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Preface

The DTrace User Guide is a lightweight introduction to the powerful tracing and analysis tool DTrace. In this book, you will find a description of DTrace and its capabilities, as well as directions on how to use DTrace to perform relatively simple and common tasks.

Who Should Use This Book

DTrace is a comprehensive dynamic tracing facility that is built into Solaris. You can use the DTrace facility can be used to examine the behavior of user programs or the behavior of the operating system. DTrace can be used by system administrators or application developers on live production systems.

DTrace allows Solaris developers and administrators to:

- Implement custom scripts that use the DTrace facility
- Implement layered tools that use DTrace to retrieve trace data

This book is not a comprehensive guide to DTrace or the D scripting language. Please refer to the Solaris Dynamic Tracing Guide for in-depth reference information.

Before You Read This Book

Basic familiarity with a programming language such as C or a scripting language such as awk(1) or perl(1) will help you learn DTrace and the D programming language faster, but you need not be an expert in any of these areas. If you have never written a program or script before in any language, “Related Books” on page 5 provides references to other documents you might find useful.

Related Books

For an in depth reference to DTrace, see the Solaris Dynamic Tracing Guide. These books and papers are recommended and related to the tasks that you need to perform with DTrace:


**Documentation, Support, and Training**

The Sun web site provides information about the following additional resources:

- Documentation (http://www.sun.com/documentation/)
- Support (http://www.sun.com/support/)
- Training (http://www.sun.com/training/)

**Typographic Conventions**

The following table describes the typographic conventions that are used in this book.

<table>
<thead>
<tr>
<th>Typeface</th>
<th>Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>AaBbCc123</td>
<td>The names of commands, files, and directories, and onscreen computer output</td>
<td>Edit your .login file.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use ls -a to list all files.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>machine_name% you have mail.</td>
</tr>
<tr>
<td>AaBbCc123</td>
<td>What you type, contrasted with onscreen computer output</td>
<td>machine_name% su</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Password:</td>
</tr>
<tr>
<td>aabbcc123</td>
<td>Placeholder: replace with a real name or value</td>
<td>The command to remove a file is rm filename.</td>
</tr>
<tr>
<td>AaBbCc123</td>
<td>Book titles, new terms, and terms to be emphasized</td>
<td>Read Chapter 6 in the <em>User's Guide</em>.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A cache is a copy that is stored locally.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Do not save the file.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Note:</strong> Some emphasized items appear bold online.</td>
</tr>
</tbody>
</table>

**Shell Prompts in Command Examples**

The following table shows the default UNIX® system prompt and superuser prompt for the C shell, Bourne shell, and Korn shell.
<table>
<thead>
<tr>
<th>Shell</th>
<th>Prompt</th>
</tr>
</thead>
<tbody>
<tr>
<td>C shell</td>
<td>machine_name%</td>
</tr>
<tr>
<td>C shell for superuser</td>
<td>machine_name#</td>
</tr>
<tr>
<td>Bourne shell and Korn shell</td>
<td>$</td>
</tr>
<tr>
<td>Bourne shell and Korn shell for superuser</td>
<td>#</td>
</tr>
</tbody>
</table>
Introduction

DTrace is a comprehensive dynamic tracing facility that is built into Solaris. DTrace can be used by administrators and developers, and can safely be used on live production systems. DTrace enables you to examine the behavior of user programs as well as the behavior of the operating system. Users of DTrace can create custom programs with the D scripting language. Custom programs provide the ability to dynamically instrument the system. Custom programs provide immediate, concise answers to specific questions about the behavior of particular applications.

DTrace Capabilities

The DTrace framework provides instrumentation points that are called probes. A DTrace user can use a probe to record and display relevant information about a kernel or user process. Each DTrace probe is activated by a specific behavior. This probe activation is referred to as firing. As an example, consider a probe that fires on entry into an arbitrary kernel function. This example probe can display the following information:

- Any argument that is passed to the function
- Any global variable in the kernel
- A timestamp that indicates when the function was called
- A stack trace that indicates the section of code that called the function
- The process that was running at the time the function was called
- The thread that made the function call

When a probe fires, you can specify a particular action for DTrace to take. A DTrace action usually records an interesting aspect of system behavior, such as a timestamp or a function argument.

Probes are implemented by providers. A probe provider is a kernel module that enables a given probe to fire. For example, the function boundary tracing provider fbt provides entry and return probes for almost every function in every kernel module.

DTrace has significant data management capabilities. These capabilities enable DTrace users to prune the data reported by probes, avoiding the overhead involved in generating and then filtering unwanted data. DTrace also provides mechanisms for tracing during the boot process and for
retrieving data from a kernel crash dump. All of the instrumentation in DTrace is dynamic. Probes are enabled discretely at the time that the probes are used, and inactive probes present no instrumented code.

A DTrace consumer is any process that interacts with the DTrace framework. While `dtrace(1M)` is the primary DTrace consumer, other consumers exist. These additional consumers mostly consist of new versions of existing utilities such as `lockstat(1M)`. The DTrace framework has no limit on the number of concurrent consumers.

The behavior of DTrace can be modified with the use of scripts that are written in the D language, which is structured similarly to C. The D language provides access to kernel C types and kernel static and kernel global variables. The D language supports ANSI C operators.

**Architecture overview**

The DTrace facility consists of the following components:

- User level consumer programs such as `dtrace`
- Providers, packaged as kernel modules, that provide probes to gather tracing data
- A library interface that consumer programs use to access the DTrace facility through the `dtrace(7D)` kernel driver

**DTrace Providers**

A provider represents a methodology for instrumenting the system. Providers make probes available to the DTrace framework. DTrace sends information to a provider regarding when to enable a probe. When an enabled probe fires, the provider transfers control to DTrace.

Providers are packaged as a set of kernel modules. Each module performs a particular kind of instrumentation to create probes. When you use DTrace, each provider has the ability to publish the probes it can provide to the DTrace framework. You can enable and bind tracing actions to any of the published probes.

Some providers have the capability to create new probes based on the user’s tracing requests.

**DTrace Probes**

A probe has the following attributes:

- It is made available by a provider
- It identifies the `module` and the `function` that it instruments
- It has a `name`

These four attributes define a 4–tuple that serves as a unique identifier for each probe, in the format `provider:module:function:name`. Each probe also has a unique integer identifier.
DTrace Predicates

Predicates are expressions that are enclosed in slashes //. Predicates are evaluated at probe firing time to determine whether the associated actions should be executed. Predicates are the primary conditional construct used for building more complex control flow in a D program. You can omit the predicate section of the probe clause entirely for any probe. If the predicate section is omitted, the actions are always executed when the probe fires.

Predicate expressions can use any of the previously described D operators. Predicate expressions refer to D data objects such as variables and constants. The predicate expression must evaluate to a value of integer or pointer type. As with all D expressions, a zero value is interpreted as false and any non-zero value is interpreted as true.

DTrace Actions

Actions are user-programmable statements that the DTrace virtual machine executes within the kernel. Actions have the following properties:

- Actions are taken when a probe fires
- Actions are completely programmable in the D scripting language
- Most actions record a specified system state
- An action can change the state of the system in a precisely described way. Such actions are called destructive actions. Destructive actions are not allowed by default.
- Many actions use expressions in the D scripting language

D Scripting Language

You can invoke the DTrace framework directly from the command line with the dtrace command for simple functions. To use DTrace to perform more complex functions, write a script in the D scripting language. Use the -s option to load a specified script for DTrace to use. See Chapter 3 for information about using the D scripting language.
This chapter provides a tour of the DTrace facility and provides examples of several basic tasks.

**Listing Probes**

You can list all DTrace probes by passing the `-l` option to the `dtrace` command:

```
# dtrace -l
```

<table>
<thead>
<tr>
<th>ID</th>
<th>PROVIDER</th>
<th>MODULE</th>
<th>FUNCTION</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>dtrace</td>
<td>BEGIN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>dtrace</td>
<td>END</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>dtrace</td>
<td>ERROR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>syscall</td>
<td>nosys</td>
<td>entry</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>syscall</td>
<td>nosys</td>
<td>return</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>syscall</td>
<td>rexit</td>
<td>entry</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>syscall</td>
<td>rexit</td>
<td>return</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>syscall</td>
<td>forkall</td>
<td>entry</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>syscall</td>
<td>forkall</td>
<td>return</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>syscall</td>
<td>read</td>
<td>entry</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>syscall</td>
<td>read</td>
<td>return</td>
<td></td>
</tr>
</tbody>
</table>

To count all the probes that are available on your system, you can type the following command:

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

The number of probes reported will vary depending on your operating platform and the software you have installed. Some probes do not list an entry under the `MODULE` or `FUNCTION` columns, such as the `BEGIN` and `END` probes in the previous example. Probes with blank entries in these fields do not correspond to a specifically instrumented program function or location. These probes refer to more abstract concepts, such as the end of a tracing request. A probe that has a module and function as part of its name is called an **anchored probe**. A probe that is not associated with a module and function is called an **unanchored probe**.

You can use additional options to list specific probes, as seen in the following examples.
### EXAMPLE 2-1 Listing Probes by Specific Function

You can list probes that are associated with a specific function by passing that function name to DTrace with the `-f` option.

```bash
# dtrace -l -f cv_wait
```

<table>
<thead>
<tr>
<th>ID</th>
<th>PROVIDER</th>
<th>MODULE</th>
<th>FUNCTION</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>12921</td>
<td>fbt</td>
<td>genunix</td>
<td>cv_wait</td>
<td>entry</td>
</tr>
<tr>
<td>12922</td>
<td>fbt</td>
<td>genunix</td>
<td>cv_wait</td>
<td>return</td>
</tr>
</tbody>
</table>

### EXAMPLE 2-2 Listing Probes by Specific Module

You can list probes that are associated with a specific module by passing that module name to DTrace with the `-m` option.

```bash
# dtrace -l -m sd
```

<table>
<thead>
<tr>
<th>ID</th>
<th>PROVIDER</th>
<th>MODULE</th>
<th>FUNCTION</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>17147</td>
<td>fbt</td>
<td>sd</td>
<td>sdopen</td>
<td>entry</td>
</tr>
<tr>
<td>17148</td>
<td>fbt</td>
<td>sd</td>
<td>sdopen</td>
<td>return</td>
</tr>
<tr>
<td>17149</td>
<td>fbt</td>
<td>sd</td>
<td>sdclose</td>
<td>entry</td>
</tr>
<tr>
<td>17150</td>
<td>fbt</td>
<td>sd</td>
<td>sdclose</td>
<td>return</td>
</tr>
<tr>
<td>17151</td>
<td>fbt</td>
<td>sd</td>
<td>sdstrategy</td>
<td>entry</td>
</tr>
<tr>
<td>17152</td>
<td>fbt</td>
<td>sd</td>
<td>sdstrategy</td>
<td>return</td>
</tr>
</tbody>
</table>

### EXAMPLE 2-3 Listing Probes by Specific Name

You can list probes that have a specific name by passing that name to DTrace with the `-n` option.

```bash
# dtrace -l -n BEGIN
```

<table>
<thead>
<tr>
<th>ID</th>
<th>PROVIDER</th>
<th>MODULE</th>
<th>FUNCTION</th>
<th>NAME</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>dtrace</td>
<td></td>
<td></td>
<td></td>
<td>BEGIN</td>
</tr>
</tbody>
</table>

### EXAMPLE 2-4 Listing Probes by Provider of Origin

You can list probes that are originate from a specific provider by passing the provider name to DTrace with the `-P` option.

```bash
# dtrace -l -P lockstat
```

<table>
<thead>
<tr>
<th>ID</th>
<th>PROVIDER</th>
<th>MODULE</th>
<th>FUNCTION</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>469</td>
<td>lockstat</td>
<td>genunix</td>
<td>mutex_enter</td>
<td>adaptive-acquire</td>
</tr>
<tr>
<td>470</td>
<td>lockstat</td>
<td>genunix</td>
<td>mutex_enter</td>
<td>adaptive-block</td>
</tr>
<tr>
<td>471</td>
<td>lockstat</td>
<td>genunix</td>
<td>mutex_enter</td>
<td>adaptive-spin</td>
</tr>
<tr>
<td>472</td>
<td>lockstat</td>
<td>genunix</td>
<td>mutex_exit</td>
<td>adaptive-release</td>
</tr>
<tr>
<td>473</td>
<td>lockstat</td>
<td>genunix</td>
<td>mutex_destroy</td>
<td>adaptive-release</td>
</tr>
<tr>
<td>474</td>
<td>lockstat</td>
<td>genunix</td>
<td>mutex_tryenter</td>
<td>adaptive-acquire</td>
</tr>
</tbody>
</table>

...
EXAMPLE 2–5 Multiple Providers Supporting a Specific Function or Module

A specific function or specific module can be supported by multiple providers, as the following example shows.

```
# dtrace -l -f read
ID PROVIDER MODULE FUNCTION NAME
 10 syscall read entry
 11 syscall read return
4036 sysinfo genunix read readch
4040 sysinfo genunix read sysread
7885 fbt genunix read entry
7886 fbt genunix read return
```

As the previous examples show, the output for a listing of probes displays the following information:

- The probe's uniquely assigned integer probe ID
- The provider name
- The module name, if applicable
- The function name, if applicable
- The probe name

---

**Note** – The probe ID is only unique within a given release or patch level of the Solaris operating system.

---

### Specifying Probes in DTrace

You can fully specify a probe by listing each component of the 4–tuple that uniquely identifies that probe. The format for the probe specification is `provider:module:function:name`. An empty component in a probe specification matches anything. For example, the specification `fbt::alloc:entry` specifies a probe with the following attributes:

- The probe must be from the fbt provider
- The probe may be in any module
- The probe must be in the alloc function
- The probe must be named entry

Elements on the left hand side of the 4–tuple are optional. The probe specification `::open:entry` is equivalent to the specification `open:entry`. Either specification will match probes from all providers and kernel modules that have a function name of open and are named entry.

```
# dtrace -l -n open:entry
ID PROVIDER MODULE FUNCTION NAME
 14 syscall genunix open entry
 7386 fbt genunix open entry
```
You can also describe probes with a pattern matching syntax that is similar to the syntax that is described in the File Name Generation section of the sh(1) man page. The syntax supports the special characters *, ?, [ and ]. The probe description syscall::open*:entry matches both the open and open64 system calls. The ? character represents any single character in the name. The [ and ] characters are used to specify a set of specific characters in the name.

Enabling Probes

You enable probes with the dtrace command by specifying the probes without the -l option. Without further directions, DTrace performs the default action when the specified probe fires. The default probe action indicates only that the specified probe has fired and does not record any other data. The following code example enables every probe in the sd module.

EXAMPLE 2-6 Enabling Probes by Module

```
# dtrace -m sd
CPU ID FUNCTION:NAME
  0 17329 sd_media_watch_cb:entry
  0 17330 sd_media_watch_cb:return
  0 17167 sdinfo:entry
  0 17168 sdinfo:return
  0 17151 sdstrategy:entry
  0 17152 sdstrategy:return
  0 17661 ddi_xbuf_qstrategy:entry
  0 17662 ddi_xbuf_qstrategy:return
  0 17649 xbuf_iostart:entry
  0 17341 sd_xbuf_strategy:entry
  0 17385 sd_xbuf_init:entry
  0 17386 sd_xbuf_init:return
  0 17342 sd_xbuf_strategy:return
  0 17177 sd_mapblockaddr_iostart:entry
  0 17178 sd_mapblockaddr_iostart:return
  0 17179 sd_pm_iostart:entry
  0 17365 sd_pm_entry:entry
  0 17366 sd_pm_entry:return
  0 17180 sd_pm_iostart:return
  0 17181 sd_core_iostart:entry
  0 17407 sd_add_buf_to_waitq:entry
...
```

The output in this example shows that the default action displays the CPU where the probe fired, the integer probe ID that is assigned by DTrace, the function where the probe fired, and the probe name.

EXAMPLE 2-7 Enabling Probes by Provider

```
# dtrace -P syscall
dtrace: description 'syscall' matched 452 probes
CPU ID FUNCTION:NAME
```
EXAMPLE 2–7 Enabling Probes by Provider  (Continued)

```
0  99       ioctl:return
0  98       ioctl:entry
0  99       ioctl:return
0  98       ioctl:entry
0  99       ioctl:return
0  234      sysconfig:entry
0  235      sysconfig:return
0  234      sysconfig:entry
0  235      sysconfig:return
0  168      sigaction:entry
0  169      sigaction:return
0  168      sigaction:entry
0  169      sigaction:return
0  168      sigaction:entry
0  169      sigaction:return
0  98       ioctl:entry
0  99       ioctl:return
0  234      sysconfig:entry
0  235      sysconfig:return
0  38       brk:entry
0  39       brk:return
...```

EXAMPLE 2–8 Enabling Probes by Name

```
# dtrace -n zfod
dtrace: description 'zfod' matched 3 probes
CPU ID FUNCTION:NAME
0 4080 anon_zero:zfod
0 4080 anon_zero:zfod
^C
```

EXAMPLE 2–9 Enabling Probes by Fully Specified Name

```
# dtrace -n clock:entry
dtrace: description 'clock:entry' matched 1 probe
CPU ID FUNCTION:NAME
0 4198 clock:entry
^C
```
DTrace Action Basics

Actions enable DTrace to interact with the system outside of the DTrace framework. The most common actions record data to a DTrace buffer. Other actions can stop the current process, raise a specific signal on the current process, or cease tracing. Actions that change the system state are considered destructive actions. Data recording actions record data to the principal buffer by default. The principal buffer is present in every DTrace invocation and is always allocated on a per-CPU basis. Tracing and buffer allocation can be restricted to a single CPU by using the -cpu option. See Chapter 11, "Buffers and Buffering," in Solaris Dynamic Tracing Guide for more information about DTrace buffering.

The examples in this section use D expressions that consist of built-in D variables. Some of the most commonly used D variables are listed below:

- **pid** This variable contains the current process ID.
- **execname** This variable contains the current executable name.
- **timestamp** This variable contains the time since boot, expressed in nanoseconds.
- **curthread** This variable contains a pointer to the kthread_t structure that represents the current thread.
- **probemod** This variable contains the module name of the current probe.
- **probefunc** This variable contains the function name of the current probe.
- **probenme** This variable contains the name of the current probe.

For a complete list of the built-in variables of the D scripting language, see Variables.

The D scripting language also provides built-in functions that perform specific actions. You can find a complete list of these built-in functions at Chapter 10, "Actions and Subroutines," in Solaris Dynamic Tracing Guide. The trace() function records the result of a D expression to the trace buffer, as in the following examples:

- `trace(pid)` traces the current process ID
- `trace(execname)` traces the name of the current executable
- `trace(curthread->t_pri)` traces the t_pri field of the current thread
- `trace(probefunc)` traces the function name of the probe

To indicate a particular action you want a probe to take, type the name of the action between {} characters, as in the following example.

**EXAMPLE 2–10 Specifying a Probe’s Action**

```
# dtrace -n 'readch {trace(pid)}'
```

```
dtrace: description 'readch ' matched 4 probes
CPU   ID   FUNCTION:NAME
  0  4036   read:readch  2040
  0  4036   read:readch  2177
```
EXAMPLE 2–10 Specifying a Probe’s Action (Continued)

Since the requested action is `trace(pid)`, the process identification number (PID) appears in the last column of the output.

EXAMPLE 2–11 Tracing an Executable Name

```bash
# dtrace -m 'ufs {trace(execname)}'
dtrace: description 'ufs' matched 889 probes
CPU ID FUNCTION:NAME
0 14977 ufs_lookup:entry ls
0 15748 ufs_iaccess:entry ls
0 15749 ufs_iaccess:return ls
0 14978 ufs_lookup:return ls
...
0 15007 ufs_seek:entry utmpd
0 15008 ufs_seek:return utmpd
0 14963 ufs_close:entry utmpd
```

EXAMPLE 2–12 Tracing A System Call’s Time of Entry

```bash
# dtrace -n 'syscall:::entry {trace(timestamp)}'
dtrace: description 'syscall:::entry' matched 226 probes
CPU ID FUNCTION:NAME
0 312 portfs:entry 157008479572713
0 98 ioctl:entry 157008479637542
0 98 ioctl:entry 157008479674339
0 234 sysconfig:entry 157008479767243
...
0 98 ioctl:entry 157008481033225
0 60 fstat:entry 157008481050686
0 60 fstat:entry 157008481074680
```

EXAMPLE 2–13 Specifying Multiple Actions

To specify multiple actions, list the actions separated by the `;` character.
**Example 2–13 Specifying Multiple Actions**

(Continued)

```bash
# dtrace -n 'zfod {trace(pid);trace(execname)}'
```

dtrace: description 'zfod ' matched 3 probes

<table>
<thead>
<tr>
<th>CPU ID</th>
<th>FUNCTION NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>anon_zero:zfod 2195 dtrace</td>
</tr>
<tr>
<td>0</td>
<td>anon_zero:zfod 2195 dtrace</td>
</tr>
<tr>
<td>0</td>
<td>anon_zero:zfod 2195 dtrace</td>
</tr>
<tr>
<td>0</td>
<td>anon_zero:zfod 2195 dtrace</td>
</tr>
<tr>
<td>0</td>
<td>anon_zero:zfod 2195 dtrace</td>
</tr>
<tr>
<td>0</td>
<td>anon_zero:zfod 2197 bash</td>
</tr>
<tr>
<td>0</td>
<td>anon_zero:zfod 2207 vi</td>
</tr>
<tr>
<td>0</td>
<td>anon_zero:zfod 2207 vi</td>
</tr>
</tbody>
</table>


**Data Recording Actions**

The actions in this section record data to the principal buffer by default, but each action may also be used to record data to speculative buffers. See “Speculative Tracing” on page 54 for more details on speculative buffers.

**The `trace()` function**

```c
void trace(expression)
```

The most basic action is the `trace()` action, which takes a D expression as its argument and traces the result to the directed buffer.

**The `tracemem()` function**

```c
void tracemem(address, size_t nbytes)
```

The `tracemem()` action copies data from an address in memory to a buffer. The number of bytes that this action copies is specified in `nbytes`. The address that the data is copied from is specified in `addr` as a D expression. The buffer that the data is copied to is specified in `buf`.

**The `printf()` function**

```c
void printf(string format, ...)
```

Like the `trace()` action, the `printf()` action traces D expressions. However, the `printf()` action lets you control formatting in ways similar to the `printf(3C)` function. Like the `printf` function, the parameters consist of a `format` string followed by a variable number of arguments. By default, the arguments are traced to the directed buffer. The arguments are later formatted for output by the `dtrace` command according to the specified format string.
For more information on the `printf()` action, see Chapter 12, “Output Formatting,” in Solaris Dynamic Tracing Guide.

**The `printa()` function**

```c
void printa(aggregation)
void printa(string format, aggregation)
```

The `printa()` action enables you to display and format aggregations. See Chapter 9, “Aggregations,” in Solaris Dynamic Tracing Guide for more detail on aggregations. If a `format` value is not provided, the `printa()` action only traces a directive to the DTrace consumer. The consumer that receives that directive processes and displays the aggregation with the default format. See Chapter 12, “Output Formatting,” in Solaris Dynamic Tracing Guide for a more detailed description of the `printa()` format string.

**The `stack()` function**

```c
void stack(int nframes)
void stack(void)
```

The `stack()` action records a kernel stack trace to the directed buffer. The depth of the kernel stack is given by the value given in `nframes`. If no value is given for `nframes`, the stack action records a number of stack frames specified by the `stackframes` option.

**The `ustack()` function**

```c
void ustack(int nframes, int strsize)
void ustack(int nframes)
void ustack(void)
```

The `ustack()` action records a user stack trace to the directed buffer. The depth of the user stack is equal to the value specified in `nframes`. If there is no value for `nframes`, the `ustack` action records a number of stack frames that is specified by the `ustackframes` option. The `ustack()` action determines the address of the calling frames when the probe fires. The `ustack()` action does not translate the stack frames into symbols until the DTrace consumer processes the `ustack()` action at the user level. If a value for `strsize` is specified and not zero, the `ustack()` action allocates the specified amount of string space and uses it to perform address-to-symbol translation directly from the kernel.

**The `jstack()` function**

```c
void jstack(int nframes, int strsize)
void jstack(int nframes)
void jstack(void)
```
The `jstack()` action is an alias for `ustack()` that uses the value specified by the `jstackframes` option for the number of stack frames. The `jstack` action uses the value specified by the `jstackstrsize` option to determine the string space size. The `jstacksize` action defaults to a non-zero value.

**Destructive Actions**

You must explicitly enable destructive actions in order to use them. You can enable destructive actions by using the `-w` option. If you attempt to use destructive actions in `dtrace` without explicitly enabling them, `dtrace` fails with a message similar to the following example:

```
dtrace: failed to enable 'syscall': destructive actions not allowed
```

For more information on DTrace actions, including destructive actions, see Chapter 10, “Actions and Subroutines,” in *Solaris Dynamic Tracing Guide*.

**Process Destructive Actions**

Some actions are destructive only to a particular process. These actions are available to users with the `dtrace_proc` or `dtrace_user` privileges. See Chapter 35, “Security,” in *Solaris Dynamic Tracing Guide* for details on DTrace security privileges.

**The `stop()` function**

When a probe fires with the `stop()` action enabled, the process that fired that probe stops upon leaving the kernel. This process stops in the same way as a process that is stopped by a `proc(4)` action.

**The `raise()` function**

```c
void raise(int signal)
```

The `raise()` action sends the specified signal to the currently running process.

**The `copyout()` function**

```c
void copyout(void *buf, uintptr_t addr, size_t nbytes)
```

The `copyout()` action copies data from a buffer to an address in memory. The number of bytes that this action copies is specified in `nbytes`. The buffer that the data is copied from is specified in `buf`. The address that the data is copied to is specified in `addr`. That address is in the address space of the process that is associated with the current thread.

**The `copyoutstr()` function**

```c
void copyoutstr(string str, uintptr_t addr, size_t maxlen)
```
The `copyoutstr()` action copies a string to an address in memory. The string to copy is specified in `str`. The address that the string is copied to is specified in `addr`. That address is in the address space of the process that is associated with the current thread.

**The `system()` function**

```c
void system(string program, ...
```

The `system()` action causes the program specified by `program` to be executed by the system as if it were given to the shell as input.

**Kernel Destructive Actions**

Some destructive actions are destructive to the entire system. Use these actions with caution. These actions affect every process on the system and may affect other systems, depending upon the affected system’s network services.

**The `breakpoint()` function**

```c
void breakpoint(void)
```

The `breakpoint()` action induces a kernel breakpoint, causing the system to stop and transfer control to the kernel debugger. The kernel debugger will emit a string that denotes the DTrace probe that triggered the action.

**The `panic()` function**

```c
void panic(void)
```

When a probe with the `panic()` action triggers, the kernel panics. This action can force a system crash dump at a time of interest. You can use this action in conjunction with ring buffering and postmortem analysis to diagnose a system problem. For more information, see Chapter 11, “Buffers and Buffering,” in Solaris Dynamic Tracing Guide and Chapter 37, “Postmortem Tracing,” in Solaris Dynamic Tracing Guide respectively.

**The `chill()` function**

```c
void chill(int nanoseconds)
```

When a probe with the `chill()` action triggers, DTrace spins for the specified number of nanoseconds. The `chill()` action is useful for exploring problems related to timing. Because interrupts are disabled while in DTrace probe context, any use of `chill()` will induce interrupt latency, scheduling latency, dispatch latency.
DTrace Aggregations

For performance-related questions, aggregated data is often more useful than individual data points. DTrace provides several built-in aggregating functions. When an aggregating function is applied to subsets of a collection of data, then applied again to the results of the analysis of those subsets, the results are identical to the results returned by the aggregating function when it is applied to the collection as a whole.

The DTrace facility stores a running count of data items for aggregations. The aggregating functions store only the current intermediate result and the new element that the function is being applied to. The intermediate results are allocated on a per-CPU basis. Because this allocation scheme does not require locks, the implementation is inherently scalable.

DTrace Aggregation Syntax

A DTrace aggregation takes the following general form:

```dtrace
@name{ keys } = aggfunc( args );
```

In this general form, the variables are defined as follows:

- `name`: The name of the aggregation, preceded by the `@` character.
- `keys`: A comma-separated list of D expressions.
- `aggfunc`: One of the DTrace aggregating functions.
- `args`: A comma-separated list of arguments appropriate to the aggregating function.

### TABLE 2–1 DTrace Aggregating Functions

<table>
<thead>
<tr>
<th>Function Name</th>
<th>Arguments</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>count</td>
<td>none</td>
<td>The number of times that the count function is called.</td>
</tr>
<tr>
<td>sum</td>
<td>scalar expression</td>
<td>The total value of the specified expressions.</td>
</tr>
<tr>
<td>avg</td>
<td>scalar expression</td>
<td>The arithmetic average of the specified expressions.</td>
</tr>
<tr>
<td>min</td>
<td>scalar expression</td>
<td>The smallest value among the specified expressions.</td>
</tr>
<tr>
<td>max</td>
<td>scalar expression</td>
<td>The largest value among the specified expressions.</td>
</tr>
<tr>
<td>lquantize</td>
<td>scalar expression, lower bound, upper bound, step value</td>
<td>A linear frequency distribution of the values of the specified expressions that is sized by the specified range. This aggregating function increments the value in the <em>highest</em> bucket that is <em>less</em> than the specified expression.</td>
</tr>
</tbody>
</table>
TABLE 2–1 DTrace Aggregating Functions (Continued)

<table>
<thead>
<tr>
<th>Function Name</th>
<th>Arguments</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>quantize</td>
<td>scalar expression</td>
<td>A power-of-two frequency distribution of the values of the specified expressions. This aggregating function increments the value in the highest power-of-two bucket that is less than the specified expression.</td>
</tr>
</tbody>
</table>

EXAMPLE 2–14 Using an Aggregating Function

This example uses the count aggregating function to count the number of write(2) system calls per process. The aggregation does not output any data until the dtrace command is terminated. The output data represents a summary of the data collected during the time that the dtrace command was active.

```
# cat writes.d
#!/usr/sbin/dtrace -s
syscall::write:entry]
{ @numWrites[execname] = count(); }

# ./writes.d
dtrace: script 'writes.d' matched 1 probe
^C
dtrace 1
date 1
bash 3
grep 20
file 197
ts 201
```

DTrace Aggregations
This chapter discusses the basic information that you need to start writing your own D language scripts.

Writing D Scripts

Complex sets of DTrace probes can become difficult to manage on the command line. The `dtrace` command supports scripts. You can specify a script by passing the `-s` option, along with the script’s file name, to the `dtrace` command. You can also create executable DTrace interpreter files. A DTrace interpreter file always begins with the line `#!/usr/sbin/dtrace -s`.

Executable D Scripts

This example script, named `syscall.d`, traces the executable name every time the executable enters each system call:

```
syscall::entry
{
    trace(execname);
}
```

Note that the filename ends with a `.d` suffix. This is the conventional ending for D scripts. You can run this script off the DTrace command line with the following command:

```
# dtrace -s syscall.d
dtrace: description ‘syscall ’ matched 226 probes
CPU ID FUNCTION:NAME
  0 312 pollsyst:entry java
  0 98 ioctl:entry dtrace
  0 98 ioctl:entry dtrace
  0 234 sysconfig:entry dtrace
  0 234 sysconfig:entry dtrace
```
You can run the script by entering the filename at the command line by following two steps. First, verify that the first line of the file invokes the interpreter. The interpreter invocation line is 
`#!/usr/sbin/dtrace -s`. Then set the execute permission for the file.

**EXAMPLE 3-1 Running a D Script from the Command Line**

```bash
# cat syscall.d
#!/usr/sbin/dtrace -s
syscall:::entry
{
    trace(execname);
}
# chmod +x syscall.d
# ls -l syscall.d
-rwxr-xr-x 1 root other 62 May 12 11:30 syscall.d
# ./syscall.d
dtrace: script './syscall.d' matched 226 probes
CPU ID FUNCTION:NAME
0  98  ioctl:entry dtrace
0  98  ioctl:entry dtrace
0  312 pollsys:entry java
0  312 pollsys:entry java
0  312 pollsys:entry java
0  98  ioctl:entry dtrace
0  98  ioctl:entry dtrace
0  234 sysconfig:entry dtrace
0  234 sysconfig:entry dtrace
^C
```

**D Literal Strings**

The D language supports literal strings. DTrace represents strings as an array of characters terminated by a null byte. The visible part of the string varies in length depending on the location of the null byte. DTrace stores each string in a fixed-size array to ensure that each probe traces a consistent amount of data. Strings cannot exceed the length of the predefined string limit. The limit can be modified in your D program or on the `dtrace` command line by tuning the `strsize` option. Refer to Chapter 16, "Options and Tunables," in *Solaris Dynamic Tracing Guide* for more information on tunable DTrace options. The default string limit is 256 bytes.
The D language provides an explicit string type rather than using the type char * to refer to strings. See Chapter 6, “Strings,” in Solaris Dynamic Tracing Guide for more information about D literal strings.

**EXAMPLE 3–2 Using D Literal Strings With The trace() Function**

```
# cat string.d

#!/usr/sbin/dtrace -s

fbt::bdev_strategy:entry
{
  trace(execname);
  trace(" is initiating a disk I/O\n");
}
```

The \n symbol at the end of the literal string produces a new line. To run this script, enter the following command:

```
# dtrace -s string.d
```

```
dtrace: script 'string.d' matched 1 probes

<table>
<thead>
<tr>
<th>CPU</th>
<th>ID</th>
<th>FUNCTION:NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>9215</td>
<td>bdev_strategy:entry bash is initiating a disk I/O</td>
</tr>
<tr>
<td>0</td>
<td>9215</td>
<td>bdev_strategy:entry vi is initiating a disk I/O</td>
</tr>
<tr>
<td>0</td>
<td>9215</td>
<td>bdev_strategy:entry vi is initiating a disk I/O</td>
</tr>
<tr>
<td>0</td>
<td>9215</td>
<td>bdev_strategy:entry sched is initiating a disk I/O</td>
</tr>
</tbody>
</table>
```

The -q option of the dtrace command only records the actions that are explicitly stated in the script or command line invocation. This option suppresses the default output that the dtrace command normally produces.

```
# dtrace -q -s string.d
```

```
ls is initiating a disk I/O
ls is initiating a disk I/O
fsflush is initiating a disk I/O
vi is initiating a disk I/O
```

---

**Creating D Scripts That Use Arguments**

You can use the dtrace command to create executable interpreter files. The file must have execute permission. The initial line of the file must be #!/usr/sbin/dtrace -s. You can specify other options to the dtrace command on this line. You must specify the options with only one dash (-). List the s option last, as in the following example.
#!/usr/sbin/dtrace -qvs

You can specify options for the `dtrace` command by using `#pragma` lines in the D script, as in the following D fragment:

```d
# cat -n mem2.d
1  #!/usr/sbin/dtrace -s
2
3  #pragma D option quiet
4  #pragma D option verbose
5
6  vminfo:::
...```

The following table lists the option names that you can use in `#pragma` lines.

**TABLE 3-1 DTrace Consumer Options**

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Value</th>
<th>dtrace Alias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>aggrate</td>
<td>time</td>
<td></td>
<td>Rate of aggregation reading</td>
</tr>
<tr>
<td>aggsize</td>
<td>size</td>
<td></td>
<td>Aggregation buffer size</td>
</tr>
<tr>
<td>bufsize</td>
<td>size</td>
<td>-b</td>
<td>Principal buffer size</td>
</tr>
<tr>
<td>cleanrate</td>
<td>time</td>
<td></td>
<td>Cleaning rate</td>
</tr>
<tr>
<td>cpu</td>
<td>scalar</td>
<td>-c</td>
<td>CPU on which to enable tracing</td>
</tr>
<tr>
<td>defaultargs</td>
<td>—</td>
<td></td>
<td>Allow references to unspecified macro arguments</td>
</tr>
<tr>
<td>destructive</td>
<td>—</td>
<td>-w</td>
<td>Allow destructive actions</td>
</tr>
<tr>
<td>dynvsize</td>
<td>size</td>
<td></td>
<td>Dynamic variable space size</td>
</tr>
<tr>
<td>flowindent</td>
<td>—</td>
<td>-F</td>
<td>Indent function entry and prefix with <code>-&gt;</code>; unindent function return and prefix with <code>&lt;-</code></td>
</tr>
<tr>
<td>grabanon</td>
<td>—</td>
<td>-a</td>
<td>Claim anonymous state</td>
</tr>
<tr>
<td>jstackframes</td>
<td>scalar</td>
<td></td>
<td>Number of default stack frames <code>jstack()</code></td>
</tr>
</tbody>
</table>
### TABLE 3-1 DTrace Consumer Options (Continued)

<table>
<thead>
<tr>
<th>Option Name</th>
<th>Value</th>
<th>dtrace Alias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>jstackstrsize</td>
<td>scalar</td>
<td></td>
<td>Default string space size for jstack()</td>
</tr>
<tr>
<td>nspec</td>
<td>scalar</td>
<td></td>
<td>Number of speculations</td>
</tr>
<tr>
<td>quiet</td>
<td>—</td>
<td>-q</td>
<td>Output only explicitly traced data</td>
</tr>
<tr>
<td>specsize</td>
<td>size</td>
<td></td>
<td>Speculation buffer size</td>
</tr>
<tr>
<td>strsize</td>
<td>size</td>
<td></td>
<td>String size</td>
</tr>
<tr>
<td>stackframes</td>
<td>scalar</td>
<td></td>
<td>Number of stack frames</td>
</tr>
<tr>
<td>stackindent</td>
<td>scalar</td>
<td></td>
<td>Number of whitespace characters to use when indenting stack() and ustack() output</td>
</tr>
<tr>
<td>statusrate</td>
<td>time</td>
<td></td>
<td>Rate of status checking</td>
</tr>
<tr>
<td>switchrate</td>
<td>time</td>
<td></td>
<td>Rate of buffer switching</td>
</tr>
<tr>
<td>ustackframes</td>
<td>scalar</td>
<td></td>
<td>Number of user stack frames</td>
</tr>
</tbody>
</table>

A D script can refer to a set of built in macro variables. These macro variables are defined by the D compiler.

- `$[0-9]+` Macro arguments
- `$egid` Effective group-ID
- `$euid` Effective user-ID
- `$gid` Real group-ID
- `$pid` Process ID
- `$pgid` Process group ID
- `$ppid` Parent process ID
- `$projid` Project ID
- `$sid` Session ID
- `$target` Target process ID
- `$taskid` Task ID
- `$uid` Real user-ID
EXAMPLE 3-3 PID Argument Example

This example passes the PID of a running vi process to the syscall2.d D script. The D script terminates when the vi command exits.

```bash
# cat -n syscall2.d
1 #!/usr/sbin/dtrace -qs
2
3 syscall::entry
4 /pid == $1/
5 {
6 @[probefunc] = count();
7 }
8 syscall::rexit:entry
9 {
10   exit(0);
11 }
```

```bash
# psgrep vi
2208
# ./syscall2.d 2208

rexit 1
setpgrp 1
creat 1
getpid 1
open 1
lstat64 1
stat64 1
fsync 1
unlink 1
close 1
alarm 1
lseek 1
sigaction 1
ioctl 1
read 1
write 1
```

**DTrace Built-in Variables**

The following list includes all of the built-in variables for the DTrace framework.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>int64_t arg0, ..., arg9</td>
<td>The first ten input arguments to a probe represented as raw 64-bit integers. If fewer than ten arguments are passed to the current probe, the remaining variables return zero.</td>
</tr>
<tr>
<td>args[]</td>
<td>The typed arguments to the current probe, if any. The args[] array is accessed using an integer index, but each element is defined to be the type corresponding to the given probe argument. For example, if the args[] array is referenced by a read(2) system call probe, args[0] is of type int, args[1] is of type void *, and args[2] is of type size_t.</td>
</tr>
<tr>
<td>uintptr_t caller</td>
<td>The program counter location of the current thread just before entering the current probe.</td>
</tr>
<tr>
<td>cpuinfo_t *curcpu</td>
<td>The CPU information for the current CPU. See Chapter 26, “sched Provider,” in Solaris Dynamic Tracing Guide for more information.</td>
</tr>
<tr>
<td>lwpsinfo_t *curlwpsinfo</td>
<td>The lightweight process (LWP) state of the LWP associated with the current thread. This structure is described in further detail in the proc(4) man page.</td>
</tr>
<tr>
<td>psinfo_t *curpsinfo</td>
<td>The process state of the process associated with the current thread. This structure is described in further detail in the proc(4) man page.</td>
</tr>
<tr>
<td>kthread_t *curthread</td>
<td>The address of the operating system kernel’s internal data structure for the current thread, the kthread_t. The kthread_t is defined in &lt;sys/thread.h&gt;. Refer to Solaris Internals for more information on this variable and other operating system data structures.</td>
</tr>
<tr>
<td>string cwd</td>
<td>The name of the current working directory of the process associated with the current thread.</td>
</tr>
<tr>
<td>uint_t epid</td>
<td>The enabled probe ID (EPID) for the current probe. This integer uniquely identifies a particular probe that is enabled with a specific predicate and set of actions.</td>
</tr>
<tr>
<td>int errno</td>
<td>The error value returned by the last system call executed by this thread.</td>
</tr>
<tr>
<td>string execname</td>
<td>The name that was passed to exec(2) to execute the current process.</td>
</tr>
<tr>
<td>gid_t gid</td>
<td>The real group ID of the current process.</td>
</tr>
<tr>
<td>Variable</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td><code>uint_t id</code></td>
<td>The probe ID for the current probe. This ID is the system-wide unique identifier for the probe as published by DTrace and listed in the output of <code>dt race -l</code>.</td>
</tr>
<tr>
<td><code>uint_t ipl</code></td>
<td>The interrupt priority level (IPL) on the current CPU at the time that the probe fires. Refer to <code>Solaris Internals</code> for more information on interrupt levels and interrupt handling in the Solaris operating system kernel.</td>
</tr>
<tr>
<td><code>lgrp_id_t lgrp</code></td>
<td>The locality group ID for the latency group of which the current CPU is a member. See Chapter 26, “sched Provider,” in <code>Solaris Dynamic Tracing Guide</code> for more information on CPU management in DTrace. See Chapter 4, “Locality Group APIs,” in <code>Programming Interfaces Guide</code> for more information about locality groups.</td>
</tr>
<tr>
<td><code>pid_t pid</code></td>
<td>The process ID of the current process.</td>
</tr>
<tr>
<td><code>pid_t ppid</code></td>
<td>The parent process ID of the current process.</td>
</tr>
<tr>
<td><code>string probefunc</code></td>
<td>The function name portion of the current probe’s description.</td>
</tr>
<tr>
<td><code>string probemod</code></td>
<td>The module name portion of the current probe’s description.</td>
</tr>
<tr>
<td><code>string probename</code></td>
<td>The name portion of the current probe’s description.</td>
</tr>
<tr>
<td><code>string probeprov</code></td>
<td>The provider name portion of the current probe’s description.</td>
</tr>
<tr>
<td><code>psetid_t pset</code></td>
<td>The processor set ID for the processor set that contains the current CPU. See Chapter 26, “sched Provider,” in <code>Solaris Dynamic Tracing Guide</code> for more information.</td>
</tr>
<tr>
<td><code>string root</code></td>
<td>The name of the root directory of the process associated with the current thread.</td>
</tr>
<tr>
<td><code>uint_t stackdepth</code></td>
<td>The current thread’s stack frame depth at probe firing time.</td>
</tr>
<tr>
<td><code>id_t tid</code></td>
<td>The thread ID of the current thread. For threads that are associated with user processes, this value is equal to the result of a call to <code>pthread_self(3C)</code>.</td>
</tr>
<tr>
<td><code>uint64_t timestamp</code></td>
<td>The current value of a nanosecond timestamp counter. This counter increments from an arbitrary point in the past and should only be used for relative computations.</td>
</tr>
<tr>
<td><code>uid_t uid</code></td>
<td>The real user ID of the current process.</td>
</tr>
<tr>
<td><code>uint64_t uregs[]</code></td>
<td>The current thread’s saved user-mode register values at probe firing time. Use of the <code>uregs[]</code> array is discussed in Chapter 33, “User Process Tracing,” in <code>Solaris Dynamic Tracing Guide</code>.</td>
</tr>
<tr>
<td><code>uint64_t vtimestamp</code></td>
<td>The current value of a nanosecond timestamp counter. The counter is virtualized to the amount of time that the current thread has been running on a CPU. The counter does not include the time that is</td>
</tr>
</tbody>
</table>
spent in DTrace predicates and actions. This counter increments from an arbitrary point in the past and should only be used for relative time computations.

uint64_t walltimestamp
The current number of nanoseconds since 00:00 Universal Coordinated Time, January 1, 1970.
This chapter examines the use of DTrace for common basic tasks, and has information on several different types of tracing.

**Performance Monitoring**

Several DTrace providers implement probes that correspond to existing performance monitoring tools:

- The `vminfo` provider implements probes that correspond to the `vmstat(1M)` tool
- The `sysinfo` provider implements probes that correspond to the `mpstat(1M)` tool
- The `io` provider implements probes that correspond to the `iostat(1M)` tool
- The `syscall` provider implements probes that correspond to the `truss(1)` tool

You can use the DTrace facility to extract the same information that the bundled tools provide, but with greater flexibility. The DTrace facility provides arbitrary kernel information that is available at the time that the probes fire. The DTrace facility enables you to receive information such as process identification, thread identification, and stack traces.

**Examining Performance Problems With The `sysinfo` Provider**

The `sysinfo` provider makes available probes that correspond to the `sys` kernel statistics. These statistics provide the input for system monitoring utilities such as `mpstat`. The `sysinfo` provider probes fire immediately before the `sys` named `kstat` increments. The probes that are provided by the `sysinfo` provider are in the following list.

- `bawrite` Probe that fires whenever a buffer is about to be asynchronously written out to a device.
<table>
<thead>
<tr>
<th>Probe</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bread</td>
<td>Probe that fires whenever a buffer is physically read from a device. bread</td>
</tr>
<tr>
<td></td>
<td>fires after the buffer has been requested from the device, but before</td>
</tr>
<tr>
<td></td>
<td>blocking pending its completion.</td>
</tr>
<tr>
<td>bwrite</td>
<td>Probe that fires whenever a buffer is about to be written out to a device,</td>
</tr>
<tr>
<td></td>
<td>whether synchronously or asynchronously.</td>
</tr>
<tr>
<td>cpu_ticks_idle</td>
<td>Probe that fires when the periodic system clock has made the determination</td>
</tr>
<tr>
<td></td>
<td>that a CPU is idle. Note that this probe fires in the context of the system</td>
</tr>
<tr>
<td></td>
<td>clock and therefore fires on the CPU running the system clock. The cpu_t</td>
</tr>
<tr>
<td></td>
<td>argument (arg2) indicates the CPU that has been deemed idle.</td>
</tr>
<tr>
<td>cpu_ticks_kernel</td>
<td>Probe that fires when the periodic system clock has made the determination</td>
</tr>
<tr>
<td></td>
<td>that a CPU is executing in the kernel. This probe fires in the context of</td>
</tr>
<tr>
<td></td>
<td>the system clock and therefore fires on the CPU running the system clock.</td>
</tr>
<tr>
<td></td>
<td>The cpu_t argument (arg2) indicates the CPU that has been deemed to be</td>
</tr>
<tr>
<td></td>
<td>executing in the kernel.</td>
</tr>
<tr>
<td>cpu_ticks_user</td>
<td>Probe that fires when the periodic system clock has made the determination</td>
</tr>
<tr>
<td></td>
<td>that a CPU is executing in user mode. This probe fires in the context of</td>
</tr>
<tr>
<td></td>
<td>the system clock and therefore fires on the CPU running the system clock.</td>
</tr>
<tr>
<td></td>
<td>The cpu_t argument (arg2) indicates the CPU that has been deemed to be</td>
</tr>
<tr>
<td></td>
<td>running in user-mode.</td>
</tr>
<tr>
<td>cpu_ticks_wait</td>
<td>Probe that fires when the periodic system clock has made the determination</td>
</tr>
<tr>
<td></td>
<td>that a CPU is otherwise idle, but some threads are waiting for I/O on the</td>
</tr>
<tr>
<td></td>
<td>CPU. This probe fires in the context of the system clock and therefore fires</td>
</tr>
<tr>
<td></td>
<td>on the CPU running the system clock. The cpu_t argument (arg2) indicates</td>
</tr>
<tr>
<td></td>
<td>the CPU that has been deemed waiting on I/O.</td>
</tr>
<tr>
<td>idlethread</td>
<td>Probe that fires whenever a CPU enters the idle loop.</td>
</tr>
<tr>
<td>intrblk</td>
<td>Probe that fires whenever an interrupt thread blocks.</td>
</tr>
<tr>
<td>inv_swtnch</td>
<td>Probe that fires whenever a running thread is forced to involuntarily give</td>
</tr>
<tr>
<td></td>
<td>up the CPU.</td>
</tr>
<tr>
<td>lread</td>
<td>Probe that fires whenever a buffer is logically read from a device.</td>
</tr>
<tr>
<td>lwrite</td>
<td>Probe that fires whenever a buffer is logically written to a device</td>
</tr>
<tr>
<td>modload</td>
<td>Probe that fires whenever a kernel module is loaded.</td>
</tr>
<tr>
<td>modunload</td>
<td>Probe that fires whenever a kernel module is unloaded.</td>
</tr>
<tr>
<td>msg</td>
<td>Probe that fires whenever a msgsnd(2) or msgrcv(2) system call is made, but</td>
</tr>
<tr>
<td></td>
<td>before the message queue operations have been performed.</td>
</tr>
<tr>
<td>mutex_adinters</td>
<td>Probe that fires whenever an attempt is made to acquire an owned adaptive</td>
</tr>
<tr>
<td></td>
<td>lock. If this probe fires, one of the lockstat provider's adaptive-block or</td>
</tr>
<tr>
<td></td>
<td>adaptive-spin probes also fires.</td>
</tr>
<tr>
<td>namei</td>
<td>Probe that fires whenever a name lookup is attempted in the filesystem.</td>
</tr>
<tr>
<td>Probe Name</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>nthreads</td>
<td>Probe that fires whenever a thread is created.</td>
</tr>
<tr>
<td>phread</td>
<td>Probe that fires whenever a raw I/O read is about to be performed.</td>
</tr>
<tr>
<td>phwrite</td>
<td>Probe that fires whenever a raw I/O write is about to be performed.</td>
</tr>
<tr>
<td>procovf</td>
<td>Probe that fires whenever a new process cannot be created because the system is out of process table entries.</td>
</tr>
<tr>
<td>pswitch</td>
<td>Probe that fires whenever a CPU switches from executing one thread to executing another.</td>
</tr>
<tr>
<td>readch</td>
<td>Probe that fires after each successful read, but before control is returned to the thread that is performing the read. A read can occur through the <code>read(2)</code>, <code>readv(2)</code> or <code>pread(2)</code> system calls. <code>arg0</code> contains the number of bytes that were successfully read.</td>
</tr>
<tr>
<td>rw_rdfails</td>
<td>Probe that fires whenever an attempt is made to read-lock a reader or writer lock when the lock is held by a writer or desired by a writer. If this probe fires, the <code>lockstat</code> provider's <code>rw-block</code> probe also fires.</td>
</tr>
<tr>
<td>rw_wrfails</td>
<td>Probe that fires whenever an attempt is made to write-lock a reader or writer lock when the lock is held by readers or by another writer. If this probe fires, the <code>lockstat</code> provider's <code>rw-block</code> probe also fires.</td>
</tr>
<tr>
<td>sema</td>
<td>Probe that fires whenever a <code>semop(2)</code> system call is made, but before any semaphore operations have been performed.</td>
</tr>
<tr>
<td>sysexec</td>
<td>Probe that fires whenever an <code>exec(2)</code> system call is made.</td>
</tr>
<tr>
<td>sysfork</td>
<td>Probe that fires whenever a <code>fork(2)</code> system call is made.</td>
</tr>
<tr>
<td>sysread</td>
<td>Probe that fires whenever a <code>read</code>, <code>readv</code>, or <code>pread</code> system call is made.</td>
</tr>
<tr>
<td>sysvfork</td>
<td>Probe that fires whenever a <code>vfork(2)</code> system call is made.</td>
</tr>
<tr>
<td>syswrite</td>
<td>Probe that fires whenever a <code>write(2)</code>, <code>writev(2)</code>, or <code>pwrite(2)</code> system call is made.</td>
</tr>
<tr>
<td>trap</td>
<td>Probe that fires whenever a processor trap occurs. Note that some processors, in particular UltraSPARC variants, handle some lightweight traps through a mechanism that does not cause this probe to fire.</td>
</tr>
<tr>
<td>ufsdirblk</td>
<td>Probe that fires whenever a directory block is read from the UFS file system. See <code>ufs(7FS)</code> for details on UFS.</td>
</tr>
<tr>
<td>ufsiget</td>
<td>Probe that fires whenever an inode is retrieved. See <code>ufs(7FS)</code> for details on UFS.</td>
</tr>
<tr>
<td>ufsinopage</td>
<td>Probe that fires after an in-core inode <em>without</em> any associated data pages has been made available for reuse. See <code>ufs(7FS)</code> for details on UFS.</td>
</tr>
</tbody>
</table>
ufsipage  Probe that fires after an in-core inode with associated data pages has been made available for reuse. This probe fires after the associated data pages have been flushed to disk. See ufs(7FS) for details on UFS.

wait_ticks_io  Probe that fires when the periodic system clock has made the determination that a CPU is otherwise idle but some threads are waiting for I/O on the CPU. This probe fires in the context of the system clock and therefore fires on the CPU running the system clock. The cpu_t argument (arg2) indicates the CPU that is described as waiting for I/O. No semantic difference between wait_ticks_io and cpu_ticks_wait; wait_ticks_io exists solely for historical reasons.

writech  Probe that fires after each successful write, but before control is returned to the thread performing the write. A write can occur through the write, writev, or pwrite system calls. arg0 contains the number of bytes that were successfully written.

xcalls  Probe that fires whenever a cross-call is about to be made. A cross-call is the operating system’s mechanism for one CPU to request immediate work of another CPU.

EXAMPLE 4–1 Using the quantize Aggregation Function With the sysinfo Probes

The quantize aggregation function displays a power-of-two frequency distribution bar graph of its argument. The following example uses the quantize function to determine the size of the read calls that are performed by all processes on the system over a period of ten seconds. The arg0 argument for the sysinfo probes states the amount by which to increment the statistic. This value is 1 for most sysinfo probes. Two exceptions are the readch and writech probes. For these probes, the arg0 argument is set to the actual number of bytes that are read or written, respectively.

    # cat -n read.d
    1  #!/usr/sbin/dtrace -s
    2  sysinfo:::readch
    3  { 
    4    @[execname] = quantize(arg0);
    5  } 
    6  
    7  tick-10sec
    8  { 
    9      exit(0);
   10  } 

    # dtrace -s read.d
    dtrace: script ’read.d’ matched 5 probes
    CPU   ID FUNCTION:NAME
    0  36754        :tick-10sec

    bash
    value ------- Distribution ------- count

---
EXAMPLE 4–1 Using the quantize Aggregation Function With the sysinfo Probes  (Continued)

<table>
<thead>
<tr>
<th>value</th>
<th>Distribution</th>
<th>count</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>64</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>128</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>256</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>512</td>
<td></td>
<td>199</td>
</tr>
<tr>
<td>1024</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>2048</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>4096</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>8192</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>16384</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

grep

<table>
<thead>
<tr>
<th>value</th>
<th>Distribution</th>
<th>count</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>99</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>64</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>128</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>256</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>512</td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>1024</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>2048</td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>4096</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>8192</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>16384</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>
EXAMPLE 4-2 Finding the Source of Cross-Calls

In this example, consider the following output form the mpstat(1M) command:

```
CPU minf mjf xcal intr ithr csw icsw migr smtx srw syscl usr sys wt idl
0 2189 0 1302 14 1 215 12 54 28 0 12995 13 14 0 73
1 3385 0 1137 218 104 195 13 58 33 0 14486 19 15 0 66
2 1918 0 1039 12 1 226 15 49 22 0 13251 13 12 0 75
3 2430 0 1284 220 113 201 10 50 26 0 13926 10 15 0 75
```

The values in the xcal and syscl columns are atypically high, reflecting a possible drain on system performance. The system is relatively idle and is not spending an unusual amount of time waiting for I/O. The numbers in the xcal column are scaled per second and are read from the xcalls field of the sys kstat. To see which executables are responsible for the cross-calls, enter the following dtrace command:

```
# dtrace -n 'xcalls {@[execname] = count()}'
```

```
dtrace: description 'xcalls' matched 3 probes
```

```
^C
```

```
find 2
cut 2
snmpd 2
mpstat 22
sendmail 101
grep 123
bash 175
dtrace 435
sched 784
xargs 22308
file 89889
```

This output indicates that the bulk of the cross calls are originating from file(1) and xargs(1) processes. You can find these processes with the pgrep(1) and ptree(1) commands.

```
# pgrep xargs
15973
```

```
# ptree 15973
204 /usr/sbin/inetd -s
5650 in.telnetd
5653 -sh
5657 bash
15970 /bin/sh ./findtxt configuration
15971 cut -f1 -d:
15973 xargs file
16686 file /usr/bin/tbl /usr/bin/troff /usr/bin/ul /usr/bin/vgrind /usr/bin/catman
```

This output indicates that the xargs and file commands form part of a custom user shell script. To locate this script, you can perform the following commands:
EXAMPLE 4-2 Finding the Source of Cross-Calls  (Continued)

```bash
# find / -name findtxt
/usrsl/james/findtxt
# cat /usrsl/james/findtxt
#!/bin/sh
find / -type f | xargs file | grep text | cut -f1 -d: > /tmp/findtxt$
rm /tmp/findtxt$
```

This script runs many process concurrently. A large amount of interprocess communication is happening through pipes. The number of pipes makes the script resource intensive. The script attempts to find every text file on the system and then searches each file for a specific text.

## Tracing User Processes

This section focuses on the DTrace facilities that are useful for tracing user process activity and provides examples to illustrate their use.

### Using the copyin() and copyinstr() Subroutines

DTrace probes execute in the Solaris kernel. Probes use the copyin() or copyinstr() subroutines to copy user process data into the kernel's address space.

Consider the following `write()` system call:

```c
ssize_t write(int fd, const void *buf, size_t nbytes);
```

The following D program illustrates an incorrect attempt to print the contents of a string that is passed to the `write` system call:

```d
syscall::write:entry
{
  printf("%s", stringof(arg1)); /* incorrect use of arg1 */
}
```

When you run this script, DTrace produces error messages similar to the following example.

```bash
dtrace: error on enabled probe ID 1 (ID 37: syscall::write:entry): \invalid address (0x10038a000) in action #1
```

The `arg1` variable is an address that refers to memory in the process that is executing the system call. Use the `copyinstr()` subroutine to read the string at that address. Record the result with the `printf()` action:
syscall::write:entry
{
    printf("%s", copyinstr(arg1)); /* correct use of arg1 */
}

The output of this script shows all of the strings that are passed to the write system call.

**Avoiding Errors**

The copyin() and copyinstr() subroutines cannot read from user addresses which have not yet been touched. A valid address might cause an error if the page that contains that address has not been faulted in by an access attempt. Consider the following example:

```
# dtrace -n syscall::open:entry '{ trace(copyinstr(arg0)); }'
```

DTrace: description 'syscall::open:entry' matched 1 probe

CPU ID FUNCTION:NAME
DTrace: error on enabled probe ID 2 (ID 50: syscall::open:entry): invalid address (0x9af1b) in action #1 at DIF offset 52

In the output from the previous example, the application was functioning properly and the address in arg0 was valid. However, the address in arg0 referred to a page that the corresponding process had not accessed. To resolve this issue, wait for the kernel or application to use the data before tracing the data. For example, you might wait until the system call returns to apply copyinstr(), as shown in the following example:

```
# dtrace -n syscall::open:entry '{ self->file = arg0; }' -n syscall::open:return '{ trace(copyinstr(self->file)); self->file = 0; }'
```

Eliminating **dtrace** Interference

If you trace every call to the write system call, you will cause a cascade of output. Each call to the write() function causes the dtrace command to call the write() function as it displays the output. This feedback loop is a good example of how the dtrace command can interfere with the desired data. You can use a simple predicate to avoid this behavior, as shown in the following example:

```c
syscall::write:entry
/pid != $pid/
{
    printf("%s", stringof(copyin(arg1, arg2)))
}
```

The $pid macro variable expands to the process identifier of the process that enabled the probes. The pid variable contains the process identifier of the process whose thread was running on the CPU where the probe was fired. The predicate /pid != $pid/ ensures that the script does not trace any events related to the running of this script.
**syscall Provider**

The syscall provider enables you to trace every system call entry and return. You can use the `prstat(1M)` command to see examine process behavior.

```
$ prstat -m -p 31337
```

```
PID USERNAME USR SYS TRP TFL DFL LCK SLP LAT VCX ICX SCL SIG PROCESS/NLWP
13499 user1 53 44 0.0 0.0 0.0 0.0 2.5 0.0 4K 24 9K 0 mystery/6
```

This example shows that the process is consuming a large amount of system time. One possible explanation for this behavior is that the process is executing a large number of system calls. You can use a simple D program specified on the command line to see which system calls are happening most often:

```
# dtrace -n syscall:::entry'/pid == 31337/{ @syscalls[probefunc] = count(); }
```

```
dtrace: description 'syscall:::entry' matched 215 probes
```

```
open
lwp_park
times
fcntl
close
sigaction
read
ioctl
sigprocmask
write
```

```
<table>
<thead>
<tr>
<th>value</th>
<th>count</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1037</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>32</td>
<td>3</td>
</tr>
<tr>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>128</td>
<td>0</td>
</tr>
<tr>
<td>256</td>
<td>0</td>
</tr>
<tr>
<td>512</td>
<td>0</td>
</tr>
<tr>
<td>1024</td>
<td>5</td>
</tr>
</tbody>
</table>
```

This report shows a large number of system calls to the `write()` function. You can use the syscall provider to further examine the source of all the `write()` system calls:

```
# dtrace -n syscall::write:entry'/pid == 31337/ { @writes[arg2] = quantize(); }
```

```
dtrace: description 'syscall::write:entry' matched 1 probe
```

```
<table>
<thead>
<tr>
<th>value</th>
<th>count</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1037</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
```

Tracing User Processes

Chapter 4 • Using DTrace
The output shows that the process is executing many `write()` system calls with a relatively small amount of data.

**The `ustack()` Action**

The `ustack()` action traces the user thread's stack. If a process that opens many files occasionally fails in the `open()` system call, you can use the `ustack()` action to discover the code path that executes the failed `open()`:

```c
syscall::open:entry
/pid == $1/
{
    self->path = copyInstr(arg0);
}
syscall::open:return
/self->path != NULL && arg1 == -1/
{
    printf("open for '\%s' failed", self->path);
    usstack();
}
```

This script also illustrates the use of the `$1` macro variable. This macro variable takes the value of the first operand that is specified on the `dtrace` command line:

```
# dtrace -s ./badopen.d 31337
```

```
CPU ID FUNCTION:NAME
0 40 open:return open for '/usr/lib/foo' failed
  libc.so.1'__open+0x4
  libc.so.1'open+0x6c
  420b0
  tcsh'dosource+0xe0
  tcsh'execute+0x978
  tcsh'execute+0x9ba
  tcsh'process+0x50c
  tcsh'main+0x1d54
  tcsh'__start+0xdc
```

The `ustack()` action records program counter (PC) values for the stack. The `dtrace` command resolves those PC values to symbol names by looking through the process's symbol tables. The `dtrace` command prints out PC values that cannot be resolved as hexadecimal integers.

When a process exits or is killed before the `ustack()` data is formatted for output, the `dtrace` command might be unable to convert the PC values in the stack trace to symbol names. In that event
the dtrace command displays these values as hexadecimal integers. To work around this limitation, specify a process of interest with the -c or -p option to dtrace. If the process ID or command is not known in advance, the following example D program can be used to work around the limitation. The example uses the open system call probe, but this technique can be used with any script that uses the usstack action.

```d
syscall::open:entry
{
    usstack();
    stop_pids[pid] = 1;
}

syscall::rexit:entry
/stop_pids[pid] != 0/
{
    printf("stopping pid %d", pid);
    stop();
    stop_pids[pid] = 0;
}
```

The previous script stops a process just before the process exits, if the usstack() action has been applied to a thread in that process. This technique ensures that the dtrace command can resolve the PC values to symbolic names. The value of stop_pids[pid] is set to 0 after clearing the dynamic variable.

The pid Provider

The pid provider enables you to trace any instruction in a process. Unlike most other providers, pid probes are created on demand, based on the probe descriptions found in your D programs.

User Function Boundary Tracing

The simplest mode of operation for the pid provider is as the user space analogue to the fbt provider. The following example program traces all function entries and returns that are made from a single function. The $1 macro variable expands to the first operand on the command line. This macro variable is the process ID for the process to trace. The $2 macro variable expands to the second operand on the command line. This macro variable is the name of the function that all function calls are traced from.

EXAMPLE 4–3 userfunc.d: Trace User Function Entry and Return

```d
pid$1::$2:entry
{
    self->trace = 1;
}
```
EXAMPLE 4-3 userfunc.d: Trace User Function Entry and Return  

(Continued)

pid$1::$2:return
/self->trace/
{
    self->trace = 0;
}

pid$1:::entry,
 pid$1:::return
/self->trace/
{

}

This script produces output that is similar to the following example:

# ./userfunc.d 15032 execute
dtrace: script './userfunc.d' matched 11594 probes
  0 -> execute
  0  -> execute
  0  -> Dfix
  0   <- Dfix
  0  -> s_strsave
  0   -> malloc
  0   <- malloc
  0   <- s_strsave
  0   -> set
  0   -> malloc
  0   <- malloc
  0   <- set
  0   -> set1
  0   -> tglob
  0   <- tglob
  0   <- set1
  0   -> setq
  0   -> s_strcmp
  0   <- s_strcmp
...

The pid provider can only be used on processes that are already running. You can use the $target macro variable and the dt race options -c and -p to create and instrument processes of interest using the dt race facility. The following D script determines the distribution of function calls that are made to libc by a particular subject process:

pid$target:libc.so:::entry
{
To determine the distribution of such calls made by the `date` command, execute the following command:

```sh
# dtrace -s libc.d -c date
dtrace: script 'libc.d' matched 2476 probes
Fri Jul 30 14:08:54 PDT 2004
dtrace: pid 109196 has exited

pthread_rwlock_unlock 1
_fflush_u 1
_rwlock_lock 1
_rw_write_held 1
_strftime 1
_close 1
_read 1
_open 1
_open 1
_strstr 1
_load_zoneinfo 1
...
_ti_bind_guard 47
_ti_bind_clear 94
```

**Tracing Arbitrary Instructions**

You can use the `pid` provider to trace any instruction in any user function. Upon demand, the `pid` provider creates a probe for every instruction in a function. The name of each probe is the offset of its corresponding instruction in the function expressed as a hexadecimal integer. To enable a probe that is associated with the instruction at offset `0x1c` in function `foo` of module `bar.so` in the process with PID 123, use the following command.

```sh
# dtrace -n pid123:bar.so:foo:0x1c
```

To enable all of the probes in the function `foo`, including the probe for each instruction, you can use the command:

```sh
# dtrace -n pid123:bar.so:foo:
```

The following example demonstrates how to combine the `pid` provider with speculative tracing to trace every instruction in a function.

**EXAMPLE 4–4 errorpath.d: Trace User Function Call Error Path**

```d
pid$1::$2:entry
{
```
When `errorpath.d` executes, the output of the script is similar to the following example.

```
# ./errorpath.d 100461 _chdir
dtrace: script './errorpath.d' matched 19 probes
CPU   ID   FUNCTION:NAME
0 25253  _chdir:entry 81e08 6d140 ffbfc20 656c73 0
0 25253  _chdir:entry
0 25269  _chdir:0
0 25270  _chdir:4
0 25271  _chdir:8
0 25272  _chdir:c
0 25273  _chdir:10
0 25274  _chdir:14
0 25275  _chdir:18
0 25276  _chdir:1c
0 25277  _chdir:20
0 25278  _chdir:24
0 25279  _chdir:28
0 25280  _chdir:2c
0 25268  _chdir:return
```
Anonymous Tracing

This section describes tracing that is not associated with any DTrace consumer. Anonymous tracing is used in situations when no DTrace consumer processes can run. Only the super user may create an anonymous enabling. Only one anonymous enabling can exist at any time.

Anonymous Enablings

To create an anonymous enabling, use the -A option with the dtrace command invocation that specifies the desired probes, predicates, actions and options. The dtrace command adds a series of driver properties that represent your request to the configuration file for the dt race(7D) driver. The configuration file is typically /kernel/drv/dtrace.conf. The dtrace driver reads these properties when the driver is loaded. The driver enables the specified probes with the specified actions and creates an anonymous state to associate with the new enabling. The dtrace driver is normally loaded on demand, along with any drivers that act as dtrace providers. To allow tracing during boot, the dtrace driver must be loaded as early as possible. The dtrace command adds the necessary forceload statements to /etc/system (see system(4)) for each required dtrace provider and for the dtrace driver.

When the system boots, the dtrace driver sends a message indicating that the configuration file has been successfully processed. An anonymous enabling can set any of the options that are available during normal use of the dtrace command.

To remove an anonymous enabling, specify the -A option to the dtrace command without any probe descriptions.

Claiming Anonymous State

When the machine has completely booted, you can claim an existing anonymous state by specifying the -a option with the dtrace command. By default, the -a option claims the anonymous state and processes the existing data, then continues to run. To consume the anonymous state and exit, add the -e option.

When the anonymous state has been consumed from the kernel, the anonymous state cannot be replaced. If you attempt to claim an anonymous tracing state that does not exist, the dtrace command generates a message that is similar to the following example:

dtrace: could not enable tracing: No anonymous tracing state

If drops or errors occur, the dtrace command generates the appropriate messages when the anonymous state is claimed. The messages for drops and errors are the same for both anonymous and non-anonymous state.
Anonymous Tracing Examples

The following example shows an anonymous DTrace enabling for every probe in the iprb(7D) module:

```bash
# dtrace -A -m iprb
```

dtrace: saved anonymous enabling in /kernel/drv/dtrace.conf
dtrace: added forceload directives to /etc/system
dtrace: run update_drv(1M) or reboot to enable changes

```bash
# reboot
```

After rebooting, the dtrace driver prints a message on the console to indicate that the driver is enabling the specified probes:

```
...  
Copyright 1983-2003 Sun Microsystems, Inc. All rights reserved.  
Use is subject to license terms.  
NOTICE: enabling probe 0 (:iprb::)  
NOTICE: enabling probe 1 (dtrace:::ERROR)  
configuring IPv4 interfaces: iprb0.  
...  
```

After rebooting the machine, specifying the -a option with the dtrace command consumes the anonymous state:

```bash
# dtrace -a
```

<table>
<thead>
<tr>
<th>CPU ID</th>
<th>FUNCTION:NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 22954</td>
<td>_init:entry</td>
</tr>
<tr>
<td>0 22955</td>
<td>_init:return</td>
</tr>
<tr>
<td>0 22800</td>
<td>iprbprobe:entry</td>
</tr>
<tr>
<td>0 22934</td>
<td>iprb_get_dev_type:entry</td>
</tr>
<tr>
<td>0 22935</td>
<td>iprb_get_dev_type:return</td>
</tr>
<tr>
<td>0 22801</td>
<td>iprbprobe:return</td>
</tr>
<tr>
<td>0 22802</td>
<td>iprbattach:entry</td>
</tr>
<tr>
<td>0 22874</td>
<td>iprb_getprop:entry</td>
</tr>
<tr>
<td>0 22875</td>
<td>iprb_getprop:return</td>
</tr>
<tr>
<td>0 22934</td>
<td>iprb_get_dev_type:entry</td>
</tr>
<tr>
<td>0 22935</td>
<td>iprb_get_dev_type:return</td>
</tr>
<tr>
<td>0 22870</td>
<td>iprb_self_test:entry</td>
</tr>
<tr>
<td>0 22871</td>
<td>iprb_self_test:return</td>
</tr>
<tr>
<td>0 22958</td>
<td>iprb_hard_reset:entry</td>
</tr>
<tr>
<td>0 22959</td>
<td>iprb_hard_reset:return</td>
</tr>
<tr>
<td>0 22862</td>
<td>iprb_get_eeprom_size:entry</td>
</tr>
<tr>
<td>0 22826</td>
<td>iprb_shiftout:entry</td>
</tr>
<tr>
<td>0 22828</td>
<td>iprb_raiseclock:entry</td>
</tr>
<tr>
<td>0 22829</td>
<td>iprb_raiseclock:return</td>
</tr>
</tbody>
</table>

```
...
```

The following example focuses only on functions that are called from iprbattach().
Run the following commands to clear the previous settings from the driver configuration file, install the new anonymous tracing request, and reboot:

```
# dtrace -AFs iprb.d
```

dtrace: cleaned up old anonymous enabling in /kernel/drv/dtrace.conf
dtrace: cleaned up forceload directives in /etc/system
dtrace: saved anonymous enabling in /kernel/drv/dtrace.conf
dtrace: added forceload directives to /etc/system
dtrace: run update_drv(1M) or reboot to enable changes

```
# reboot
```

After rebooting, the dtrace driver prints a different message on the console to indicate the slightly different enabling:

```
Copyright 1983-2003 Sun Microsystems, Inc. All rights reserved.
Use is subject to license terms.
NOTICE: enabling probe 0 (fbt::iprbattach:entry)
NOTICE: enabling probe 1 (fbt:::)
NOTICE: enabling probe 2 (fbt::iprbattach:return)
NOTICE: enabling probe 3 (dtrace::ERROR)
configuring IPv4 interfaces: iprb0.
...```

After the machine has finished booting, run the dtrace command with the -a and the -e options to consume the anonymous data and then exit.

```
# dtrace -ae
CPU FUNCTION
  0  -> iprbattach
  0  -> gld_mac_alloc
  0  -> kmem_zalloc
  0  -> kmem_cache_alloc
  0  -> kmem_cache_alloc_debug
  0  -> verify_and_copy_pattern
```
Speculative Tracing

This section discusses the DTrace facility for speculative tracing. Speculative tracing is the ability to tentatively trace data and decide whether to commit the data to a tracing buffer or discard it. The primary mechanism to filter out uninteresting events is the predicate mechanism. Predicates are
useful when you know at the time that a probe fires whether or not the probe event is of interest. Predicates are not well suited to dealing with situations where you do not know if a given probe event is of interest or not until after the probe fires.

If a system call is occasionally failing with a common error code, you might want to examine the code path that leads to the error condition. You can use the speculative tracing facility to tentatively trace data at one or more probe locations, then decide to commit the data to the principal buffer at another probe location. The resulting trace data contains only the output of interest and requires no postprocessing.

Speculation Interfaces

The following table describes the DTrace speculation functions.

<table>
<thead>
<tr>
<th>Function Name</th>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>speculation</td>
<td>None</td>
<td>Returns an identifier for a new speculative buffer</td>
</tr>
<tr>
<td>speculate</td>
<td>ID</td>
<td>Denotes that the remainder of the clause should be traced to the speculative buffer specified by ID</td>
</tr>
<tr>
<td>commit</td>
<td>ID</td>
<td>Commits the speculative buffer that is associated with ID</td>
</tr>
<tr>
<td>discard</td>
<td>ID</td>
<td>Discards the speculative buffer associated with ID</td>
</tr>
</tbody>
</table>

Creating a Speculation

The speculation() function allocates a speculative buffer and returns a speculation identifier. Use the speculation identifier in subsequent calls to the speculate() function. A speculation identifier of zero is always invalid, but can be passed to speculate(), commit() or discard(). If a call to speculation() fails, the dtrace command generates a message that is similar to the following example.

dtrace: 2 failed speculations (no speculative buffer space available)

Using a Speculation

To use a speculation, use a clause to pass an identifier that has been returned from speculation() to the speculate() function before any data-recording actions. All data-recording actions in a clause that contains a speculate() are speculatively traced. The D compiler generates a compile-time error if a call to speculate() follows data recording actions in a D probe clause. Clauses can contain either speculative tracing requests or non-speculative tracing requests, but not both.
Aggregating actions, destructive actions, and the exit action may never be speculative. Any attempt to take one of these actions in a clause that contains a \texttt{speculate()} results in a compile-time error. A \texttt{speculate()} function may not follow a previous \texttt{speculate()} function. Only one speculation is permitted per clause. A clause that contains only a \texttt{speculate()} function will speculatively trace the default action, which is defined to trace only the enabled probe ID.

The typical use of the \texttt{speculation()} function is to assign the result of the \texttt{speculation()} function to a thread-local variable. That thread-local variable acts as a subsequent predicate to other probes, as well as an argument to \texttt{speculate()}.  

\textbf{EXAMPLE 4-5} Typical Use of The \texttt{speculation()} Function

```c
syscall::open:entry
{
    self->spec = speculation();
}

syscall:::
/self->spec/
{
    speculate(self->spec);
    printf("this is speculative");
}
```

\section*{Committing a Speculation}

Commit speculations by using the \texttt{commit()} function. When you commit a speculative buffer the buffer’s data is copied into the principal buffer. If the data in the speculative buffer exceeds the available space in the principal buffer, no data is copied and the drop count for the buffer increments. If the buffer has been speculatively traced on more than one CPU, the speculative data on the committing CPU is copied immediately, while speculative data on other CPUs is copied after the \texttt{commit()}.  

A speculative buffer that is being committed is not available to subsequent \texttt{speculation()} calls until each per-CPU speculative buffer is completely copied into its corresponding per-CPU principal buffer. Subsequent attempts to write the results of a \texttt{speculate()} function call to the committing buffer discard the data without generating an error. Subsequent calls to \texttt{commit()} or \texttt{discard()} also fail without generating an error. A clause that contains a \texttt{commit()} function cannot contain a data recording action, but a clause can contain multiple \texttt{commit()} calls to commit disjoint buffers.

\section*{Discarding a Speculation}

Discard speculations by using the \texttt{discard()} function. If the speculation has only been active on the CPU that is calling the \texttt{discard()} function, the buffer is immediately available for subsequent calls to the \texttt{speculation()} function. If the speculation has been active on more than one CPU, the
discarded buffer will be available for subsequent calls to the speculation() function after the call to discard(). If no speculative buffers are available at the time that the speculation() function is called adtrace message that is similar to the following example is generated:

dtrace: 905 failed speculations (available buffer(s) still busy)

Speculation Example

One potential use for speculations is to highlight a particular code path. The following example shows the entire code path under the open(2) system call when the open() fails.

EXAMPLE 4–6 specopen.d: Code Flow for Failed open()

```d
#!/usr/sbin/dtrace -Fs
syscall::open:entry,
syscall::open64:entry
{
    /*
     * The call to speculation() creates a new speculation. If this fails,
     * dtrace(1M) will generate an error message indicating the reason for
     * the failed speculation(), but subsequent speculative tracing will be
     * silently discarded.
     */
    self->spec = speculation();
    speculate(self->spec);

    /*
     * Because this printf() follows the speculate(), it is being
     * speculatively traced; it will only appear in the data buffer if the
     * speculation is subsequently committed.
     */
    printf("%s", stringof(copyinstr(arg0)));
}

fbt:::
/self->spec/
{
    /*
     * A speculate() with no other actions speculates the default action:
     * tracing the EPID.
     */
    speculate(self->spec);
}
syscall::open:return,
syscall::open64:return
/self->spec/
```
EXAMPLE 4-6 specopen.d: Code Flow for Failed open() (Continued)

```c
{
    /*
     * To balance the output with the -F option, we want to be sure that
     * every entry has a matching return. Because we speculated the
     * open entry above, we want to also speculate the open return.
     * This is also a convenient time to trace the errno value.
     */
    speculate(self->spec);
    trace(errno);
}
```

```c
syscall::open:return,
syscall::open64:return
/self->spec && errno != 0/
{
    /*
     * If errno is non-zero, we want to commit the speculation.
     */
    commit(self->spec);
    self->spec = 0;
}
```

```c
syscall::open:return,
syscall::open64:return
/self->spec && errno == 0/
{
    /*
     * If errno is not set, we discard the speculation.
     */
    discard(self->spec);
    self->spec = 0;
}
```

When you run the previous script, the script generates output that is similar to the following example.

```
# ./specopen.d
dtrace: script './specopen.d' matched 24282 probes
CPU FUNCTION
  1 => open /var/ld/ld.config
  1  -> open
     1  -> copen
     1  -> falloc
     1  -> ufalloc
     1  -> fd_find
  1  -> mutex_owned
```
Speculative Tracing

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1 <- mutex_owned
1 <- fd_find
1 -> fd_reserve
1 -> mutex_owned
1 <- mutex_owned
1 -> mutex_owned
1 <- mutex_owned
1 <- fd_reserve
1 <- ufalloc
1 -> kmem_cache_alloc
1 -> kmem_cache_alloc_debug
1 -> verify_and_copy_pattern
1 <- verify_and_copy_pattern
1 -> file_cache_constructor
1 -> mutex_init
1 <- mutex_init
1 <- file_cache_constructor
1 -> tsc_gethrttime
1 <- tsc_gethrttime
1 -> getpcstack
1 <- getpcstack
1 -> kmem_log_enter
1 <- kmem_log_enter
1 -> kmem_cache_alloc_debug
1 <- kmem_cache_alloc
1 -> crhold
1 <- crhold
1 -> falloc
1 -> vn_openat
1 -> lookupnameat
1 -> copyinstr
1 <- copyinstr
1 -> lookuppnat
1 -> lookuppnvp
1 -> pn_fixslash
1 <- pn_fixslash
1 -> pn_getcomponent
1 <- pn_getcomponent
1 -> ufs_lookup
1 -> dnlc_lookup
1 -> bcmp
1 <- bcmp
1 <- dnlc_lookup
1 -> ufs_iaccess
1 -> crgetuid
1 <- crgetuid
1 -> groupmember
1 -> supgroupmember
Speculative Tracing

1 <- supgroupmember
1 <- groupmember
1 <- ufs_iaccess
1 <- ufs_lookup
1 -> vn_rele
1 <- vn_rele
1 -> pn_getcomponent
1 <- pn_getcomponent
1 -> ufs_lookup
1 -> dnlc_lookup
1 -> bcmp
1 <- bcmp
1 <- dnlc_lookup
1 -> ufs_iaccess
1 -> crgetuid
1 <- crgetuid
1 <- ufs_iaccess
1 <- ufs_lookup
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1 <- vn_rele
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1 <- lookupnameat
1 <- vn_openat
1 -> setf
1 -> fd_reserve
1 -> mutex_owned
1 <- mutex_owned
1 -> mutex_owned
1 <- fd_reserve
1 -> cv_broadcast
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<- cv_broadcast
<- setf
-> unfalloc
-> mutex_owned
<- mutex_owned
-> crfree
<- crfree
-> kmem_cache_free
-> kmem_cache_free_debug
<- kmem_log_enter
<- kmem_log_enter
-> tsc_gethrt ime
<- tsc_gethrt ime
-> getpcstack
<- getpcstack
-> kmem_log_enter
<- kmem_log_enter
-> file_cache_destructor
-> mutex_destroy
<- mutex_destroy
<- file_cache_destructor
-> copy_pattern
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