DTrace for Rust*

*and everything else too

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Level: Intermediate

Some of this will be
“Introductory and overview”

I’m sorry

What is DTrace?

- Dynamic tracing facility
- Built to explore problems ***in production*** on ***mission critical*** systems
- Systemic in scope: kernel, drivers, user-land, dynamic languages, etc.
- Developed at Sun for Solaris; first available in 2003
- Ported to FreeBSD, macOS, Linux, Windows (and others)

The values of DTrace

- The focus on production use requires certain fundamental values
- Safety – a diagnostic system should do no harm
- Availability – you want tools at the ready when you hit problems
- Zero disabled probe-effect – when not in use, DTrace should have no impact to system performance
- These should sound familiar to Rust users!
    - Memory safety; rigorous error handling
    - Production use
    - Zero-cost abstractions

Early DTrace

- DTrace started as a tool for **us** to answer questions about the system
- Added dynamic instrumentation for kernel functions
- No special compilation or wide-spread code changes required

Statically Defined Tracing (SDT)

- Dynamic probes let us see pathologies that had previously been **very** expensive to observe
- Required a lot of familiarity with the implementation
- Fragile release-to-release
- Introduced Statically Defined Tracing to statically mark points of semantic importance
- E.g. I/O, thread scheduling, process lifecycle, locking events

User-land tracing

- There’s a lot more user-land code than kernel code out there so we also wanted to see into process activity
- Added the “pid” provider that can instrument user-land functions
- Again, fully dynamic; no need for special compilation
- Works by replacing instructions with a trap
- The trap handler invokes DTrace’s machinery

User-land Statically Defined Tracing (USDT)

- As before, function tracing requires familiarity with the implementation
- Added USDT to embed probes in user-land programs
- Those probes are part of the compiled binary
- Register with the kernel when the process starts
- Great for exposing higher level semantics (e.g. `postgres:::transaction-start`)
- Turned out to let us inspect dynamic languages such as Java, Ruby, JavaScript, Python, Perl, PHP

DTrace for Rust

- Rust generates binaries that look very much like binaries from C or C++
- We can use the same DTrace facilities for dynamic instrumentation to look at them!

Let’s trace!

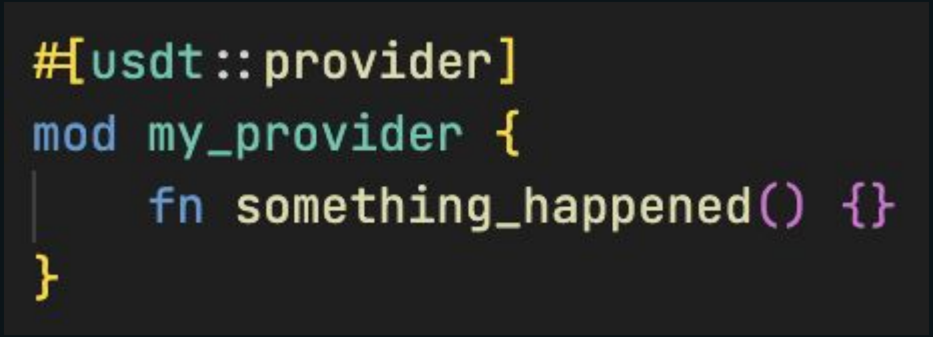
Adding USDT probes to Rust code

- Use the `usdt` crate

```
$ cargo add usdt
```

- Written by me and my Oxide colleague, Ben Naecker
- At Oxide we use this **everywhere**!
- Where to add probes?
  - Where you log
  - Points of interest
  - Before and after actions whose latency you might want to measure
  - …

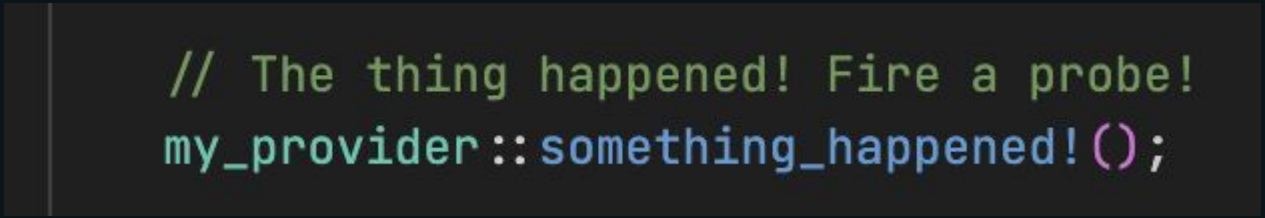
Define your provider



```rust
#[usdt::provider]
mod my_provider {
    fn something_happened() {}
}
```

Note: you'll generally want this at the crate root i.e. main.rs or lib.rs.

Invoke the probe in your code

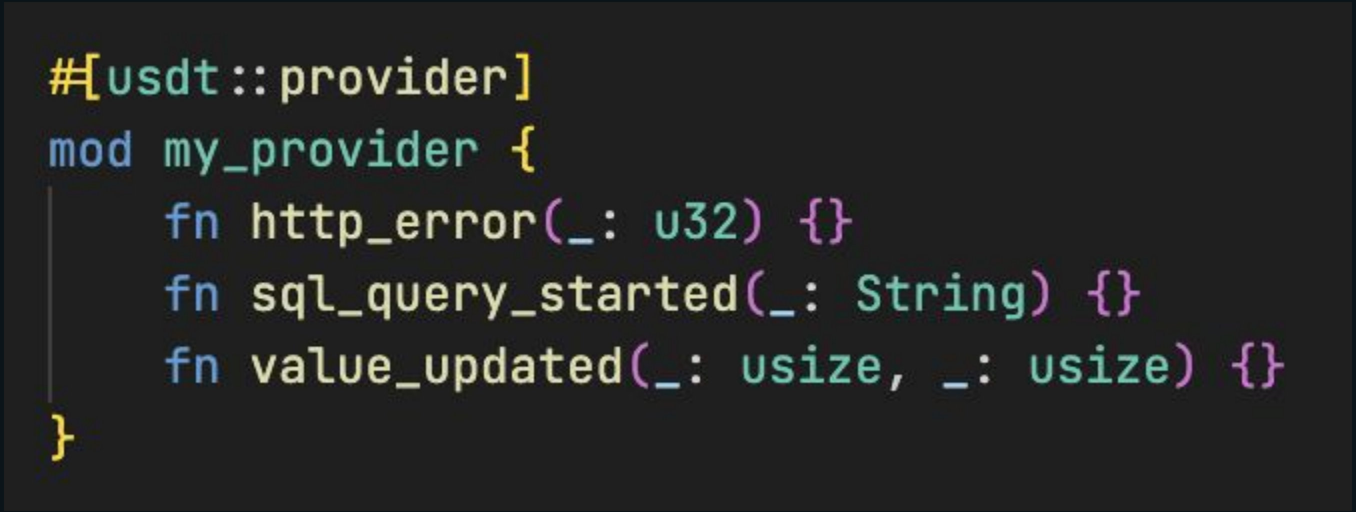


```
// The thing happened! Fire a probe!
my_provider::something_happened!();
```

Neat! But only starting to be useful…

ADVANCED CONTENT:
A macro just output another macro and no one even blinked

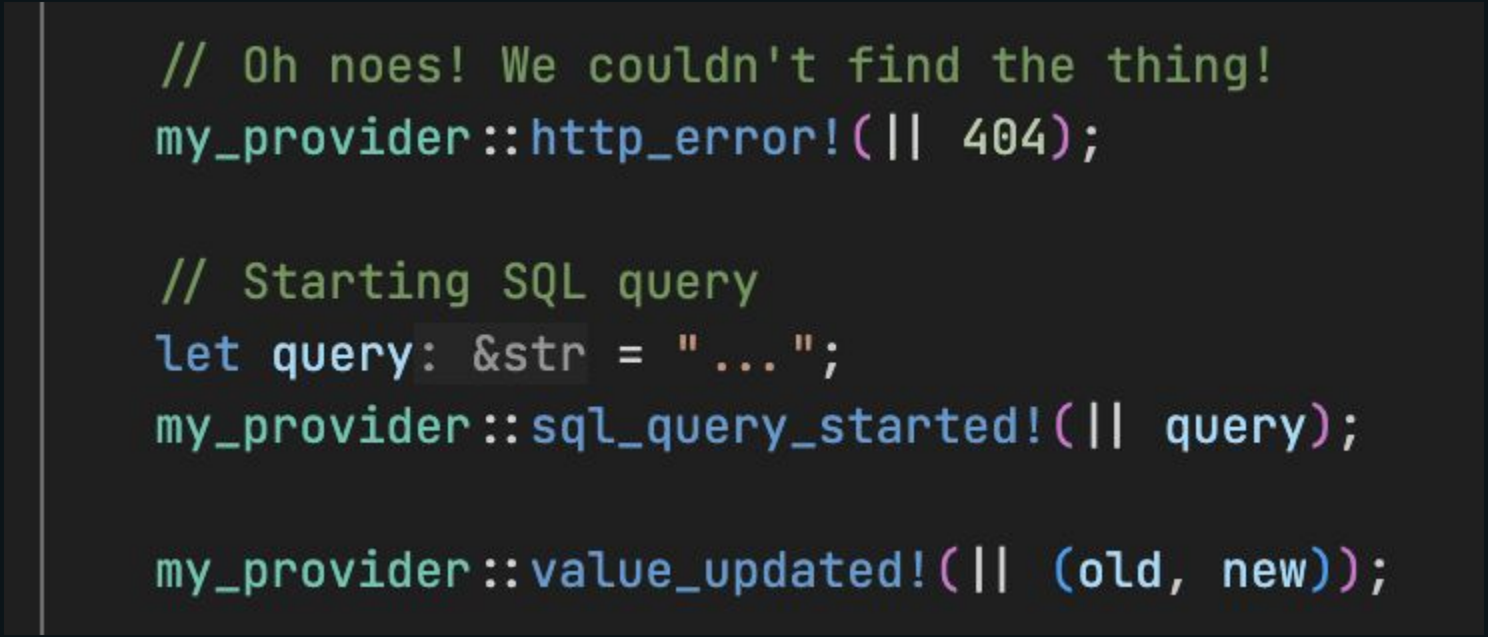
Adding arguments



```
#[usdt::provider]
mod my_provider {
    fn http_error(_: u32) {}
    fn sql_query_started(_: String) {}
    fn value_updated(_: usize, _: usize) {}
}
```

Integral and string types are straightforward

Probes with arguments


```rust
// Oh noes! We couldn't find the thing!
my_provider::http_error!(|| 404);

// Starting SQL query
let query: &str = "...";
my_provider::sql_query_started!(|| query);

my_provider::value_updated!(|| (old, new));
```

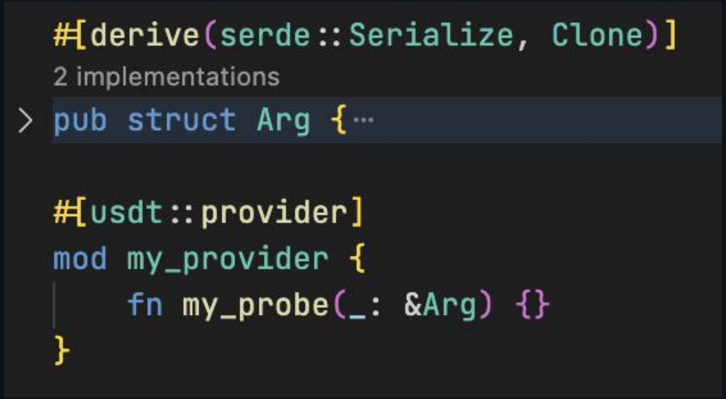
Note: invoke with a closure that returns the values to be traced.

More arguments

- Wait, why do probes take closures rather than the actual arguments?
- Good question! First, let’s look at arguments that aren’t just strings and numbers
- We can pass in value of any type that implements `serde::Serialize`

- Why `Serialize`? Hold that thought…

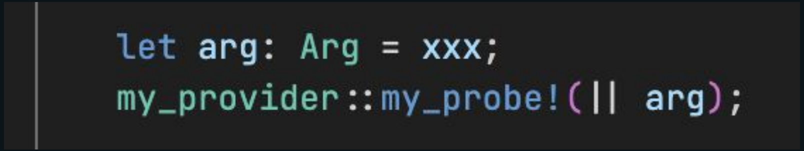
Probes with more complex arguments



```
#[derive(serde::Serialize, Clone)]
2 implementations
> pub struct Arg {…

#[usdt::provider]
mod my_provider {
    fn my_probe(_: &Arg) {}
}
```

Invoke the probe as before:



```
    let arg: Arg = xxx;
    my_provider::my_probe!(|| arg);
```

Consuming USDT probes in DTrace

- DTrace probes have arguments named arg0, arg1, arg2, …

```
# dtrace -n 'my_provider*:::http_error{ trace(arg0); }'
dtrace: description 'my_provider*:::http_error' matched 0 probes
CPU     ID                    FUNCTION:NAME
  1 521333 _ZN9test_usdt4main17h4f231f0987428b4bE:http_error        404
```

Strings are in userland so we need to copy them in

```
# cat sql.d
my_provider*:::sql_query_started
{
    trace(copyinstr(arg0));
}

# dtrace -s sql.d
dtrace: script 'sql.d' matched 0 probes
CPU     ID                    FUNCTION:NAME
  1   3106 _ZN9test_usdt4main17h4f231f0987428b4bE:sql_query_started
                   SELECT * FROM data
```

Tracing complex types

- Recall that more complex types need to impl serde::Serialize
- The probe invocation serializes the value to JSON
- DTrace's built-in `json()` function lets us navigate the serialized structure
- Serialization is fallible so there are top-level properties `ok` or `err`

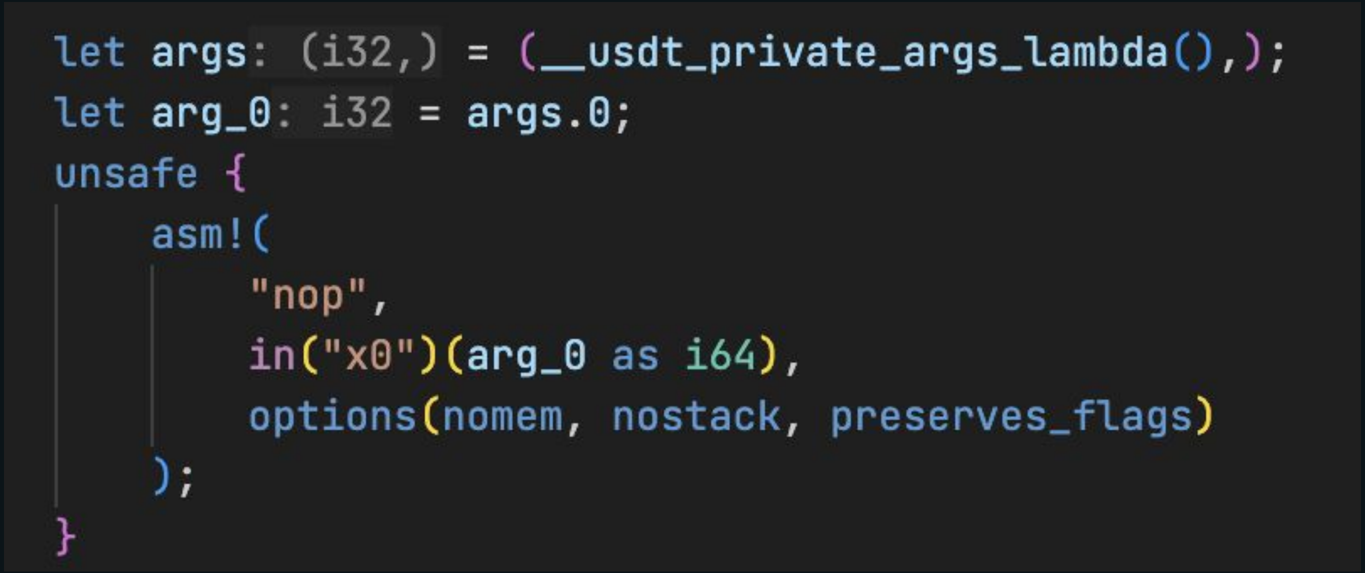
```
# cat complex.d
my_provider*:::my_probe
{
    trace(json(copyinstr(arg0), "ok.val"));
}
# dtrace -s complex.d
dtrace: script 'complex.d' matched 0 probes
CPU     ID                    FUNCTION:NAME
 13   4693 _ZN9test_usdt4main17h4f231f0987428b4bE:my_probe   7
```

Ew… gross.

- Hard otherwise to convey complex structure into DTrace
- JSON is, broadly, the interchange we’ve settled on (for good or ill)
- The probe macros (generated by the provider macro) encapsulate quite a bit of complexity
- Tricky to make these probes have zero disabled probe-effect (zero-cost abstractions)

ADVANCED CONTENT

Expanding a probe macro (simple)

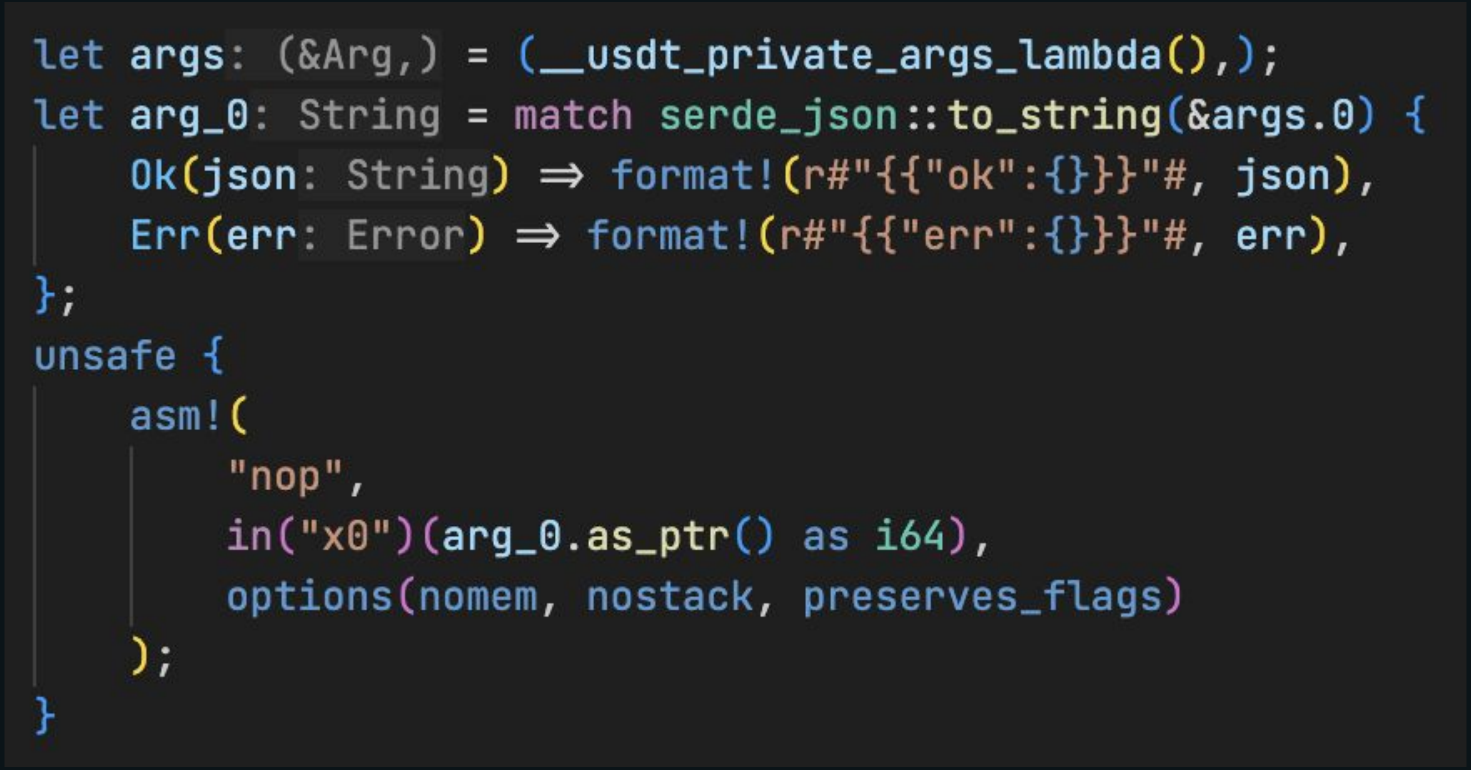


```
let args: (i32,) = (__usdt_private_args_lambda(),);
let arg_0: i32 = args.0;
unsafe {
    asm!(
        "nop",
        in("x0")(arg_0 as i64),
        options(nomem, nostack, preserves_flags)
    );
}
```

DTrace replaces the `nop` with a trap when enabled

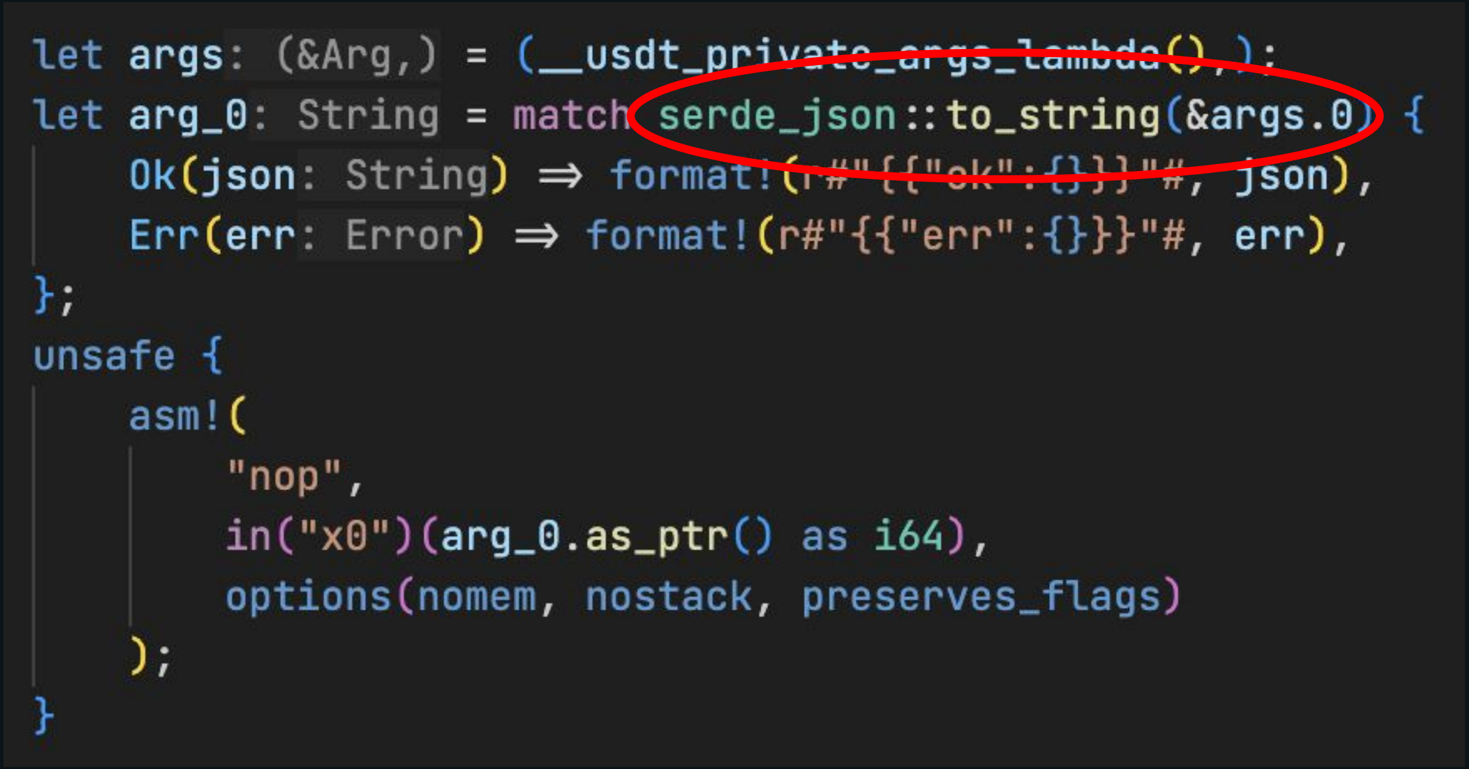
* Some non-code details elided

Expanding a probe macro (complex)



```rust
let args: (&Arg,) = (__usdt_private_args_lambda(),);
let arg_0: String = match serde_json::to_string(&args.0) {
    Ok(json: String) => format!(r#"{{"ok":{}}}"#, json),
    Err(err: Error) => format!(r#"{{"err":{}}}"#, err),
};
unsafe {
    asm!(
        "nop",
        in("x0")(arg_0.as_ptr() as i64),
        options(nomem, nostack, preserves_flags)
    );
}
```

Expanding a probe macro (complex)



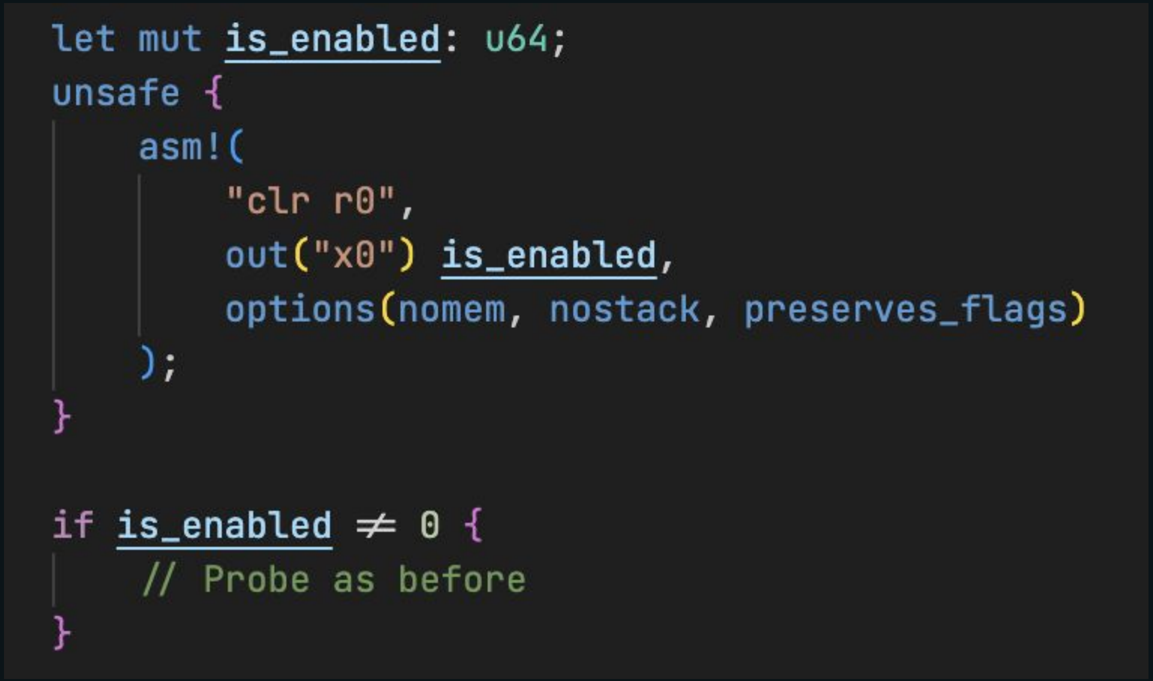
```rust
let args: (&Arg,) = (__usdt_private_args_lambda(),);
let arg_0: String = match serde_json::to_string(&args.0) {
    Ok(json: String) ⇒ format!(r#"{{"ok":{}}}"#, json),
    Err(err: Error) ⇒ format!(r#"{{"err":{}}}"#, err),
};
unsafe {
    asm!(
        "nop",
        in("x0")(arg_0.as_ptr() as i64),
        options(nomem, nostack, preserves_flags)
    );
}
```

Is-enabled probes

- Back in time, back in C, we had a similar problem
- What if the arguments to probes were expensive to compute?
- We came up with a new kind of dynamic instrumentation
- Rather than trap into the kernel, change the flow of code

```
if my_probe_is_enabled() {
    // calculate expensive arguments
    fire_my_probe(expensive arguments)
}
```

In Rust



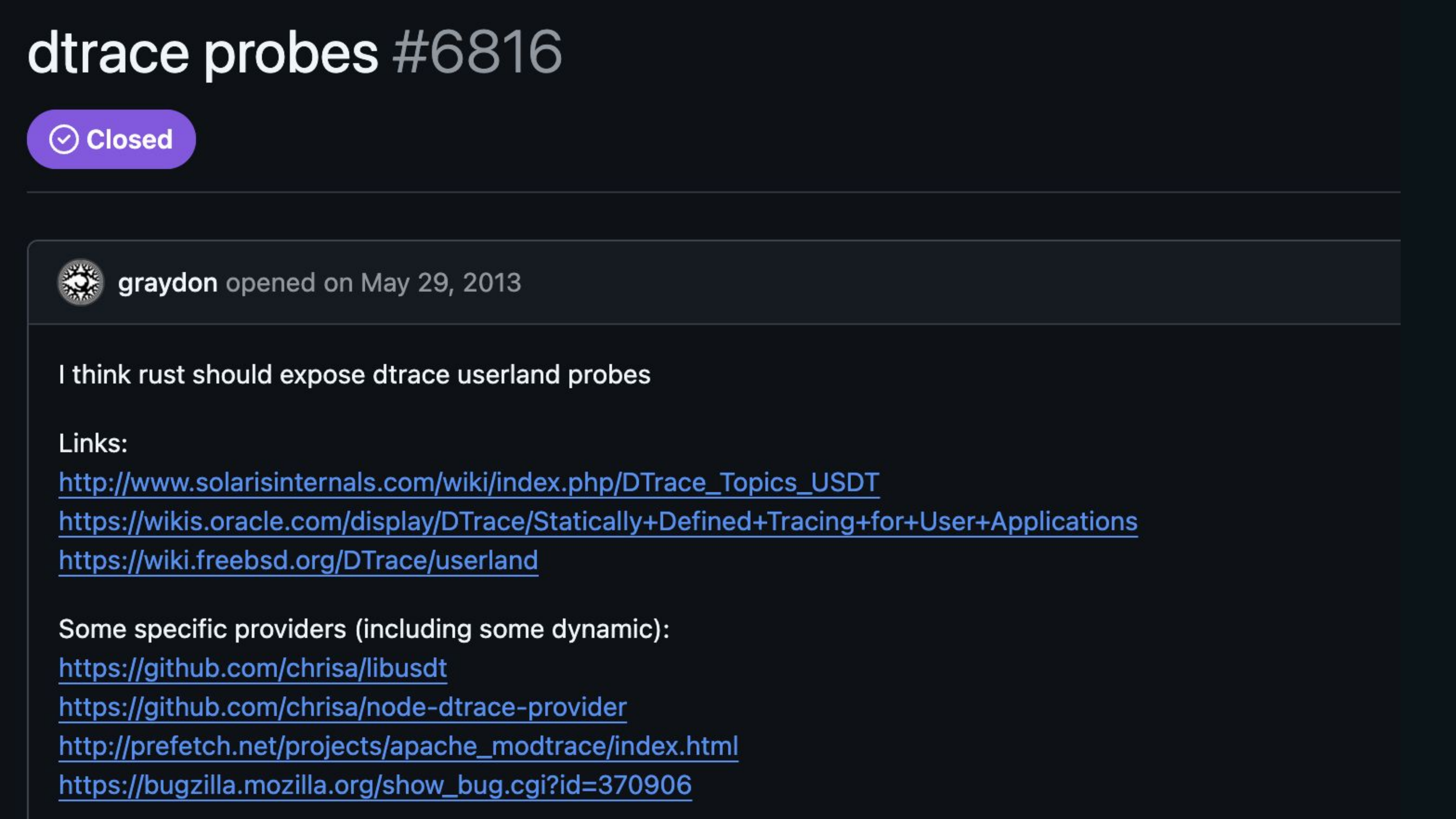
```rust
let mut is_enabled: u64;
unsafe {
    asm!(
        "clr r0",
        out("x0") is_enabled,
        options(nomem, nostack, preserves_flags)
    );
}

if is_enabled ≠ 0 {
    // Probe as before
}
```

This time, DTrace replaces the `clr` with a instruction that sets the register to 1

Good news!

- Fortunately, we don’t have to worry about that!
- That’s the power of zero-cost abstractions
- Probe arguments are closures to remind us that they might not be invoked!
- Rust lets us encapsulate that complexity…
- (at least, mostly …)
- … and add probes liberally



dtrace probes #6816

Closed

graydon opened on May 29, 2013

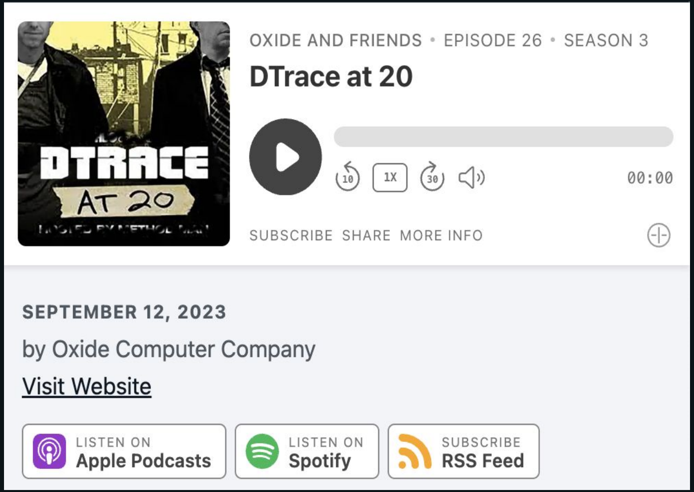
I think rust should expose dtrace userland probes

Links:
http://www.solarisinternals.com/wiki/index.php/DTrace_Topics_USDT
https://wikis.oracle.com/display/DTrace/Statically+Defined+Tracing+for+User+Applications
https://wiki.freebsd.org/DTrace/userland

Some specific providers (including some dynamic):
https://github.com/chrisa/libusdt
https://github.com/chrisa/node-dtrace-provider
http://prefetch.net/projects/apache_modtrace/index.html
https://bugzilla.mozilla.org/show_bug.cgi?id=370906

Go forth, and DTrace

- Running on a system with DTrace?
- Think about adding probes with the usdt crate
- Next time you want to inspect a system at runtime, think about dynamic tracing rather than kill/println!/build/deploy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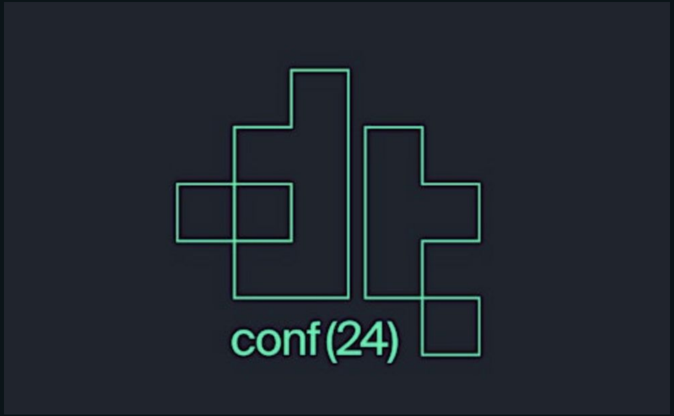

Thanks!

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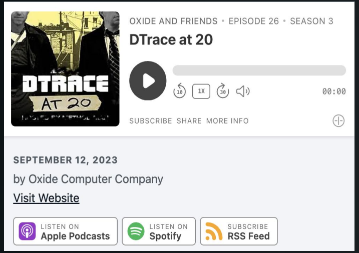
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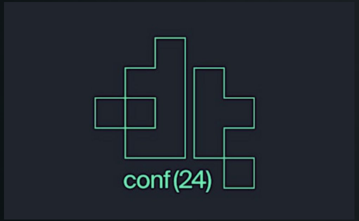

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