lived process analysis. easily.
- interrupt driver on-CPU time

- So what else couldn't you answer on older Solaris?

End of Chapter 1

Chapter 1 – Solaris 9 Performance Tools
Chapter 2 – Introducing DTrace
Chapter 3 – Command Line DTrace
Chapter 4 – DTrace one-liners
Chapter 5 – DTrace Mentality 1
Chapter 6 – Providers
Chapter 7 – The D Language
Chapter 8 – Advanced Scripting
Chapter 9 – The DTraceToolkit
Chapter 10 – DTrace Mentality 2

Chapter 2

Introducing DTrace

- What DTrace is
- What role DTrace plays
- A one-liner Demonstration
- DTrace Scripting
- DTrace resources

DTrace

- Dynamic Tracing
- Solaris 10 & OpenSolaris
- Difficult to fully explain! We will use,
  a) features
  b) what it is like
  c) what is “DTrace”
  d) when to use it
  e) demonstrations

DTrace Features

- A framework for performance observability and debugging in real-time
- Examines from user space to the kernel,
    - user-land functions and instructions
    - library calls and instructions
    - system calls
    - kernel functions
    - device driver functions

  ... from the same tool
- Is safe to use in production

DTrace Features

- Can examine applications without restarting them
- Has low impact when running, and zero impact when not
- Dynamically inserts trace points into the kernel and running applications, called *probes*
- Can trace over 30,000 kernel probes

DTrace Features

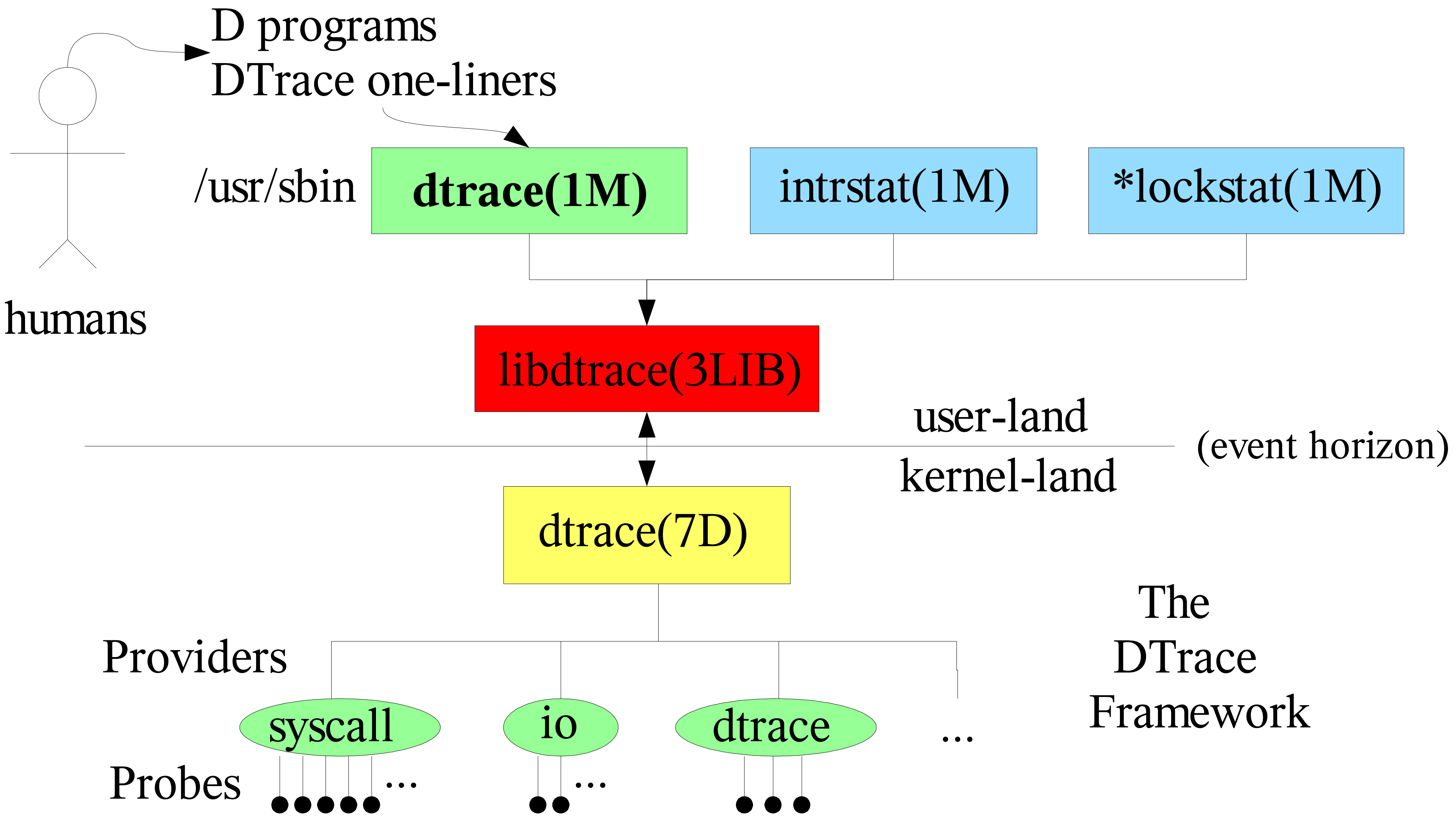
- Can trace as many application probes as it finds functions and instructions (possibly millions)
- Can trace system boot activity – before init!
- Provides a C-like language for writing custom scripts
- Has solved countless long-term performance issue mysteries – often easily
- One of the most significant additions to the field of Operating Systems

What DTrace is like

DTrace has similar features to the following,

truss	tracing system calls
apptrace	tracing library calls
truss -ua.out	tracing user functions
prex/tnf*	tracing kernel functions
lockstat	profiling the kernel
mdb -k	access to kernel VM
mdb -p	access to user VM
C, awk	programming languages
...	+ more

What is “DTrace”



When to use DTrace

Sysadmins can use DTrace for performance analysis and troubleshooting,

1. **Monitoring**
   SNMP, sar, SunMC, ...
2. **Identification**
   kstat (vmstat, mpstat, iostat)
   procfs (ps, prstat), ...
3. **Analysis**
   --> DTrace <--

When to use DTrace

Application developers can use DTrace for code profiling and fault finding,

1. **Development**
   IDEs, vim/emacs

2. **Testing**
   Compiler profiling, coded statistics
   --> *DTrace* <--

3. **Production**
   coded statistics
   --> *DTrace* <--

Demonstration

- This demonstration will introduce key DTrace components and terminology
- The aim is to explain the following,

```
# dtrace -n 'syscall::exec*:return { trace(execname); }'
dtrace: description 'syscall::exec*:return ' matched 2 probes
CPU     ID                    FUNCTION:NAME
  0   5992                     exece:return   staroffice
  0   5992                     exece:return   grep
  0   5992                     exece:return   grep
  0   5992                     exece:return   soffice
  0   5992                     exece:return   dirname
  0   5992                     exece:return   expr
  0   5992                     exece:return   basename
  0   5992                     exece:return   expr
  0   5992                     exece:return   sopatchlevel.sh
  0   5992                     exece:return   dirname
  0   5992                     exece:return   expr
...
```

Listing Probes

```
# dtrace -l
   ID   PROVIDER            MODULE                          FUNCTION NAME
    1     dtrace                                                     BEGIN
    2     dtrace                                                     END
    3     dtrace                                                     ERROR
    4        fbt              pool                         pool_info entry
    5        fbt              pool                         pool_info return
    6        fbt              pool                       pool_detach entry
...

# dtrace -l | wc -l
   44797
```

- **`dtrace -l`** lists probes
- For this demonstration, there were 44796 probes. This number varies depending on the OS build, and which providers have been recently used.

Finding Probes

- Since there are so many probes, being able to find useful probes is a crucial task
- grep can be used to filter the **`dtrace -l`** output, since grep is well known and RE's are powerful

```
# dtrace -l | grep syscall | grep exec
 1089    syscall                                                exec entry
 1090    syscall                                                exec return
 5991    syscall                                               exece entry
 5992    syscall                                               exece return
```

- Here we matched two forms of exec()

Specifying Probes #1

```
# dtrace -ln 'syscall::exec:entry'
   ID   PROVIDER            MODULE                        FUNCTION NAME
 1089    syscall                                              exec entry

# dtrace -ln 'syscall::exec*:'
   ID   PROVIDER            MODULE                        FUNCTION NAME
 1089    syscall                                              exec entry
 1090    syscall                                              exec return
 5991    syscall                                             exece entry
 5992    syscall                                             exece return
```

- First, a single probe was matched by specifying its fully qualified probe name
- Second, multiple probes were matched. “*****” is a wildcard, as are blank fields “`::`”

Specifying Probes #2

- Short cuts exist – dropping left-hand fields is the same as wildcards.
- For example, the following are the same
  - dtrace:::BEGIN
  - :::BEGIN
  - BEGIN
- dtrace:::BEGIN fires when DTrace begins tracing, much the same as awk's BEGIN (and used for the same reasons too – printing headers).

Specifying Probes #3

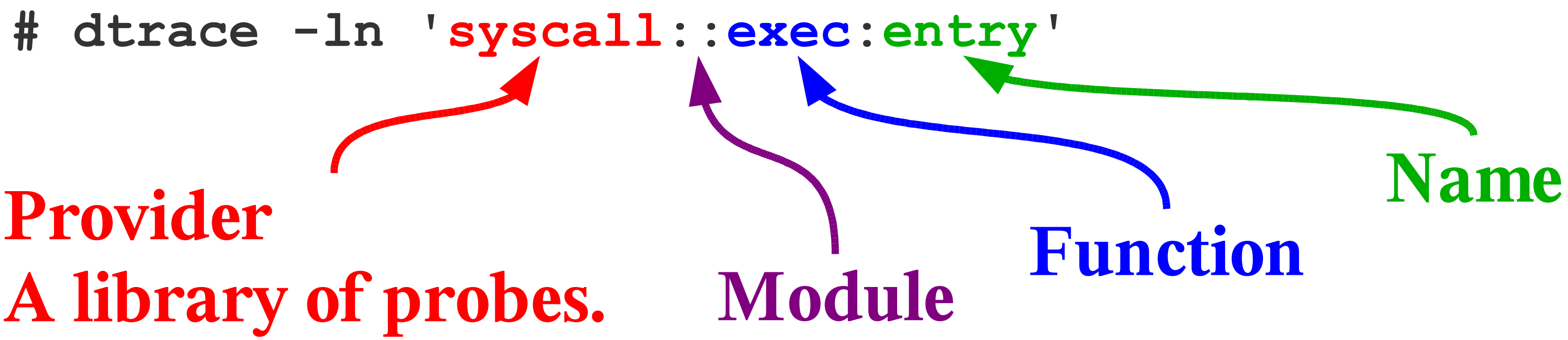
- The following are *not* the same,
  - syscall::read:entry
  - read:entry

```
# dtrace -ln 'read:entry'
   ID   PROVIDER             MODULE                     FUNCTION NAME
 1073    syscall                                            read entry
12978        fbt            genunix                         read entry
49474     pid581          libc.so.1                         read entry
```

- If we only intended to match the syscall read(), this shortcut matches others by mistake.

Brendan's Style Hint:
Use fully-qualified probe names, they are safest

Probe Names



```
# dtrace -ln 'syscall::exec:entry'
```

Provider

A library of probes.

The provider defines the remaining fields.

Module

Function

Name

To best understand these last fields,
1. choose provider
2. see chapter in the DTrace Guide

```
   ID   PROVIDER            MODULE                          FUNCTION NAME
 1089    syscall                                                exec entry
```

Tracing

- After finding the desired probes (`-l`), you are ready to trace activity,

```
# dtrace -n 'syscall::exec*:'
dtrace: description 'syscall::exec*:' matched 4 probes
CPU     ID                    FUNCTION:NAME
  0   5991                      exece:entry
  0   5992                     exece:return
  0   5991                      exece:entry
  0   5992                     exece:return
  0   5991                      exece:entry
...
```

- This is the default output
- Each output line represents a probe firing

Default Output

```
# dtrace -n 'syscall::exec*:'
dtrace: description 'syscall::exec*:' matched 4 probes
CPU     ID                     FUNCTION:NAME
  0   5991                       exece:entry
  0   5992                      exece:return
...
```

DTrace Probe-id. not so interesting

Last 2 fields of probe that fired

The CPU-id. if this changes, the output may be shuffled!

How many probes your probe description actually matched

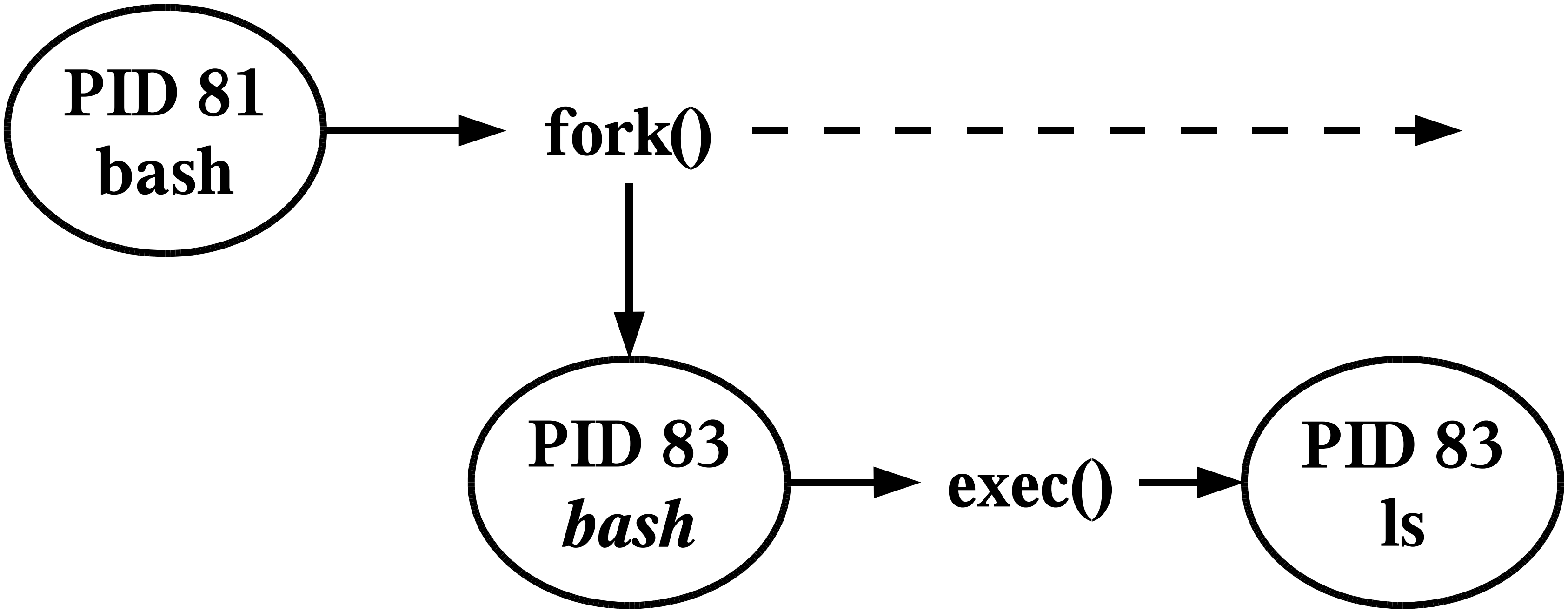
Actions

- A custom action can be performed when a probe fires

```
# dtrace -n 'syscall::exec*: { trace(execname); }'
dtrace: description 'syscall::exec*: ' matched 4 probes
CPU     ID                    FUNCTION:NAME
  0   5991                      exece:entry   bash
  0   5992                     exece:return   date
  0   5991                      exece:entry   bash
  0   5992                     exece:return   ls
...
```

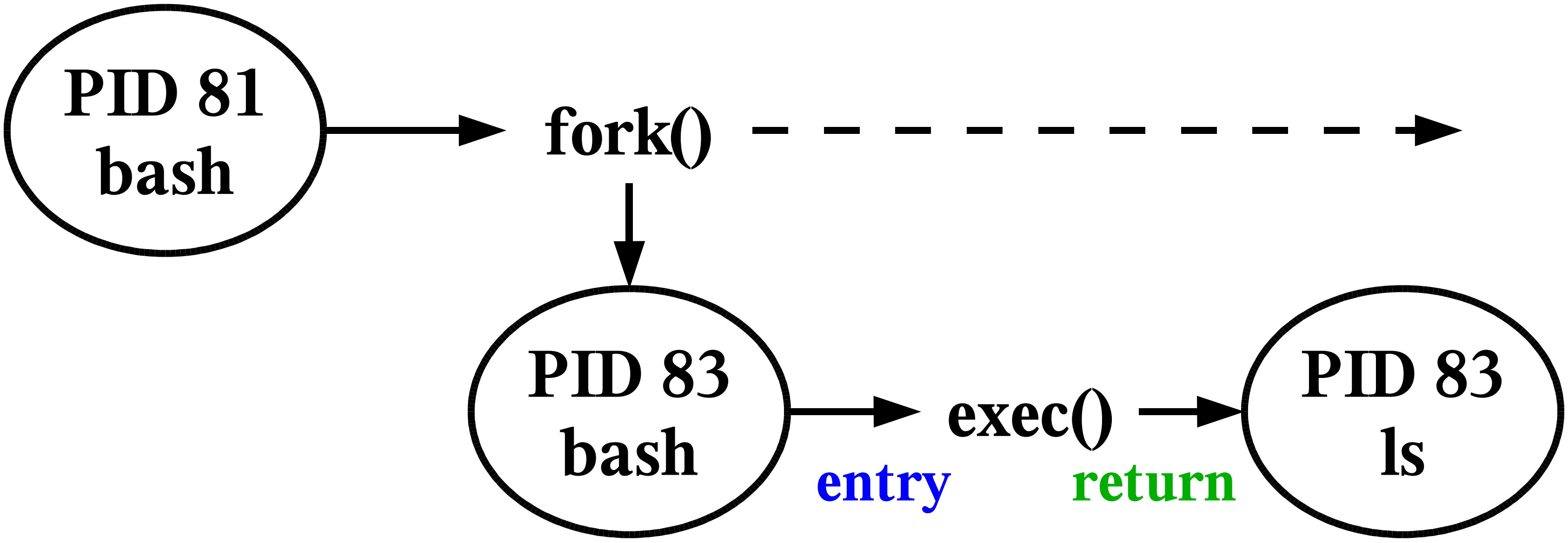
- **`trace()`** prints one argument
- **`execname`** is the process name

Process Creation



- fork variants: fork1(2), forkall(2), vfork(2)
- exec variants: exec(2), exece(2)

Syscall Entry and Return



```
# dtrace -n 'syscall::exec*: { trace(execname); }'
dtrace: description 'syscall::exec*: ' matched 4 probes
CPU     ID                    FUNCTION:NAME
  0   5991                     exece:entry   bash
  0   5992                    exece:return   ls
...
```

- Both syscall entry and return can be traced

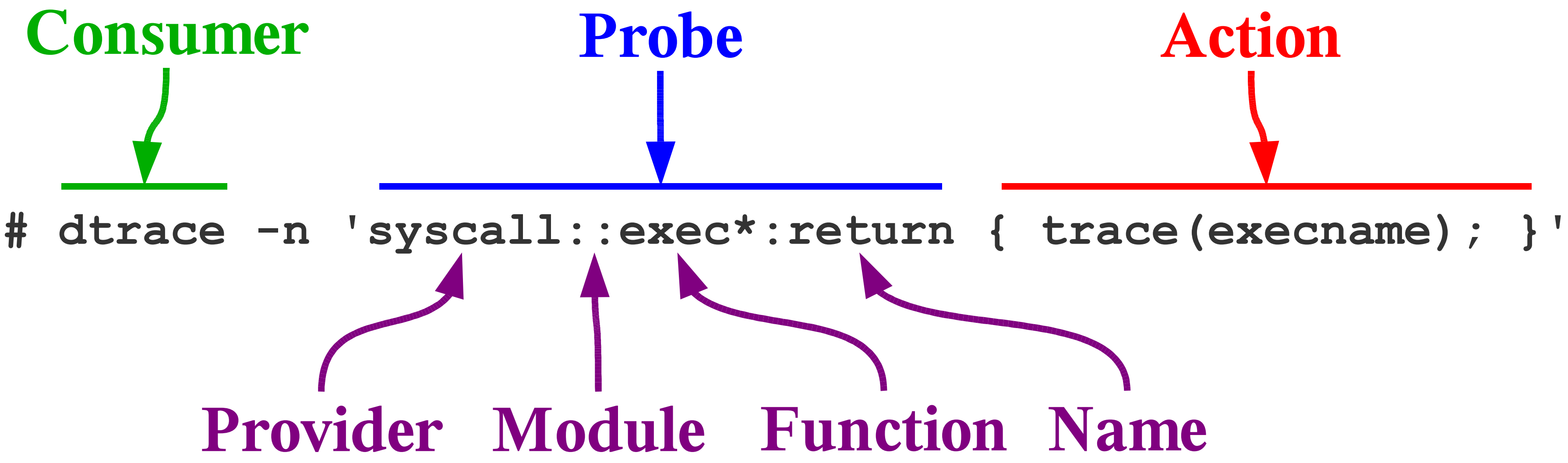
Tracing Process Creation

```
# dtrace -n 'syscall::exec*:return { trace(execname); }'
dtrace: description 'syscall::exec*:return ' matched 2 probes
CPU     ID                    FUNCTION:NAME
  0   5992                     exece:return   staroffice
  0   5992                     exece:return   grep
  0   5992                     exece:return   grep
  0   5992                     exece:return   soffice
  0   5992                     exece:return   dirname
  0   5992                     exece:return   expr
  0   5992                     exece:return   basename
  0   5992                     exece:return   expr
  0   5992                     exece:return   sopatchlevel.sh
  0   5992                     exece:return   dirname
...
```

- For exec() the return probe is traced, as this is when the destination execname is available on-CPU
- This shows new processes from running “soffice”

Terminology

- A summary of DTrace terminology,



Consumer **Probe** **Action**

```
# dtrace -n 'syscall::exec*:return { trace(execname); }'
```

Provider **Module** **Function** **Name**

It's important to be able to talk-the-talk...

Provider Intro

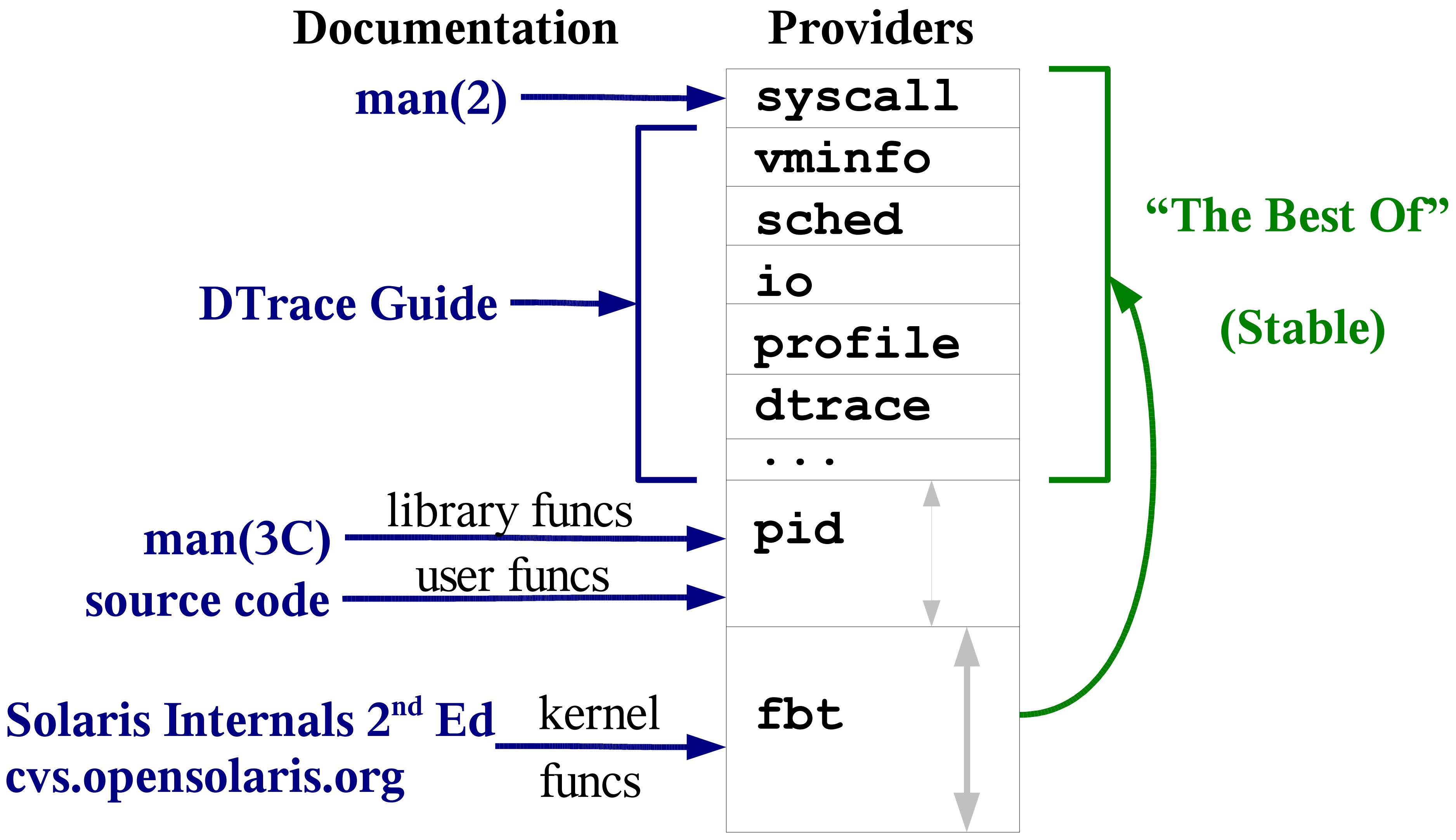
- There are many providers,

`syscall`	System call entry and return probes
`vminfo`	Virtual Memory statistic probes
`sysinfo`	Classic sysinfo statistic probes
`io`	Disk and NFS events
`sched`	system scheduling events
`profile`	fixed sampling
`dtrace`	program BEGIN/END probes
`pid`	user-level tracing
`fbt`	raw kernel tracing
`...`	

Provider Questions

1. Where are syscalls documented?
2. The pid provider traces user-level activity:
   Where are library functions documented?
   Where are user functions documented?
3. The fbt provider traces kernel-level activity:
   Where are kernel functions documented?
4. DTrace provides its own custom providers.
   Where would they be documented?

Provider Documentation



Documentation

Providers

man(2)

DTrace Guide

man(3C)

source code

Solaris Internals 2^{nd} Ed

cvs.opensolaris.org

library funcs

user funcs

kernel funcs

`syscall`

`vminfo`

`sched`

`io`

`profile`

`dtrace`

`. . .`

`pid`

`fbt`

"The Best Of"

(Stable)

Action Intro

- trace() prints 1 argument
- printf() may also be used
- DTrace variable builtins include,

execname	process name
pid	process ID
timestamp	time since boot, nanoseconds
probefunc	probe function component
probename	probe name component
curthread	pointer to current thread
curpsinfo	pointer to psinfo like structure

printf Example

- Enhancing our previous one-liner,

```
# dtrace -n 'syscall::exec*:return { printf("%6d %s", pid, execname); }'
dtrace: description 'syscall::exec*:return ' matched 2 probes
CPU     ID                    FUNCTION:NAME
  0   5992                     exece:return  28751 staroffice
  0   5992                     exece:return  28752 grep
  0   5992                     exece:return  28755 grep
  0   5992                     exece:return  28753 soffice
...
```

- format characters include,

%d	integers
%f	floats
%s	strings
%S	safe strings – escaped binary characters
%Y	text formatted time (use with “walltimestamp”)

Style: spaces after commas.

walltimestamp

```
# dtrace -n 'syscall::exec*:return { printf("%-20Y %6d %s", walltimestamp, pid,
   execname); }'
dtrace: description 'syscall::exec*:return ' matched 2 probes
CPU     ID                    FUNCTION:NAME
  0   5992                     exece:return 2006 May 22 02:12:36  28762 staroffice
  0   5992                     exece:return 2006 May 22 02:12:36  28763 grep
  0   5992                     exece:return 2006 May 22 02:12:36  28765 grep
  0   5992                     exece:return 2006 May 22 02:12:36  28766 soffice
  0   5992                     exece:return 2006 May 22 02:12:36  28767 dirname
  0   5992                     exece:return 2006 May 22 02:12:36  28764 expr
  0   5992                     exece:return 2006 May 22 02:12:36  28768 basename
...
```

- *Our output still contains the DTrace defaults.*
  This can be eliminated using -q.
- *Our command is > 80 characters.*
  This can be better managed using a script file.

quiet mode

```
# dtrace -qn 'syscall::exec*:return { printf("%-20Y %6d %s\n",
   walltimestamp, pid, execname); }'
2006 May 22 02:14:36  28773 staroffice
2006 May 22 02:14:36  28774 grep
2006 May 22 02:14:36  28776 grep
2006 May 22 02:14:36  28777 soffice
2006 May 22 02:14:36  28778 dirname
2006 May 22 02:14:36  28775 expr
2006 May 22 02:14:36  28779 basename
2006 May 22 02:14:36  28780 expr
2006 May 22 02:14:36  28781 sopatchlevel.sh
2006 May 22 02:14:36  28782 dirname
^C
```

- **`dtrace -q`** suppresses the default output
- A **`\n`** is now needed to terminate each line

DTrace Script File

```
# cat -n exec.d
     1  #!/usr/sbin/dtrace -qs
     2
     3  syscall::exec*:return
     4  {
     5          printf("%-20Y %6d %s\n", walltimestamp, pid, execname);
     6  }
#
# chmod 755 exec.d
#
# ./exec.d
2006 May 22 02:20:59  28788 staroffice
2006 May 22 02:20:59  28789 grep
2006 May 22 02:20:59  28791 grep
2006 May 22 02:20:59  28792 soffice
2006 May 22 02:20:59  28793 dirname
...
```

Style:
tab indent
actions.

- So far, so good. The script file is easier to edit.
- *Some improvements can be made...*

DTrace Scripting

```
# cat -n exec.d
     1  #!/usr/sbin/dtrace -s
     2
     3  #pragma D option quiet
     4
     5  dtrace:::BEGIN
     6  {
     7          printf("%-20s %6s %s\n", "TIME", "PID", "CMD");
     8  }
     9
    10  syscall::exec*:return
    11  {
    12          printf("%-20Y %6d %s\n", walltimestamp, pid, execname);
    13  }
#
# ./exec.d
TIME                    PID CMD
2006 May 22 02:24:17  28801 staroffice
2006 May 22 02:24:17  28802 grep
2006 May 22 02:24:17  28804 grep
2006 May 22 02:24:17  28805 soffice
...
```

DTrace Scripting

- Seems like awk!
- “pragma D option quiet” is the same as -q, however is more obvious (especially when more options are used).
- Printing a heading serves to both label the output, and to indicate when DTrace has began tracing.
  - dtrace:::BEGIN probe fires at start (headings)
  - dtrace:::END probe fires at end (reports)

curpsinfo->pr_psargs

- To print more than just the execname: try,

```
# dtrace -qn 'syscall::exec*:return { printf("%6d %s\n", pid,
    curpsinfo->pr_psargs); }'

 29396 /bin/sh /usr/bin/soffice
 29397 grep StarOffice 7 /export/home/brendan/.sversionrc
 29398 grep StarOffice 7 /export/home/brendan/.sversionrc
 29396 /bin/sh /usr/staroffice7/program/soffice
 29400 /usr/bin/sh /usr/bin/dirname /usr/staroffice7/program/soffice
 29400 /usr/bin/expr /usr/staroffice7/program/soffice/ : \(/\)/*[^/]*//*$
   | /usr/staro
 29402 /usr/bin/sh /usr/bin/basename /usr/staroffice7/program/soffice
 29402 /usr/bin/expr //usr/staroffice7/program/soffice : \(.*[^/]\)/*$ : .
   */\(..*\) :
 29404 /bin/sh /usr/staroffice7/program/sopatchlevel.sh
 29405 /usr/bin/sh /usr/bin/dirname /
   usr/staroffice7/program/sopatchlevel.sh
 29405 /usr/bin/expr /usr/staroffice7/program/sopatchlevel.sh/ : \(/\)/*
   [^/]*//*$ | /u
 29406 uname -s
^C
```

DTrace Resources

- OpenSolaris DTrace Community
  http://www.opensolaris.org/os/community/dtrace
- DTrace Guide
  http://docs.sun.com/app/docs/doc/817-6223
- DTrace Tools
  http://www.brendangregg.com/dtrace.html
- Solaris Performance and Tools: DTrace and MDB Techniques for Solaris 10 and OpenSolaris. McDougall/Mauro/Gregg
  ISBN: 0-13-156819-1

End of Chapter 2

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Chapter 3

Command Line DTrace

- The syscall Provider
- Entry/Return Arguments
- Predicates
- Aggregations
- Stack tracing
- Intro to sysinfo Provider
- Intro to profile Provider

syscall Provider

- This provider traces syscall entry and returns
- syscalls are the interface between user-land and the kernel, and reflect much of an applications behaviour
- syscalls are well documented – man(2)
- This provider is a great place to start learning DTrace

Entry Arguments

- The syscall entry arguments are available as unsigned 64-bit ints, with the names: arg0, arg1, arg2, ...
- These arguments can be casted if need be to the appropriate types. eg, (int)arg0
- Typed versions may be provided as args[0], args[1], args[2], ...
- Arguments are listed in the syscall's man page

Entry Argument Examples

- syscall::read:entry,

arg0	(int) file descriptor
arg1	(void *) buffer
arg2	(size_t) requested read size

- syscall::mkdir:entry,

arg0	(char *) path
arg1	(mode_t) mode

- String pointers can't be read unless you dereference them. Use copyinstr().

Entry Arguments: Integers

```
# dtrace -n 'syscall::read:entry { trace(arg2); }'
dtrace: description 'syscall::read:entry ' matched 1 probe
CPU     ID                    FUNCTION:NAME
  0   1073                      read:entry              8192
  0   1073                      read:entry              8192
  0   1073                      read:entry              8192
  0   1073                      read:entry              1495
  0   1073                      read:entry              1329
  0   1073                      read:entry               785
  0   1073                      read:entry              4096
  0   1073                      read:entry              4096
...
```

- Integer arguments are easy to use.
- Here read()'s arg2 is printed – the requested read size. *Most are over 1 Kbyte*.

Entry Arguments: Strings

```
# dtrace -n 'syscall::open:entry { trace(copyinstr(arg0)); }'
dtrace: description 'syscall::open:entry ' matched 1 probe
CPU     ID                    FUNCTION:NAME
  0   1077                       open:entry   /var/ld/ld.config
  0   1077                       open:entry   /usr/lib/libc.so.1
  0   1077                       open:entry   /var/ld/ld.config
  0   1077                       open:entry   /usr/lib/libgen.so.1
  0   1077                       open:entry   /usr/lib/libc.so.1
  0   1077                       open:entry   /var/ld/ld.config
  0   1077                       open:entry   /usr/lib/libgen.so.1
  0   1077                       open:entry   /usr/lib/libc.so.1
  0   1077                       open:entry   /var/ld/ld.config
  0   1077                       open:entry   /usr/lib/libc.so.1
...
```

- copyinstr() is a convienent function to fetch strings from user-land to the kernel.
- copyin() also exists, for fetching any data.

Return Code

- The syscall return code is available from the return probe as arg0.
- The man page for the syscall should explain what the return code is.
- In general, the return code is,

-1	failure
>= 0	success

- If a syscall fails, the error code is available as the DTrace built-in “errno”. See /usr/include/sys/errno.h for a description.

Return Code Example

- For example, syscall::read:return has,

  arg0 number of successful bytes read, or -1 for failure

```
# dtrace -n 'syscall::read:return { trace(arg0); }'
dtrace: description 'syscall::read:return ' matched 1 probe
CPU     ID                    FUNCTION:NAME
  0   1074                      read:return                80
  0   1074                      read:return                45
  0   1074                      read:return                63
  0   1074                      read:return                63
  0   1074                      read:return                80
  0   1074                      read:return               315
  0   1074                      read:return                80
...
```

- Most actual bytes read are < 1 Kbyte.

Return Code Hints

- The return code is often typed as an int, but sometimes (x86) isn't,

```
# dtrace -n 'syscall::open:return { trace(arg0); }'
dtrace: description 'syscall::open:return ' matched 1 probe
CPU     ID                    FUNCTION:NAME
  0   1078                      open:return        4294967295
  0   1078                      open:return                 3
  0   6280                    open64:return        4294967295
^C
# dtrace -n 'syscall::open:return { trace((int)arg0); }'
dtrace: description 'syscall::open:return ' matched 1 probe
CPU     ID                    FUNCTION:NAME
  0   1078                      open:return        -1
  0   1078                      open:return         3
  0   6280                    open64:return        -1
```

- Here a “cat /etc/shadow” was run as non-root on x86, with arg0 uncasted and casted.

Questions

- Would it be useful to only trace syscalls that failed? (ie, return arg0 == -1)
- Would it be useful to trace syscalls with unusual entry arguments: eg, read()s of a size less than 8 bytes?
- Would it be useful to match on execname and pid?
- You could just dump everything and grep later. But there is a better way...

Predicates

- Allow filtering of trace data
- Are a boolean expression used to determine if an action is performed
- For example,

```
# dtrace -n 'syscall::read:entry /arg2 < 8/ { printf("%-16s %d",
   execname, arg2); }'
dtrace: description 'syscall::read:entry ' matched 1 probe
CPU     ID                    FUNCTION:NAME
  0   1073                       read:entry bash             1
  0   1073                       read:entry bash             1
  0   1073                       read:entry bash             1
...
```

- This matches < 8 byte requested read()s.

Predicates

- General Syntax,

```
probe-description
/predicate/
{
    action;
    action;
    ...
}
```

Style: place the probe, predicate and braces on separate lines.

- This is the most common way DTrace does if-then-else statements (which DTrace does not have directly).

Predicate Examples

- `/execname == “ls”/` process is “ls” - will match multiple processes, all called “ls”
- `/(int)arg0 < 0/` arg0 as int is less than 0
- `/pid != 0/` not the kernel
- `/pid/` same as above
- `/execname != “dtrace” && pid != 0/` neither the dtrace command nor the kernel

truss-like DTrace

```
# dtrace -n 'syscall:::entry /execname == "ls"/ { printf("%x %x %x",
   arg0, arg1, arg2); }'
dtrace: description 'syscall:::entry ' matched 231 probes
CPU     ID                    FUNCTION:NAME
  0   6247                resolvepath:entry 8047fed 804738c 3ff
  0   6119                  sysconfig:entry 6 468d fec1d444
  0   6247                resolvepath:entry d27fd9dc 804738c 3ff
  0   6093                      xstat:entry 2 8047fed 80477b8
  0   1077                       open:entry d27f7a24 0 0
  0   6093                      xstat:entry 2 d27fbf38 8047070
  0   6247                resolvepath:entry d27fbf38 80470f8 3ff
  0   1077                       open:entry d27fbf38 0 0
...
```

- This snoops syscalls from all processes called “ls”
- It prints three arguments in hex (or tries to)
- The output is verbose. Much more so for bigger apps. Remember truss -c?

Aggregations

- A DTrace variable type.
- In rough order of complexity,
  - char
  - int
  - long
  - double
  - float
  - pointer
  - array
  - associative array
  - ***aggregation***
  - struct
  - object

Complexity

Common Programming Language Variable Types

Why Aggregations First

- Aggregations are introduced early because we *want* you to use them as much as possible!
- Their advantages are:
  - They summarise the data in often the most appropriate way – providing the final report
  - Aggregations are **fast** – they do not lock between CPUs in the same way as other data types

Aggregation count()

```
# dtrace -n 'syscall:::entry { @fred = count(); }'
dtrace: description 'syscall:::entry ' matched 231 probes
^C

            11783
```

- The Aggregation name is “@fred”
- The Aggregation function is “count()” - which counts occurrences
- When Ctrl-C is hit, DTrace prints @fred. This is for convience. Manually printing aggregations is possible if desired.
- Here, DTrace observed 11783 system calls.

Aggregation by execname

```
# dtrace -n 'syscall::entry { @fred[execname] = count(); }'
dtrace: description 'syscall::entry ' matched 231 probes
^C

  svc.configd                                                      1
  svc.startd                                                       3
  nautilus                                                         3
  httpd                                                            6
  nscd                                                            38
  java                                                            73
  bash                                                            95
  dtrace                                                         119
  sshd                                                           128
  acroread                                                       321
  find                                                         15068
```

- The key is now execname, using “@fred[execname]”
- This is producing a frequency count by execname report
- Here, “find” processes caused 15,068 syscalls

Aggregation by syscall

```
# dtrace -n 'syscall:::entry /execname == "find"/ { @fred[probefunc] =
   count(); }'
dtrace: description 'syscall:::entry ' matched 231 probes
^C

  write                                                            47
  fcntl                                                           127
  fsat                                                            127
  close                                                           129
  fstat64                                                         254
  fchdir                                                          256
  getdents64                                                      261
  acl                                                            3131
  gtime                                                          3131
  lstat64                                                        3132
```

- “probefunc” is the 3rd probe field, which for the syscall provider is the syscall name
- Here, we can see which syscalls find is calling

Aggregation Syntax

- The general syntax is,

  `@name[key] = function(args)`
- The name and the key are optional
- Examples,
  - `@num[execname] = count();`
  - `@[execname] = count();`
  - `@total = count();`
- Multiple keys can be used. Eg,
  - `@num[pid, execname] = count();`

Style:
I like to name my aggregates.

Multiple Keys

```
# dtrace -n 'syscall:::entry { @num[pid, execname] = count(); }'
dtrace: description 'syscall:::entry ' matched 231 probes
^C

     3104  gnome-terminal                                              2
     3153  gnome-terminal                                              2
     3098  nautilus                                                    3
     4804  java                                                       10
      599  sshd                                                       24
     8117  acroread                                                   45
    28921  dtrace                                                     71
      113  nscd                                                      270
    28920  find                                                     3418
```

- The key is now [pid, execname]
- DTrace has printed them in neat columns

  Any fancier key combinations, and DTrace may not be so neat – we'll need to tweak the output.

Aggregating Functions

- So far we have only seen count().
  Which is certainly fairly useful.
- Aggregating functions,

count()	count occurances
sum(value)	sum value
avg(value)	average value
min(value)	find value minimum
max(value)	find value maximum
quantize(value)	power-of-2 distribution plot
lquantize(value, min, max, step)	linear distribution plot

Aggregation Demos

- The Aggregating functions will be used to analyse the behaviour of the following “wc” command:

```
# wc /usr/share/man/windex
```

- This file is 931886 bytes (910 Kbytes)
- The “wc” command will read through the input file – so there should be many syscalls to trace.

Aggregation sum()

```
# dtrace -n 'syscall::read:entry { @bytes[execname] = sum(arg2); }'
dtrace: description 'syscall::read:entry ' matched 1 probe
^C

  bash                                                              4
  sshd                                                          98304
  wc                                                           942080
```

- This sums the requested read() bytes by execname
- “wc” requested 942080 bytes. This almost matches the file,

```
# ls -l /usr/share/man/windex
-rw-r--r--   1 root     root     931886 Dec 22 14:23 /usr/share/man/windex
```

- *Why would there be a difference?*

sum() on return

- Summing the return is now attempted,

```
# dtrace -n 'syscall::read:return { @bytes[execname] = sum(arg0); }'
dtrace: description 'syscall::read:return ' matched 1 probe
^C

  sshd                                                         188
  wc                                                        931886
```

- Perfect match!

```
# ls -l /usr/share/man/windex
-rw-r--r--   1 root     root    931886 Dec 22 14:23 /usr/share/man/windex
```

- Although be careful: syscalls can return -1 for failure – which would wreck our sum() value. A predicate could be used to avoid this.

Questions

- What would be the size of each read?
- How many reads would occur?

Aggregation avg()

- The average read size can be aggregated:

```
# dtrace -n 'syscall::read:return { @bytes[execname] = avg(arg0); }'
dtrace: description 'syscall::read:return ' matched 1 probe
^C

  bash                                                            1
  sshd                                                           37
  wc                                                           8103
```

- The average read size is 8103 bytes.
- Since 8 Kbytes == 8192 bytes, it sounds like there is an 8 Kbyte ceiling. Could we check this?

Aggregation min(), max()

- The following fetches the min then max:

```
# dtrace -n 'syscall::read:return { @bytes[execname] = min(arg0); }'
dtrace: description 'syscall::read:return ' matched 1 probe
^R
^C

  wc                                                             0
  bash                                                           1
  sshd                                                           2

# dtrace -n 'syscall::read:return { @bytes[execname] = max(arg0); }'
dtrace: description 'syscall::read:return ' matched 1 probe
^C

  bash                                                           1
  sshd                                                          52
  wc                                                          8192
```

- 8.00 Kbytes is indeed the maximum.

Aggregation count()

- Counting syscalls is always useful:

```
# dtrace -n 'syscall::read:entry { @num[execname] = count(); }'
dtrace: description 'syscall::read:entry ' matched 1 probe
^C

  bash                                                           4
  sshd                                                           8
  wc                                                           115
```

- 115 reads()s occurred.
- This makes sense,
  - average read size: 8103 bytes
  - file size: 931886 bytes
  - 931886 / 8103 = 115.005

Aggregations so far

- By running,
    - count()
    - sum()
    - min(), max()
    - avg()
- we have learnt much about the behaviour of the wc command.
- Similar knowledge can be gained much more quickly using quantize().

Aggregation quantize()

```
# dtrace -n 'syscall::read:return { @dist[execname] = quantize(arg0); }'
dtrace: description 'syscall::read:return ' matched 1 probe
^C
...

  wc
           value  ------------- Distribution ------------- count
              -1 |                                         0
               0 |                                         1
               1 |                                         0
               2 |                                         0
               4 |                                         0
               8 |                                         0
              16 |                                         0
              32 |                                         0
              64 |                                         0
             128 |                                         0
             256 |                                         0
             512 |                                         0
            1024 |                                         0
            2048 |                                         0
            4096 |                                         1
            8192 |@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@  113
           16384 |                                         0
```

Distribution Plots

```
           value  ------------- Distribution ------------- count
              -1 |                                         0
               0 |                                         1
               1 |                                         0
               2 |                                         0
               4 |                                         0
               8 |                                         0
              16 |                                         0
              32 |                                         0
              64 |                                         0
             128 |                                         0
             256 |                                         0
             512 |                                         0
            1024 |                                         0
            2048 |                                         0
            4096 |                                         1
            8192 |@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@  113
           16384 |                                         0
```

occurrence was at least this value

number of occurrences

mostly 8192 to 16383 byte reads

- Conveys a count, min, max, avg, (and with some mental calculations) a sum; all at once!

Aggregation lquantize()

- When power-of-2 distributions are not suitable, lquantize provides linear customisable distributions.
- The arguments are, lquantize(value, min, max, step)

Aggregation lquantize()

```
# dtrace -n 'syscall::read:entry { @dist[execname] = lquantize(arg0, 0,
   128, 1); }'
dtrace: description 'syscall::read:entry ' matched 1 probe
^C

  bash
           value  ------------- Distribution ------------- count
             < 0 |                                         0
               0 |@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@ 4
               1 |                                         0
...

  wc
           value  ------------- Distribution ------------- count
               2 |                                         0
               3 |@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@ 115
               4 |                                         0
```

- This is read() file discriptor. wc used FD 3, while bash using FD 0 (STDIN).

Raw Data

- Remember that raw data can always be dumped, for other post processing:

```
# dtrace -n 'syscall::read:return /execname == "wc"/ { trace(arg0); }'
dtrace: description 'syscall::read:return ' matched 1 probe
CPU     ID                    FUNCTION:NAME
  0   1074                      read:return              8192
  0   1074                      read:return              8192
  0   1074                      read:return              8192
...
  0   1074                      read:return              8192
  0   1074                      read:return              6190
  0   1074                      read:return                 0
^C
```

- Aggregations are great summaries, but sometimes you just want the raw data.

Stack Traces

- DTrace provides 3 stack trace functions:
  - stack()   kernel stack trace
  - ustack()   user stack trace
  - jstack()   java stack trace
- These explain why your event is occurring – the ancestory.
- dtrace(1M) needs the process to still exist to evaluate symbols for ustack() and jstack().

ustack()

```
# dtrace -n 'syscall::read:return /execname == "bash"/ { ustack(); }'
dtrace: description 'syscall::read:return ' matched 1 probe
CPU     ID                    FUNCTION:NAME
  0   1074                      read:return
              libc.so.1`_read+0x15
              bash`rl_getc+0x1f
              bash`rl_read_key+0xad
              bash`readline_internal_char+0x5c
              bash`0x80abf72
              bash`0x80abf8c
              bash`readline+0x37
              bash`0x80675ad
              bash`0x8067525
              bash`0x8067d2b
              bash`0x80686b4
              bash`0x8068275
              bash`yyparse+0x12f
              bash`parse_command+0x56
              bash`read_command+0x8c
              bash`reader_loop+0xdd
              bash`main+0x638
              bash`0x806395a

^C
```

ustack() short-lived processes

- Now we will run ustack() on the read() from the short-lived “wc” command:

```
# dtrace -n 'syscall::read:return /execname == "wc"/ { ustack(); }'
dtrace: description 'syscall::read:return ' matched 1 probe
CPU     ID                    FUNCTION:NAME
  0   1074                      read:return
              0xd279e465
              0xd27856de
              0x8050c70
              0x8050a56
```

← ?

- wc completes and dissapears before the dtrace(1M) command can read its symbol table.

ustack() and mdb

- One technique is to use mdb to set a breakpoint on exit:

```
$ mdb /usr/bin/wc
> exit:b
> :r /usr/share/man/windex
   11821  113846  931886 /usr/share/man/windex
mdb: stop at 0x805090c
mdb: target stopped at:
PLT:exit:       jmp    *0x8062014
>

# dtrace -n 'syscall::read:return /execname == "wc"/ { ustack(); }'
dtrace: description 'syscall::read:return ' matched 1 probe
CPU     ID                    FUNCTION:NAME
  0   1074                      read:return
              libc.so.1`_read+0x15
              libc.so.1`fread+0xb6
              wc`main+0x184
              wc`0x8050a56
...
```

!

ustack() aggregations

- The entire stack trace can be used as a key.
- This measures the most frequent stack trace that caused the probe.
- The stack can be truncated using an integer argument: eg, ustack(5) for 5 lines only.

```
# dtrace -n 'syscall::read:return /execname == "zsh"/ { @num[ustack
   ()] = count(); }'
dtrace: description 'syscall::read:return ' matched 1 probe
^C
              libc.so.1`_read+0x15
              libc.so.1`getlogin+0x2a
              zsh`createparamtable+0x1e2
              zsh`setupvals+0x5bd
              zsh`zsh_main+0x1ae
              zsh`main+0xe
              zsh`0x8059b9e
                1
```

This stack trace occurred only once

… continued

```
...

              libc.so.1`_read+0x15
              zle.so`0xd251fd22
              zle.so`getkey+0x130
              zle.so`0xd251f520
              zle.so`getkeymapcmd+0x48
              zle.so`getkeycmd+0x2c
              zle.so`zlecore+0x6b
              zle.so`zleread+0x403
              zsh`autoload_zleread+0x3e
              zsh`0x8079c59
              zsh`ingetc+0x6d
              zsh`0x80734fa
              zsh`gettok+0x18
              zsh`yylex+0x17
              zsh`parse_event+0x23
              zsh`loop+0x91
              zsh`zsh_main+0x1d0
              zsh`main+0xe
              zsh`0x8059b9e
               20
```

This entire stack trace occurred 20 times

Back to the Syscall Provider

- So far we have just used the syscall provider
- There are some difficulties to be aware of:
    - when tracing writes – be aware that there is write(), writev(), pwrite(), pwrite64()
    - when tracing reads – be aware that there is read(), readv(), pread(), pread64()
      There is also readlink() - for symlinks
    - other variants exist. open(), open64()...
- readv() and writev() cause problems – fetching the size from an iovec isn't easy

sysinfo Provider Intro

- sysinfo provides probes that trace regular system activity
- sysinfo:::readch traces all the read variants, and provides the successful bytes read as arg0
- sysinfo:::writech traces all the write variants, and provides the successful bytes written as arg0
- Don't need to worry about syscall return of -1

Bytes Read by Process Name

- sysinfo does this easily,

```
# dtrace -n 'sysinfo:::readch { @bytes[execname] = sum(arg0); }'
dtrace: description 'sysinfo:::readch ' matched 4 probes
^C

  bash                                                             14
  sshd                                                            591
```

- Handles read variants
- This could use quantize(), or trace writech
- We should now be able to construct many useful one-liners using syscall, sysinfo and aggregations

profile Provider Intro

- profile samples activity at a custom rate
- The maximum sample rate is 5000 Hertz

```
# dtrace -n 'profile:::profile-100hz { @num[execname] = count(); }'
dtrace: description 'profile:::profile-100hz ' matched 1 probe
^C

  dirname                                                           1
  bash                                                              2
  sopatchlevel.sh                                                   2
  uname                                                             2
  expr                                                              3
  soffice                                                           3
  staroffice                                                        3
  javaldx                                                           4
  soffice.bin                                                       8
  pagein                                                           84
  sched                                                           389
```

- This is sampling execname at 100 Hertz

profile and ustack()

```
# dtrace -n 'profile:::profile-100hz /execname == "prstat"/ {
    @num[ustack(5)] = count(); }'
dtrace: description 'profile:::profile-100hz ' matched 1 probe
^C

              libc.so.1`memcpy+0x41
              prstat`0x8053a54
              prstat`main+0x791
              prstat`0x8051dc2
                1
...

              libc.so.1`_pread+0x15
              prstat`0x8053606
              prstat`0x80537d3
              prstat`main+0x791
              prstat`0x8051dc2
               39
```

- This can help identify where a process is spending its time

Using profile

- The profile provider allows simple and useful one-liners and scripts to be written
- The overheads of using profile are fixed to the sampling rate; unlike other providers, where a high frequency of traced events can slow the target.
- Be aware of sampling issues. If accurate measurements are desired, use other providers to measure on an event-by-event basis.

End of Chapter 3

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Chapter 4

DTrace one-liners

- List useful one-liners
- Discuss when to use them

One-Liners Are Great

- Remember “handy one-liners for sed”?
- One-liners can provide simple solutions to common problems
- One-liners may not need the same arduous approval procedures that scripts may require
- Someone once emailed me to say:

> *thanks for the DTraceToolkit. I got as far as the one-liners, and found I could do everything I needed to.*

(so much for writing 100+ scripts!)

Useful One-Liners

- The DTrace one-liners list is kept in the DTraceToolkit under Docs/oneliners.txt

  (http://www.opensolaris.org/os/community/dtrace/dtracetoolkit)
- So far we have covered enough DTrace syntax to understand most of them.
- Many probes they use will be new, but readily understandable in such a practical context.
- I will demonstrate many of these live...

One-liners #1

```
# New processes with arguments,
dtrace -n 'proc::exec-success { trace(curpsinfo->pr_psargs); }'

# Files opened by process name,
dtrace -n 'syscall::open*:entry { printf("%s %s",execname,copyinstr(arg0)); }'

# Files created using creat() by process name,
dtrace -n 'syscall::creat*:entry { printf("%s %s",execname,copyinstr(arg0)); }'

# Syscall count by process name,
dtrace -n 'syscall:::entry { @num[execname] = count(); }'

# Syscall count by syscall,
dtrace -n 'syscall:::entry { @num[probefunc] = count(); }'

# Syscall count by process ID,
dtrace -n 'syscall:::entry { @num[pid,execname] = count(); }'

# Read bytes by process name,
dtrace -n 'sysinfo:::readch { @bytes[execname] = sum(arg0); }'

# Write bytes by process name,
dtrace -n 'sysinfo:::writech { @bytes[execname] = sum(arg0); }'
```

One-liners #2

```
# Read size distribution by process name,
dtrace -n 'sysinfo:::readch { @dist[execname] = quantize(arg0); }'

# Write size distribution by process name,
dtrace -n 'sysinfo:::writech { @dist[execname] = quantize(arg0); }'

# Disk size by process ID,
dtrace -n 'io:::start { printf("%d %s %d",pid,execname,args[0]->b_bcount); }'

# Disk size aggregation
dtrace -n 'io:::start { @size[execname] = quantize(args[0]->b_bcount); }'

# Pages paged in by process name,
dtrace -n 'vminfo:::pgpgin { @pg[execname] = sum(arg0); }'

# Minor faults by process name,
dtrace -n 'vminfo:::as_fault { @mem[execname] = sum(arg0); }'

# Interrupts by CPU,
dtrace -n 'sdt:::interrupt-start { @num[cpu] = count(); }'

# CPU cross calls by process name,
dtrace -n 'sysinfo:::xcalls { @num[execname] = count(); }'
```

One-liners #3

```
# Lock time by process name,
dtrace -n 'lockstat:::adaptive-block { @time[execname] = sum(arg1); }'

# Lock distribution by process name,
dtrace -n 'lockstat:::adaptive-block { @time[execname] = quantize(arg1); }'

# Kernel funtion calls by module
dtrace -n 'fbt:::entry { @calls[probemod] = count(); }'

# Stack size for processes
dtrace -n 'sched:::on-cpu { @[execname] = max(curthread->t_procp->p_stksize);}'

# Kill all top processes when they are invoked,
dtrace -wn 'syscall::exece:return /execname == "top"/ { raise(9); }'

# New processes with arguments and time,
dtrace -qn 'syscall::exec*:return { printf("%Y %s\n",walltimestamp,
   curpsinfo->pr_psargs); }'

# Successful signal details,
dtrace -n 'proc:::signal-send /pid/ { printf("%s -%d %d",execname,args[2],
   args[1]->pr_pid); }'
```

End of Chapter 4

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Chapter 5

DTrace Mentality 1

- Approach Strategies
- Thinking in DTrace

Strategy #1: snoop or summary

- snoop
  - \+ watch events as they occur
  - \+ raw data shows all details
  - \- may be too verbose
  - achieved using trace() or printf()
- summary
  - \+ produce a summary report of data
  - \+ often the fastest way to process data
  - \- may lose information due to summarising
  - achieved using aggregates @

Snoop

```
# dtrace -n 'syscall::exece:return { trace(execname); }'
dtrace: description 'syscall::exece:return ' matched 1 probe
CPU     ID                    FUNCTION:NAME
  0   5992                     exece:return   staroffice
  0   5992                     exece:return   grep
  0   5992                     exece:return   grep
  0   5992                     exece:return   soffice
  0   5992                     exece:return   dirname
  0   5992                     exece:return   expr
...
```

- Output “chugs” along at 1 Hertz. To improve:
  - `dtrace -x switchrate=10hz` command line
  - `#pragma D option switchrate=10hz` script
- Output can be shuffled slightly – check the CPU column, or print timestamp and post-process.

Summary

```
# dtrace -n 'syscall::exece:return { @num[execname] = count(); }'
dtrace: description 'syscall::exece:return ' matched 1 probe
^C

  soffice.bin                                                    1
  pagein                                                         1
  javaldx                                                        1
  basename                                                       1
  sopatchlevel.sh                                                1
  soffice                                                        1
  staroffice                                                     1
  dirname                                                        2
  grep                                                           2
  expr                                                           3
  uname                                                          4
```

- The most frequent occurring item is often an issue, but not always.

Strategy #2: drill down analysis

- Start broad, then focus on potential issues
- For example:

```
# 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 41 857772 109964 20 86 24  1  1  0  4  2  0  0  0  277  416  216  1  1 98
 0 0 51 707120 75408  0  36  0  0  0  0  0  0  0  0  0  290 1218  268  1  3 96
 0 0 51 707120 75408  0   0  0  0  0  0  0  0  0  0  0  279 1285  269  1  4 95
 0 0 51 707120 75408  0   0  0  0  0  0  0  0  0  0  0  285 1188  263  0  3 97
 0 0 51 707120 75408  0   0  0  0  0  0  0  0  0  0  0  276 1154  234  1  3 96
^C
```

- vmstat provides a general system-wide view - a good starting point. Chapter 1 lists others.
- *What may be interesting from this output?*

drill down analysis

- vmstat showed many syscalls
- DTrace can identify if a single process (name) is responsible:

```
# dtrace -n 'syscall:::entry { @num[execname] = count(); }'
dtrace: description 'syscall:::entry ' matched 231 probes
^C

  svc.configd                                                       1
  inetd                                                             1
  nscd                                                             13
  httpd                                                            15
  svc.startd                                                       46
  sshd                                                             56
  java                                                            155
  dtrace                                                          167
  acroread                                                        659
  top                                                            4615
```

drill down analysis

- top is calling most of the system calls
- Now the syscall type is identified:

```
# dtrace -n 'syscall:::entry /execname == "top"/ { @num[probefunc] =
   count(); }'
dtrace: description 'syscall:::entry ' matched 231 probes
^C

  pollsys                                                          7
  write                                                            7
  gtime                                                            7
  sysconfig                                                        7
  getuid                                                           7
  uadmin                                                           7
  llseek                                                          14
  getdents64                                                      14
  ioctl                                                           28
  open                                                          2121
  read                                                          2121
  close                                                         2121
```

drill down analysis

- open(), read(), close() were all called 2121 times – perhaps by the same function.
- DTrace can now aggregate the user stack for these functions:

```
# dtrace -n 'syscall::open:entry /execname == "top"/ {
    @num[ustack()] = count(); }'
dtrace: description 'syscall::open:entry ' matched 1 probe
^C

              libc.so.1`__open+0x15
              libc.so.1`open+0x77
              top`getptable+0xe5
              top`get_process_info+0x14
              top`main+0x695
              top`_start+0x80
             2424
```

drill down analysis

```
  libc.so.1`__open+0x15
  libc.so.1`open+0x77
  top`getptable+0xe5
  top`get_process_info+0x14
  top`main+0x695
  top`_start+0x80
2424
```

culprit

- The same stack trace is seen for all syscalls
- Great – we have identified the function responsible for calling so many syscalls
- *What can be done next?*

further drill down analysis

- Other analysis that can then be performed:
  - examine arguments to syscalls to understand the nature of the activity.
  - measure elapsed and on-cpu timestamps to prove that this large number of syscalls really is an issue (it may not be!)
  - read the source code to the application (if available) to fully understand the issue and suggest a fix.
  - examine activity from other providers other than the syscall layer.
- A *lot* more can be done. We have only just begun!

Strategy #3: frequency count

- When in doubt, frequency count.

```
# dtrace -n 'sysinfo::: /execname == "top"/ { @num[probename] =
   count(); }'
dtrace: description 'sysinfo::: ' matched 59 probes
^C

  trap                                                          2
  writech                                                       9
  syswrite                                                      9
  outch                                                         9
  inv_swtch                                                    48
  pswitch                                                      68
  readch                                                     2727
  sysread                                                    2727
  namei                                                      2727
```

- Be aware that this is counting occurrences that a probe was fired. ie, the readch statistic probe was called 2727 times. Don't infer too much...

Frequency Count

```
# dtrace -n 'sysinfo::: /execname == "top"/ { @num[probename] =
    sum(arg0); }'
dtrace: description 'sysinfo::: ' matched 59 probes
^C

  syswrite                                                         8
  inv_swtch                                                       38
  pswitch                                                         56
  sysread                                                       2424
  namei                                                         2424
  writech                                                       3135
  outch                                                         3158
  readch                                                      814464
```

- Now we can see the value of the statistic. readch is at 814464 bytes.

Frequency Count

```
# dtrace -ln mib:::| wc
     486    2430   41475
```

- Why study 485 probes if most are *never* called? If it's never called, it's never called!

```
# dtrace -n 'mib::: { @num[probename] = count(); }'
dtrace: description 'mib::: ' matched 485 probes
^C

  udpInDatagrams                                                   1
  ipInDelivers                                                     1
  tcpInAckBytes                                                   74
  tcpRttUpdate                                                    74
  tcpInDataInorderSegs                                            74
  tcpInAckSegs                                                    74
  tcpInDataInorderBytes                                           74
  ipOutRequests                                                   81
  tcpOutDataBytes                                                 81
  tcpOutDataSegs                                                  81
  ipInReceives                                                   142
```

Strategy #4: known count

- Cause a fault or workload a known number of times. Probes of interest will occur that known number of times (or a multiple).
- Here a non-root user modifies /etc/motd and tries to save 17 times:

```
# dtrace -n 'syscall:::entry /execname == "vi"/ { @num[probefunc] =
   count(); }'
dtrace: description 'syscall:::entry ' matched 231 probes
^C

  getpid                                                        17
  stat64                                                        17
  ioctl                                                         34
  read                                                          51
  write                                                        102
```

Yellow Pig

- I like to create 17 events, as 17 is not a commonly occurring number, and is more likely to be related to your test. A similar moderately sized prime would be 23.
- The number of eyelashes on a yellow pig is supposedly 17
- Hence, the “Yellow Pig number” is 17
- “Yellow Pig Day” is July 17th, celebrated by mathematicians
- (I'm not making this up - try google!)

Strategy #5: aggregate stacks

- Stack Traces can be aggregated in at least two ways:
  - A) Event probes
    - when an event of interest occurs, the stack is aggregated
    - this can explain why the event is taking place – the functions that lead up to the event
  - B) Profile sampling
    - the stack trace is aggregated at 100hz (at least)
    - this is a crude but often effective way to show where the application is spending most of its time

Thinking in DTrace

- DTrace itself is an easy language, with the syntax well defined in the DTrace Guide
- Being successful with DTrace is about the application – being able to think in DTrace
- Tips for thinking in DTrace
  - practise, practise, practise
  - know the existing tools inside out (chapter 1)
  - know the OS well (Solaris Internals 2nd edition)
  - study source code, and how applications are constructed and operate
  - think outside the box!

End of Chapter 5

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Chapter 6

Providers

- Provider Guide
- Using fbt
- Using pid

Providers

`syscall`	System call entry and return probes
`sysinfo`	Classic sysinfo statistic probes
`vminfo`	Virtual Memory statistic probes
`io`	Disk and NFS events
`proc`	Process events such as creation
`sched`	System scheduling events
`lockstat`	Kernel synchronisation lock events
`plockstat`	User synchronisation lock events
`mib`	MIB statistic updates
`fasttrap`	User location tracing
`fpuinfo`	SPARC FPU simulation events

Providers

`sdt`	Statically defined tracing
`profile`	Fixed sampling
`dtrace`	Program BEGIN/END probes
`fbt`	Raw kernel tracing
`pid`	User-level tracing

- Check the DTrace Guide for additional providers

syscall

- Example one-liner,

```
# Syscall count by syscall,
dtrace -n 'syscall:::entry { @num[probefunc] = count(); }'
```

- Probes the interface between user-land and the kernel
- Provides many insights into application behaivour
- syscalls are documented in section 2 of the man pages

sysinfo

- Example one-liner,

```
# Read bytes by process name,
dtrace -n 'sysinfo:::readch { @bytes[execname] = sum(arg0); }'
```

- Probes the sysinfo statistics, which are provided by kstat to tools such as mpstat
- Provides many insights into application and system behaivour
- Documented in the DTrace Guide (chap 23)
- Also see /usr/include/sys/sysinfo.h, cpu_sysinfo.h

vminfo

- Example one-liner,

```
# Pages paged in by process name,
dtrace -n 'vminfo:::pgpgin { @pg[execname] = sum(arg0); }'
```

- Probes the vminfo statistics, which are provided by kstat to tools such as vmstat
- Provides many insights into virtual memory behaivour
- Documented in the DTrace Guide (chap 24)
- Also see /usr/include/sys/sysinfo.h, cpu_vminfo.h

io

- Example one-liner,

```
# Disk size aggregation
dtrace -n 'io:::start { @sz[execname] = quantize(args[0]->b_bcount); }'
```

- Probes I/O events, for both disk and NFS
- Provides a probe for the start and finish of each I/O transaction
- Provides crucial data for understanding how applications are driving the disks
- Documented in the DTrace Guide (chap 27)

proc

- Example one-liner,

```
# New processes with arguments,
dtrace -n 'proc:::exec-success { trace(curpsinfo->pr_psargs); }'
```

- Probes process events such as exec, exit, thread creation and exit, and signals
- Provides high level probes so that process analysis can be performed easily
- Documented in the DTrace Guide (chap 25)

sched

- Example one-liner,

```
# Times the schedular begins to run a thread,
dtrace -n 'sched:::on-cpu { @on[execname] = count(); }'
```

- Probes thread scheduling events
- Provides high level probes so that schedular analysis can be performed easily
- Documented in the DTrace Guide (chap 26)
- Also see Solaris Internals 2nd edition

fbt

- Example one-liner,

```
# Kernel funtion calls by module
dtrace -n 'fbt:::entry { @calls[probemod] = count(); }'
```

- Function Boundary Tracing – traces raw kernel function events
- These probes are “unstable” - their names and arguments can and do change between minor releases of Solaris (which is why we have the higher level providers)
- fbt is usually the bulk of the probes: 30,000+

fbt

- Since fbt can trace the entire kernel, observing just about any kernel behaviour is possible
- Enabling all fbt probes (30,000+) will slow the kernel noticeably. Be selective
- Documentation for the fbt probes (which is really documentation for the kernel) is in:
  - The DTrace Guide (chap 20)
  - Solaris Internals 2nd edition
  - cvs.opensolaris.org

pid

- Example one-liner,

```
# Trace user-level function entries,
dtrace -n 'pid$target:a.out::entry' -c 'some_command'
```

- The pid provider runs a command (-c cmd), or traces a particular process (-p PID).
- The pid provider can:
  - trace user functions
  - trace user instructions
  - trace library functions
  - trace library instructions
- The pid provider can create millions of probes

pid:::

- The provider name is,
  - pidPID Where PID is the target to trace
  - pid81 Trace PID 81
  - pid$target Trace the target of -c or -p
- The full syntax is, pidPID:segment:function:name
  - segment is the name of the mapping. eg,
    - libc.so.1 (or “libc”) a library
    - a.out the binary
  - function is the function name. eg, “main”
  - name is either: entry, return, or an instruction address

pid demonstrations

- user functions,

```
# dtrace -n 'pid$target:a.out::entry' -c 'ping mars'
dtrace: description 'pid$target:a.out::entry' matched 16 probes
mars is alive
dtrace: pid 29890 has exited
CPU     ID                    FUNCTION:NAME
  0  39187                     __fsr:entry
  0  39188                      main:entry
  0  39191      send_scheduled_probe:entry
  0  39198          set_IPv4_options:entry
  0  39190          schedule_sigalrm:entry
  0  39199               check_reply:entry
  0  39195                 seq_match:entry
  0  39191      send_scheduled_probe:entry
```

pid demonstrations

- user instructions,

```
# dtrace -n 'pid$target:a.out:set_IPv4_options:' -c 'ping mars'
dtrace: description 'pid$target:a.out:set_IPv4_options:' matched 169 probes
mars is alive
dtrace: pid 29900 has exited
CPU     ID                    FUNCTION:NAME
  0  39188           set_IPv4_options:entry
  0  39189               set_IPv4_options:0
  0  39190               set_IPv4_options:1
  0  39191               set_IPv4_options:3
  0  39192               set_IPv4_options:6
  0  39193               set_IPv4_options:7
  0  39194               set_IPv4_options:8
  0  39195               set_IPv4_options:9
  0  39196              set_IPv4_options:10
  0  39197              set_IPv4_options:12
  0  39198              set_IPv4_options:19
  0  39199              set_IPv4_options:1b
  0  39200              set_IPv4_options:1f
  0  39301             set_IPv4_options:15d
  0  39302             set_IPv4_options:15e
  0  39303             set_IPv4_options:15f
  0  39304             set_IPv4_options:160
  0  39305             set_IPv4_options:162
  0  39306             set_IPv4_options:163
  0  39187          set_IPv4_options:return
```

pid demonstrations

- library functions,

```
# dtrace -n 'pid$target:::entry' -c 'ping mars'
dtrace: description 'pid$target:::entry' matched 5318 probes
mars is alive
dtrace: pid 29905 has exited
CPU     ID                    FUNCTION:NAME
  0  39320                call_array:entry
  0  39321                 call_init:entry
  0  39352                     leave:entry
  0  39351                fmap_setup:entry
  0  39596                    munmap:entry
  0  39296             rt_bind_clear:entry
  0  39287            _rt_bind_clear:entry
  0  39294           rt_mutex_unlock:entry
  0  39289                  _rt_null:entry
  0  39296             rt_bind_clear:entry
  0  39287            _rt_bind_clear:entry
  0  65195                 libc_init:entry
  0  63314                    atexit:entry
  0  64852                   lmalloc:entry
...
```

pid demonstrations

- library instructions,

```
# dtrace -n 'pid$target:libc:getpid:' -c 'ping mars'
dtrace: description 'pid$target:libc:getpid:' matched 9 probes
mars is alive
dtrace: pid 29914 has exited
CPU     ID                    FUNCTION:NAME
  0  39188                     getpid:entry
  0  39189                         getpid:0
  0  39190                         getpid:5
  0  39191                         getpid:6
  0  39192                         getpid:b
  0  39193                         getpid:d
  0  39194                        getpid:13
  0  39195                        getpid:15
  0  39187                    getpid:return
  0  39188                     getpid:entry
  0  39189                         getpid:0
  0  39190                         getpid:5
  0  39191                         getpid:6
...
```

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Chapter 7

The D Language

- Comments
- Variable Types
- Macros
- Script Options
- Pragmas

Comments

- The D language is related to the C programming language. This includes comment syntax:

```
/* this is a one line comment */

/*
 * This is a
 * block comment.
 */
```

Variable Types

- DTrace tries to figure out the variable type on first declaration
- Variable types can be predeclared
- Types include:
  - integer
  - string
  - pointer
  - associative array
  - aggregate
  - thread-local
  - clause-local

Integers

- Using integers:

`int mycount;`	declaration
`mycount = 1;`	declaration / setting
`mycount++;`	increment by 1
`/mycount > 10/`	testing in a predicate

- A declaration of the form “int mycount;” must be placed outside of any action block. They are usually placed at the top of the program.

Strings

- Using strings:

`string name;`	declaration
`name = “Fred Nurke”;`	declaration / setting
`/name == “Fred”/`	predicate testing
`name = 0;`	memory cleanup

- Strings are null terminated
- printf() supports,

%s	string format
%S	safe string format (escapes odd chars)

Pointers

- Used in the same way as C programming
- DTrace can walk most structures without casting (eg, vnode_t, proc_t, ...)
- Special builtins,
  - curthread pointer to the on-cpu thread
  - curpsinfo poniter to a psinfo like structure
- Eg,
  - curpsinfo->pr_psargs 80 char arg list
  - curthread->t_procp->p_lwpcnt # of LWPs

Associative Arrays

- Also known as “hashed arrays”, or “key/value arrays”
- Using associative arrays:

`string name[int];`	decleration
`name[3] = “Fred”;`	decleration / setting
`/name[3] == “Fred”/`	predicate testing
`name[3] = 0;`	memory cleanup
`name[“sd0”, 1] = 4;`	two key array

- *Try to use aggregates instead*

Aggregates

- Discussed in Chapter 3
- Using Aggregates:

`@name[keys] = func();`	setting
`printa(“%s... %@d”, @name);`	printing
`trunc(@name);`	clearing
`trunc(@name, size);`	truncating to size
`clear(@name);`	clearing values
`normalize(@name, n);`	dividing by n

- Aggregates perform well, and produce great reports

Thread-local

- A variable stored private to each thread.
- Using thread-local:
  - `self->start = timestamp;` setting
  - `self int start;` declaration
  - `/self->start > 0/` predicates
  - `self->start = 0;` memory cleanup
- Thread-local variables are crucial, and are used heavily when scripting in DTrace.

Clause-local

- A temporary variable for calculations within an action clause
- Using clause-local:
  - `this->delta = 5;` setting
  - `this int delta;` declaration
- These are used to improve performance, rather than using global integers or strings that require lock overheads between CPUs
- Only use these within one action

Kernel Variables

- Any symbol from the kernel can be read, along with its struct members
- Example kernel variables:

`` `freemem ``	free mem in pages
`` `utsname.nodename ``	hostname

- Often only the source code can explain what these really are
- Module variables can also be read (prefix with the module name)

Macro Variables

- DTrace provides some useful macro variables for scripting:

`$1, $2, ...`	arguments to script as ints
`$$1, $$2, ...`	arguments to script as strings
`$pid`	PID of dtrace(1M)
`$uid`	real UID of dtrace(1M)
`$target`	PID target of dtrace (-c or -p)

- For the argument variables to assume default values (0 or “”), use:
  - `#pragma D option defaultargs`

Script Options

- When writing complex scripts, it can be useful for them to process options. Eg:

```
# ./DTraceToolkit-0.96/dvmstat -h
USAGE: dvmstat [-h] { -p PID | -n name | command }
           -p PID          # examine this PID
           -n name         # examine this process name
  eg,
       dvmstat -p 1871     # examine PID 1871
       dvmstat -n tar      # examine processes called "tar"
       dvmstat df -h       # run and examine "df -h"
```

- Currently this is best achieved by embedding the DTrace script in a shell script, and using the shell's getopts function. Be careful to write neatly and follow programming best practices – such scripts get messy fast.

Pragmas

- These change the behaviour of DTrace, and often an alternative to command line options
- Useful pragmas:
  - `#pragma D option quiet`
  - `#pragma D option switchrate=10hz`
  - `#pragma D option bufsize=16m`
  - `#pragma D option flowindent`
  - `#pragma D option destructive`
- Others are listed in the DTrace Guide (chapter 16)

Destructive Actions

- These do more than just read data:
  - **`stop()`** freeze the current process
  - **`raise(sig)`** send this sig to the current PID
  - **`chill(ns)`** pause for nanoseconds
  - **`system(cmd)`** run this shell command
  - **`copyout(buf, addr, bytes)`** copy this data to user-land
- Use extreme caution when using destructive actions

End of Chapter 7

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Chapter 8

Advanced Scripting

- Step through an example script
- Discuss script internals

Example: shortlived.d

- The following is from the DTraceToolkit:

```
# ./shortlived.d
Tracing... Hit Ctrl-C to stop.
^C
short lived processes:       0.924 secs
total sample duration:       4.308 secs

Total time by process name,
           soffice                3 ms
   sopatchlevel.sh               10 ms
              grep               14 ms
             uname               24 ms
           javaldx               33 ms
              expr               36 ms
       soffice.bin               93 ms
            pagein              696 ms

Total time by PPID,
             29854               30 ms
               625               93 ms
             29846              786 ms
```

shortlived.d

- shortlived.d calculates CPU time consumed by short-lived processes (processes that began and ended while DTrace was tracing).
- A common performance issue is short-lived processes hogging the CPU, which can be difficult to identify using traditional tools such as prstat.
- It is useful to discuss the entire internals of this script, from comments to code.

shortlived.d

```
#!/usr/sbin/dtrace -qs
/*
 * shortlived.d - determine time spent by short lived processes.
 *                Written in DTrace (Solaris 10 3/05).
 *
 * 27-May-2006, ver 0.94
 *
 * USAGE:    shortlived.d       # wait, then hit Ctrl-C
 *
 * Applications that run many short lived processes can cause load
 * on the system that is difficult to identify - the processes
 * aren't sampled in time by programs such as prstat. This program
 * illustrates how much time was spent processing those extra
 * processes, and a table of process name by total times for each.
 *
 * SEE ALSO: execsnoop
 *
 * Notes:
 * - The measurements are minimum values, not all of the overheads
 *   caused by process generation and destruction are measured (DTrace
 *   can do so, but the script would become seriously complex).
 * - The summary values are accurate, the by program and by PPID values
 *   are usually slightly smaller due to rounding errors.
 *
```

shortlived.d

```
* COPYRIGHT: Copyright (c) 2005, 2006 Brendan Gregg.
*
* CDDL HEADER START
*
*  The contents of this file are subject to the terms of the
*  Common Development and Distribution License, Version 1.0 only
*  (the "License").  You may not use this file except in compliance
*  with the License.
*
*  You can obtain a copy of the license at Docs/cddl1.txt
*  or http://www.opensolaris.org/os/licensing.
*  See the License for the specific language governing permissions
*  and limitations under the License.
*
* CDDL HEADER END
*
* 22-Apr-2005  Brendan Gregg   Created this.
*/
```

shortlived.d

```
/*
 * Start
 */
dtrace:::BEGIN
{
        /* save start time */
        start = timestamp;

        /* this is time spent on shortlived processes */
        procs = 0;

        /* print header */
        printf("Tracing... Hit Ctrl-C to stop.\n");
}
```

shortlived.d

```
/*
 * Measure parent fork time
 */
syscall::*fork*:entry
{
        /* save start of fork */
        self->fork = vtimestamp;
}
syscall::*fork*:return
/arg0 != 0 && self->fork/
{
        /* record on-CPU time for the fork syscall */
        procs += vtimestamp - self->fork;
        self->fork = 0;
}



/*
 * Measure child processes time
 */
```

shortlived.d

```
syscall::*fork*:return
/arg0 == 0/
{
        /* save start of child process */
        self->start = vtimestamp;

        /* memory cleanup */
        self->fork = 0;
}
proc:::exit
/self->start/
{
        /* record on-CPU time for process execution */
        this->oncpu = vtimestamp - self->start;
        procs += this->oncpu;

        /* sum on-CPU by process name and ppid */
        @Times_exec[execname] = sum(this->oncpu/1000000);
        @Times_ppid[ppid] = sum(this->oncpu/1000000);

        /* memory cleanup */
        self->start = 0;
}
```

shortlived.d

```
/*
 * Print report
 */
dtrace:::END
{
        this->total = timestamp - start;
        printf("short lived processes: %6d.%03d secs\n",
            procs/1000000000, (procs%1000000000)/1000000);
        printf("total sample duration: %6d.%03d secs\n",
            this->total/1000000000, (this->total%1000000000)/1000000);
        printf("\nTotal time by process name,\n");
        printa("%18s %@12d ms\n", @Times_exec);
        printf("\nTotal time by PPID,\n");
        printa("%18d %@12d ms\n", @Times_ppid);
}
```

End of Chapter 8

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Chapter 9

The DTraceToolkit

- Introduce the DTraceToolkit
- Explain Layout
- A Recipe For Getting Started

DTraceToolkit

- http://www.opensolaris.org/os/community/dtrace/dtracetoolkit
- http://www.brendangregg.com/dtrace.html
- Version 0.96 contains over 100 scripts
- Freeware (CDDL)
- Serves to:
  - Provide tools to analyse to common problems
  - Provide numerous demonstrations of programming in D
  - Promote DTrace
- Written for Solaris 10 3/05 as much as possible

Main Parts

- The DTraceToolkit is currently 3 main parts:

• The Scripts	*
• Man Pages	Man
• Examples	Docs/Examples

- There is a man page for every script, and an example file for every script.
- It took considerable time to write 100+ man pages – so please read them!
- The example files are often more useful than the man pages

Installation

- Isn't required – the scripts can be run immediately after extraction
- If desired, an install script has been provided. It prompts for install options, and defaults to installing under /opt/DTT

```
# ./install
DTraceToolkit Installation
---------------------------
DTraceToolkit version 0.96, 24-Apr-2006

hit Ctrl-C any time you wish to quit.

Enter target directory for installation [/opt/DTT]:
```

Script Layout

- The scripts are positioned in a hierarchy: the most useful are in the top directory, and others are in meaningful subdirectories
- The “Bin” directory contains symlinks to all the scripts

```
DTraceToolkit-0.96# ls -F
Apps/         Guide         Proc/         dapptrace*    iosnoop*
Bin/          Kernel/       README@       dexplorer*    iotop*
Cpu/          License@      System/       dtruss*       opensnoop*
Disk/         Locks/        User/         dvmstat*      procsystime*
Docs/         Man/          Version       errinfo*      rwsnoop*
Extra/        Mem/          Zones/        execsnoop*    rwtop*
FS/           Net/          dappprof*     install*
```

The Scripts

- If they end in **`.d`**, they are pure DTrace. See the man page or try reading their header.
- If they don't end in **`.d`**, they are wrapped in shell or Perl. See their man page and try running them with **`-h`**.
- If they begin with,
  - **`Tracing... Hit Ctrl-C to end.`**
    they are tracing events
  - **`Sampling... Hit Ctrl-C to end.`**
    they are sampling events using the profile provider

The Man Pages

- Man Pages can be read using,

```
# MANPATH=$MANPATH:/opt/DTT/Man     # or wherever
# man iosnoop
Reformatting page.  Please Wait... done

USER COMMANDS                                          iosnoop(1m)

NAME
     iosnoop - snoop I/O events as they occur. Uses DTrace.

SYNOPSIS
     iosnoop [-a|-A|-Deghinostv] [-d device]  [-f  filename]  [-m
     mount_point] [-n name] [-p PID]

DESCRIPTION
     iosnoop prints  I/O  events  as  they  happen,  with  useful
     details such as UID, PID, block number, size, filename, etc.

     This is useful to  determine  the  process  responsible  for
     using  the  disks,  as  well as details on what activity the
     process is requesting. Behaviour such as random  or  sequen-
     tial I/O can be observed by reading the block numbers.
```

The Example Files

- Read using,

```
# more Docs/Examples/bitesize_example.txt
In this example, bitesize.d was run for several seconds then Ctrl-C was hit.
As bitesize.d runs it records how processes on the system are accessing the
disks - in particular the size of the I/O operation. It is usually desirable
for processes to be requesting large I/O operations rather than taking many
small "bites".

The final report highlights how processes performed. The find command mostly
read 1K blocks while the tar command was reading large blocks - both as
expected.

   # bitesize.d
   Tracing... Hit Ctrl-C to end.
   ^C

        PID  CMD
       7110  -bash\0

              value  ------------- Distribution ------------- count
                512 |                                         0
               1024 |@@@@@@@@@@@@@@@@@@@@@@@@@@               2
```

Script Subdirectories

- So far there is,

`Bin/`	`Symlinks to the scripts`
`Apps/`	`Application specific scripts`
`Cpu/`	`Scripts for CPU analysis`
`Disk/`	`Scripts for disk I/O analysis`
`Extra/`	`Misc scripts`
`Kernel/`	`Scripts for kernel analysis`
`Locks/`	`Scripts for lock analysis`
`Mem/`	`Scripts for memory analysis`
`Net/`	`Scripts for network analysis`
`Proc/`	`Scripts for process analysis`
`System/`	`Scripts for system analysis`
`User/`	`Scripts for user based activity analysis`
`Zones/`	`Scripts for analysis by zone`

- Remember to check the top-level scripts first

DTraceToolkit Recipe

- Running the following scripts in this order has proved a useful recipe:
  1) **`execsnoop`**
  2) **`iosnoop`**
  3) **`opensnoop`**
  4) **`errinfo`**
  5) **`procsystime`**
  6) **`rwtop`**
  7) **`iotop`**
  8) **`dvmstat`**
  9) **`Disk/bitesize.d`**

dexplorer

- This exists to capture DTrace data in the most broad possible way
- It creates a tar file containing the output from numerous DTrace commands
- If you only had 5 minutes to “DTrace” a server, dexplorer may be the best tool to run – it creates many files for later offline analysis
- A html-iser for dexplorer has yet to be written (it won't be hard to do)

Behind the DTraceToolkit

- The DTraceToolkit is a product of much testing – far more time has gone into testing the scripts than actually writing them
- The scripts need to be tested on:
  - SPARC and x86
  - Solaris 10 3/05, Solaris 10 1/06, ...
  - Different builds of OpenSolaris (makes a huge difference for any fbt based scripts)
  - All possible workloads
- *If a script's output is 99% correct, is that "correct"?*

Testing

- A script's output that is incorrect 1% of the time, is incorrect.
- Imagine a “ps -ef” that has 1 bad line out of every 100.
- Only in some cases is this acceptable – where the data is clearly marked as an estimation.
- For example, prstat's “SIZE” and “RSS” are not 100% accurate, but they are still useful estimates as we are aware that they are estimates.

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Chapter 10

DTrace Mentality 2

- More DTrace Strategies

Strategy #6: Elapsed Time

- Elapsed time is the calculated using,

```
start = timestamp;
...
elapsed = timestamp - start;
```

- Elapsed time explains why an application is experiencing slow response times
- Elapsed time includes disk I/O times, network I/O times, scheduling latency, ...
- Elapsed times can be measured at the application, treating the OS as a black box

Measuring Times

- Some difficulties when measuring these:
  - Knowing what is the start probe and what is the end probe.
    - If you are lucky, the provider will already have it as :entry and :return, or :start and :done.
    - If you are unlucky, you will need to find the probes from what is available. Try a previous strategy – “known count”.
  - Associating the start probe to the end probe
    - If you are lucky, they will be in the same thread and you can use a thread-local variable. Eg, self->start
    - If you are unlucky, you'll need associative arrays and some other ID as the key.

Strategy #7: On-CPU Time

- On-CPU time is the calculated using,

```
start = vtimestamp;
...
oncpu = vtimestamp - start;
```

- On-CPU time explains why the CPUs are busy
- On-CPU time *excludes* disk I/O times, network I/O times, scheduling latency, ...

Elapsed vs On-CPU

```
DTraceToolkit-0.96# more Docs/Examples/dtruss_example.txt
...
In the following example, syscall elapsed and overhead times are measured.
Elapsed times represent the time from syscall start to finish; overhead
times measure the time spent on the CPU,

 # dtruss -eon bash
 PID/LWP    ELAPSD    CPU SYSCALL(args)           = return
  3911/1:       41     26 write(0x2, "1\0", 0x1)          = 1 0
  3911/1:  1001579     43 read(0x0, "s\0", 0x1)           = 1 0
  3911/1:       38     26 write(0x2, "s\0", 0x1)          = 1 0
  3911/1:  1019129     43 read(0x0, " \001\0", 0x1)       = 1 0
  3911/1:       38     26 write(0x2, " \0", 0x1)          = 1 0
  3911/1:   998533     43 read(0x0, "-\0", 0x1)           = 1 0
  3911/1:       38     26 write(0x2, "-\001\0", 0x1)      = 1 0
  3911/1:  1094323     42 read(0x0, "1\0", 0x1)           = 1 0
  3911/1:       39     27 write(0x2, "1\001\0", 0x1)      = 1 0
  3911/1:  1210496     44 read(0x0, "\r\0", 0x1)          = 1 0
  3911/1:       40     28 write(0x2, "\n\001\0", 0x1)     = 1 0
  3911/1:        9      1 lwp_sigmask(0x3, 0x2, 0x0)      = 0xFFBFFEFF 0
  3911/1:       70     63 ioctl(0x0, 0x540F, 0x80F6D00)           = 0 0
```

Strategy #8: Milestones

- Try to understand the behaviour of the target by identifying application-level activity milestones. For example:
    - establishing a connection
    - beginning a transaction
    - completing a transaction
    - writing to a log
- These may be identified using:
    - the probe name – ie, the function name
    - ustack() when solaris statistics are triggered
    - engaging in “known count” strategy
    - dereferencing random strings

End of Chapter 10

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Workshops

DTrace Workshops

- Now it's time for you to get your hands dirty solving a variety of problems
- I'll create problems on your systems at random
- When you solve them, don't shout out the answer!
- Many people find this this is the best way to learn – you need to think on your own
- Good Luck!