stapdyn: Porting SystemTap onto Dyninst

Josh Stone & David Smith
Performance Tools @ Red Hat
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systemtap

stapdyn: Porting SystemTap onto Dyninst

- Motivation for porting to Dyninst
- Overview of SystemTap operation
- Porting all the probe types
- Porting the runtime and tapset
- Wish list for Dyninst

Motivation

- User Privilege
  - Attach to one's own processes freely
  - No setuid helper necessary
- Performance
  - Run instrumentation directly
- Stability
  - We always strive for probe safety, but...
  - Only participating processes are at risk

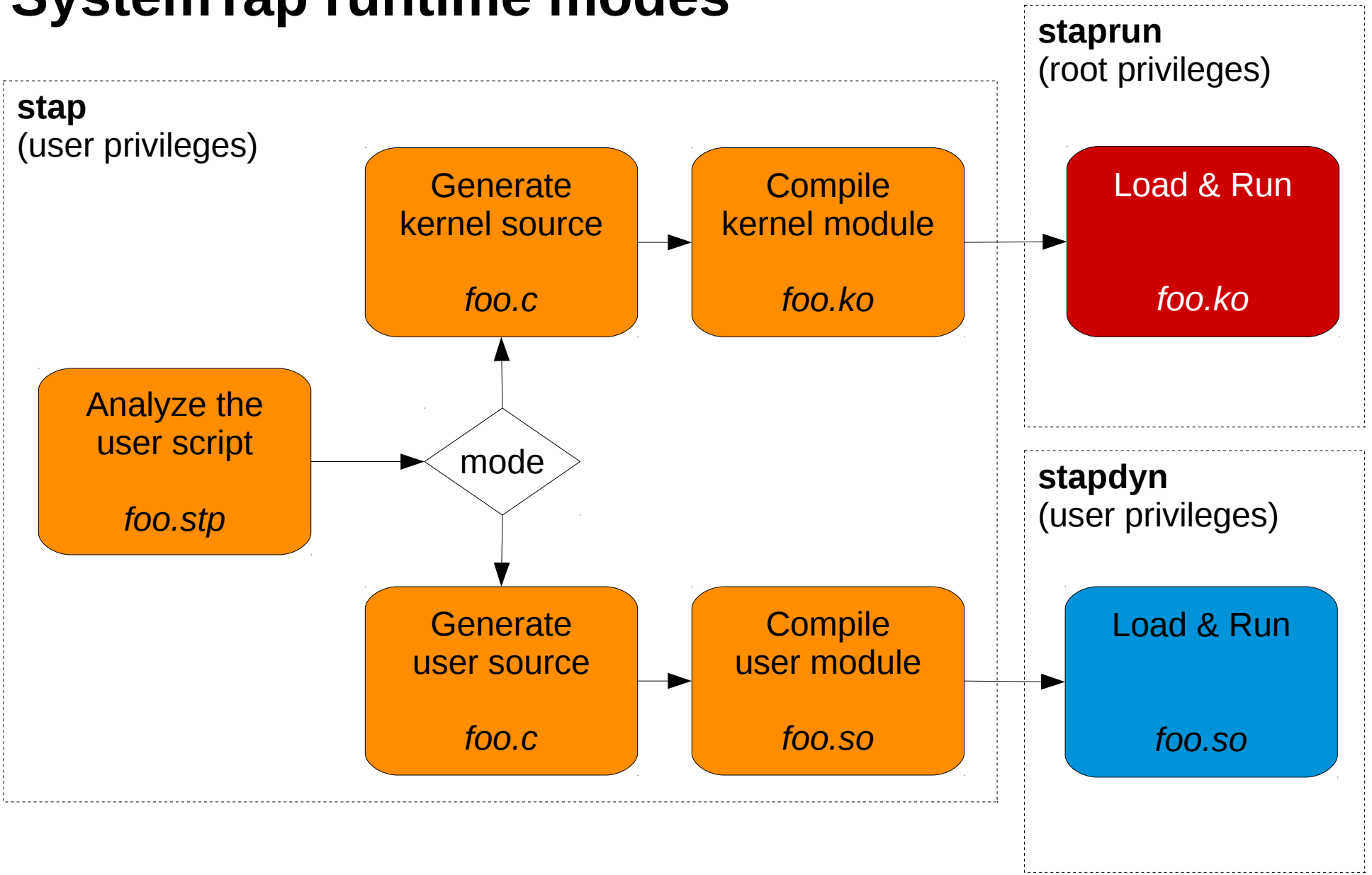
Anatomy of a SystemTap script

```
global foo

function total(p, n) {
  return (foo[p] += n)
}


probe process.function("foo") {
  t = total(pid(), $var->member)
  if (t > 1000)
    printf("%s(%d) total %d\n",
        execname(), pid(), t)
}
```

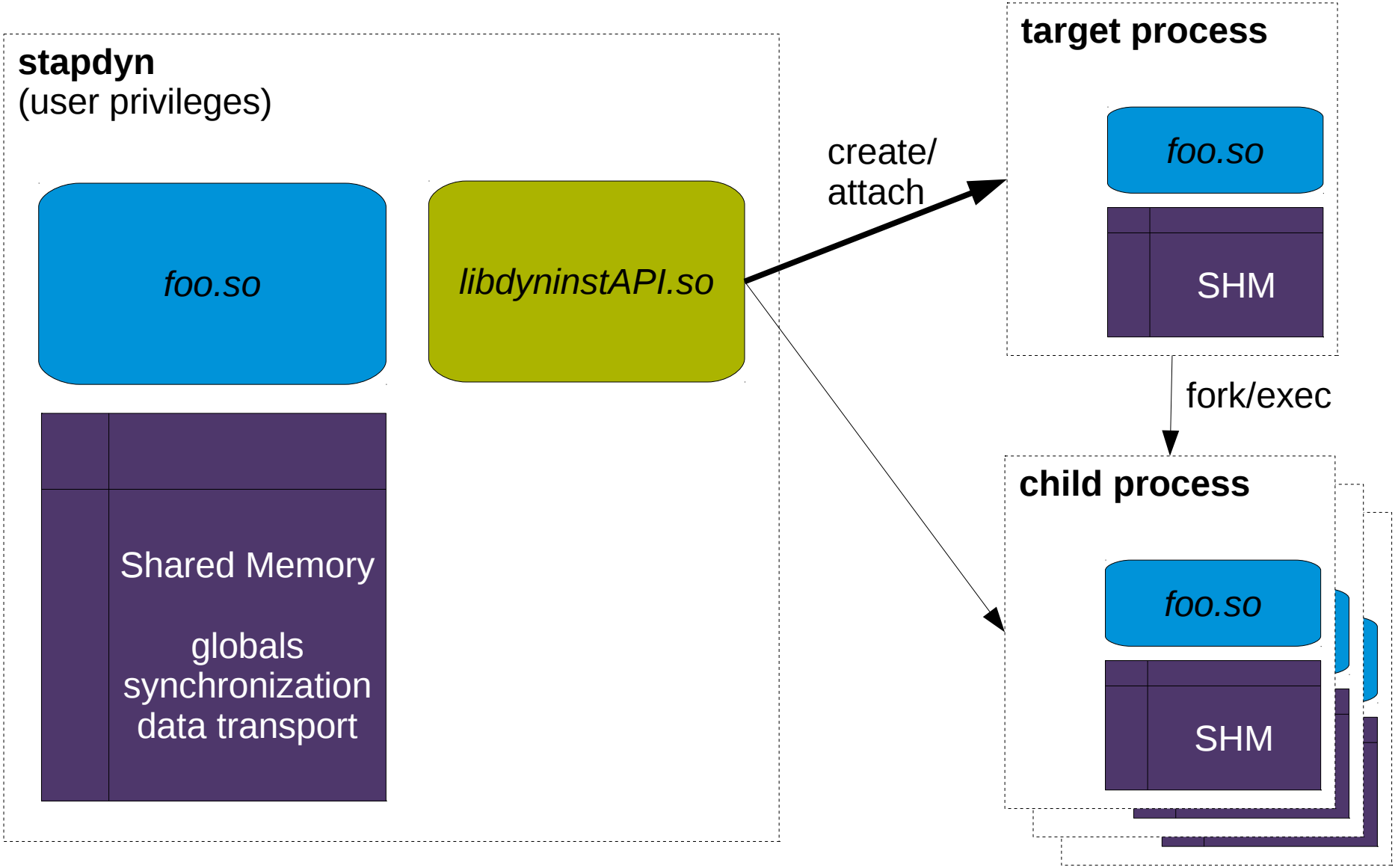
SystemTap runtime modes



Contents of a generated module

- Every compiled “foo.so” contains:
  - Metadata describing the probe types and locations
  - Instrumentation entry functions for each probe type
  - Code for the user's functions and probe handlers
  - Runtime code for shared memory, data output, etc.

High-level view of stapdyn



Probe implementations

Examples of different probe points
in **Kernel** and **Dyninst** modes

Probe the beginning and end of everything

```
begin end error
```

Kernel

- Called directly in-kernel
- Runs when the module loads and unloads

Dyninst

- Called directly in stapdyn
- Runs when stapdyn starts and finishes

Probe a specific process address

```
process.function[.call|.inline]
process.statement process.mark
```

Kernel

- Uses uprobes
  - Inserts a breakpoint
- Runs in the process' context, but transitions to ring-0

Dyninst

- Direct instrumentation
  - `fileOffsetToAddr()`
  - `insertSnippet()`
- Runs in-process, no ring or context switches at all

Probe when a function returns

`process.function.return`

Kernel

- Uses uretprobes
  - Breakpoint on entry
  - Replaces stack PC with a “trampoline” location
- Runs in the process' context, but transitions to ring-0, twice

Dyninst

- Direct instrumentation
  - `fileOffsetToAddr()`
  - `getFunction()`
  - `findPoint(locExit)`
  - `insertSnippet()`
- Runs in-process, no ring or context switches at all

Probe the beginning and end of a process

```
process.begin process.end
```

Kernel

- Uses utrace / tracepoints
  - On all forks and execs, it's an end and a begin
  - On exit, it's just an end
- Runs in the process' context, already ring-0 for kernel setup

Dyninst

- `processCreate()`
- `processAttach()`
- Callbacks for `postFork`, `Exec`, and `Exit`
- RPC `oneTimeCode()`

Probe the beginning and end of a thread

`process.thread.begin` `process.thread.end`

Kernel

- Uses utrace / tracepoints
  - A clone() is a begin
  - A sys_exit, is an end
- Runs in the process' context, already ring-0 for kernel setup

Dyninst

- Uses `threadEvent` callbacks
- RPC `oneTimeCode()`

Probe periodically

`timer.{hz,s,ms,us,ns}`

Kernel

- Uses hrtimers
- Runs in no specific context

Dyninst

- POSIX timer
  - `timer_create()`
- Runs directly in stapdyn

Unimplemented probes

Impossible:

`kernel.*`

`kprobe.*`

`module.*`

`netfilter.*`

`perf.*` (?)

Maybe possible:

`process.syscall`

`timer.profile`

`procfs.*` (similar)

Porting the runtime and tapsets

- Much is shared code, forked for different APIs
  - Userspace APIs are more stable than the kernel's
- Runtime changes locking, shared memory, transport
- Tapset functions also change
  - cpu(): `smp_processor_id()` vs. `sched_getcpu()`
- Most tapset probepoints don't really translate
  - `scheduler.* syscall.* vfs.*`

So far, the userspace code is not really Dyninst-specific

Dyninst wishlist

- Cooperation with exception handling
  - Instrumentation confuses the unwinder
- Fuller register access
  - Currently missing 32-bit x86
  - Direct `pt_regs` would be nice
- Hook system calls (e.g. PTRACE_SYSCALL)
- Support for ARM and AArch64
- Use elfutils' libdw instead of libdwarf

http://sourceware.org/systemtap

systemtap@sourceware.org

Josh Stone <jistone@redhat.com>

David Smith <dsmith@redhat.com>