Collaboration Summit 2013

LTTng-UST: Efficient System-Wide User-Space Tracing

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whoami

- Christian Babeux, Software Developer, EfficiOS,
- Background in embedded and ASIC tools,
- Active contributor to the LTTng projects:
  - lttng-tools & lttng-ust,
  - CI infra, Website, Twitter.
- AUR package maintainer for Arch Linux.

Content

- Overview of LTTng 2.x and UST,
- User-space instrumentation sources,
- Trace format standardisation efforts,
- Tales from a user-space tracer,
- Recent features & future work.

Overview of LTTng 2.x

Overview of LTTng 2.x

- ✓ Unified user interface, API, kernel and user space tracers,

- Trace output in a unified format,

- Low overhead,

- Shipped in distros: Ubuntu, Debian, Suse, Fedora, Linaro, Wind River, etc.

Project overview

Tracers

Utilities

Viewers

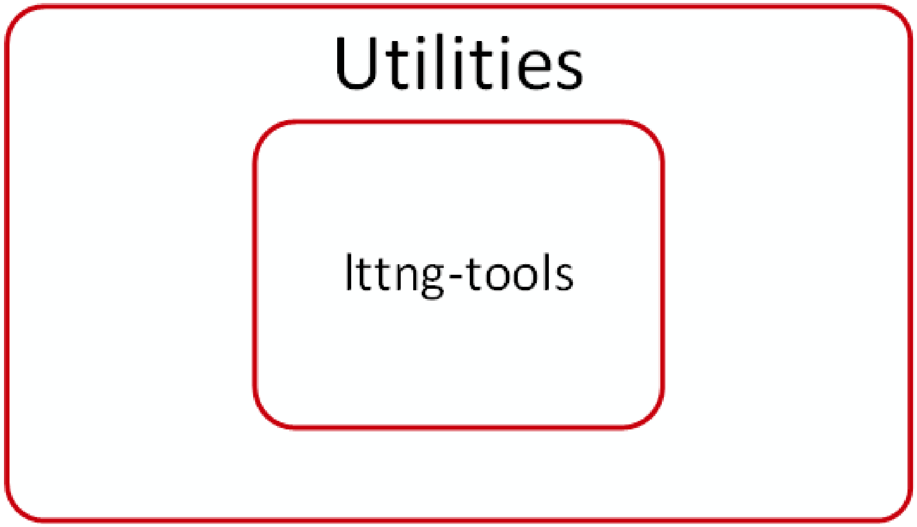
Tracers

lttng-modules
Tracers
lttng-ust

- lttng-modules: kernel tracer module, compatible with kernels from 2.6.38* to 3.9,
- lttng-ust: user-space tracer, in-process library.

* Kernel tracing is now possible on 2.6.32 to 2.6.37 by backport of 3 Linux Kernel patches [1].

Utilities

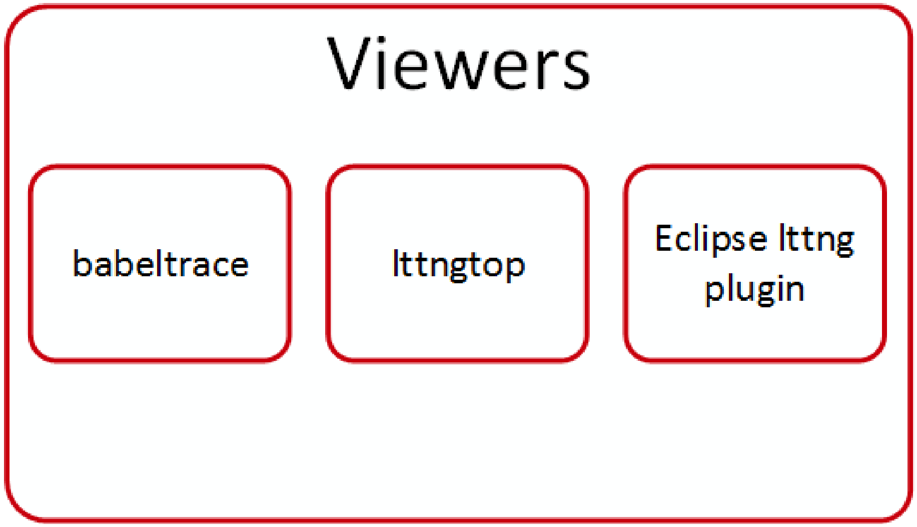


Utilities

lttng-tools

- lttng-tools: cli utilities and daemons for trace control,
  - lttng: cli utility for tracing control,
  - lttng-sessiond: tracing registry daemon,
  - lttng-consumerd: consume trace data,
  - lttng-relayd: network streaming daemon.

Viewers



Viewers

babeltrace

lttngtop

Eclipse lttng plugin

- babeltrace: cli text viewer, trace converter, plugin system,
- lttngtop: ncurse top-like viewer,
- Eclipse lttng plugin: front-end for lttng, collect, visualize and analyze traces, highly extensible.

Overview of LTTng-UST

LTTng-UST – Features

- Pure userspace implementation,
  - Shared memory map between apps and trace consumers,
  - Portable to other OS: BSDs, Cygwin (experimental).

- Optimized for low-overhead, high-throughput [2],
  - Generic kernel ringbuffer ported to userspace,
  - Efficient concurrent data structures for trace control.

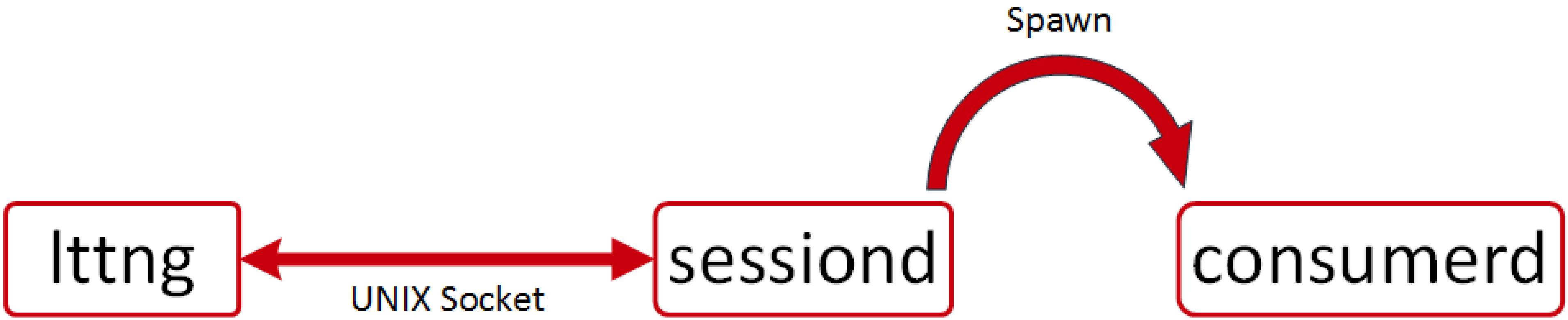
LTTng-UST – Features (cont.)

- Dynamically enabled, statically defined instrumentation,
- Per user tracing and system-wide tracing,
  - Tracing group for system-wide tracing.
- Traces recoverable even after application crash.

LTTng-UST – How does it work?

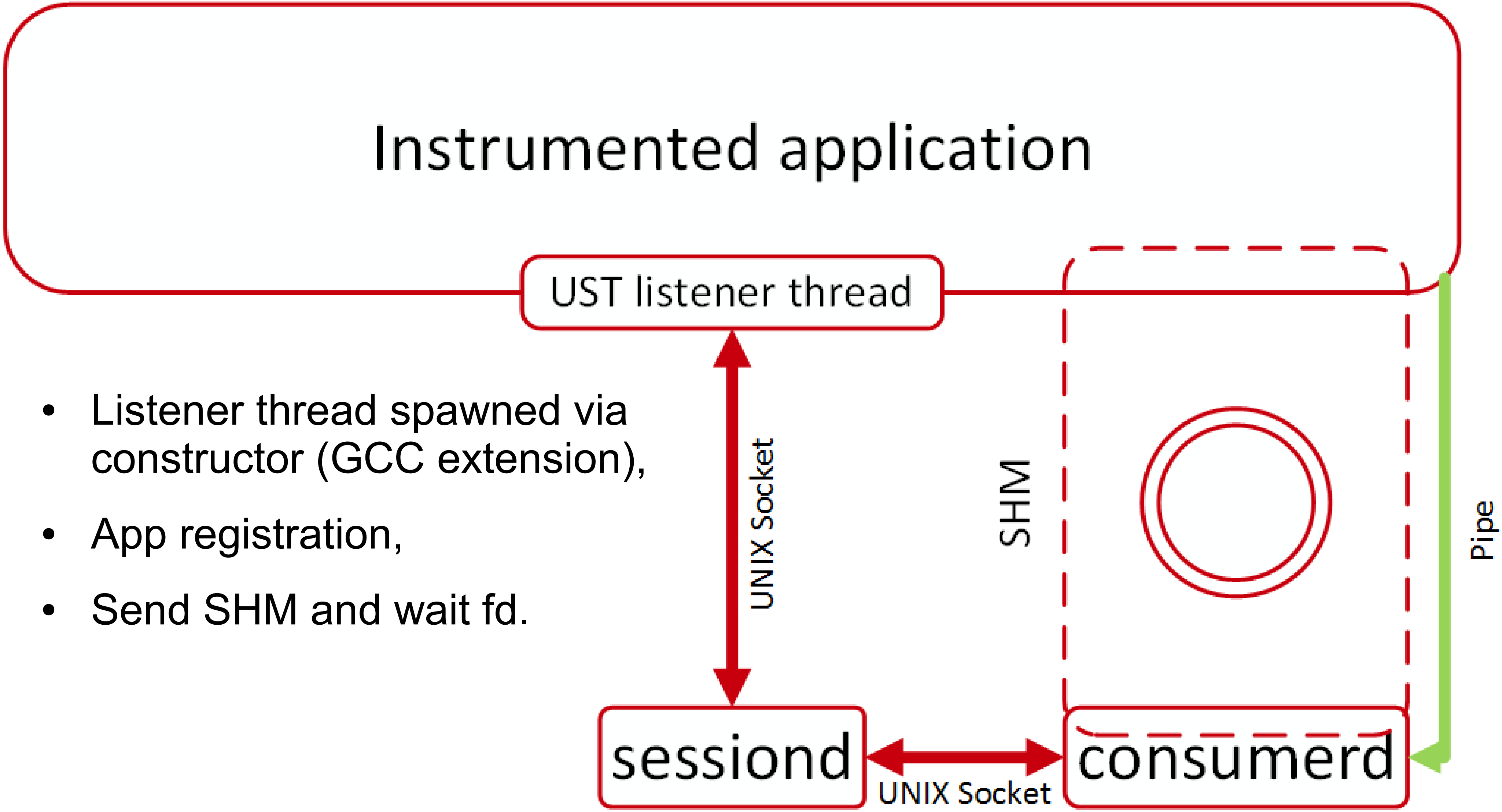
- Users instrument their applications with static tracepoints,
- liblttng-ust, in-process library, dynamically linked with application,
- Session setup, etc.,
- Run app, collect traces,
- Post analysis with viewers.

Tracing session - Setup



Session setup	$ lttng create
User-space event enabling	$ lttng enable-event -u -a
Start tracing	$ lttng start

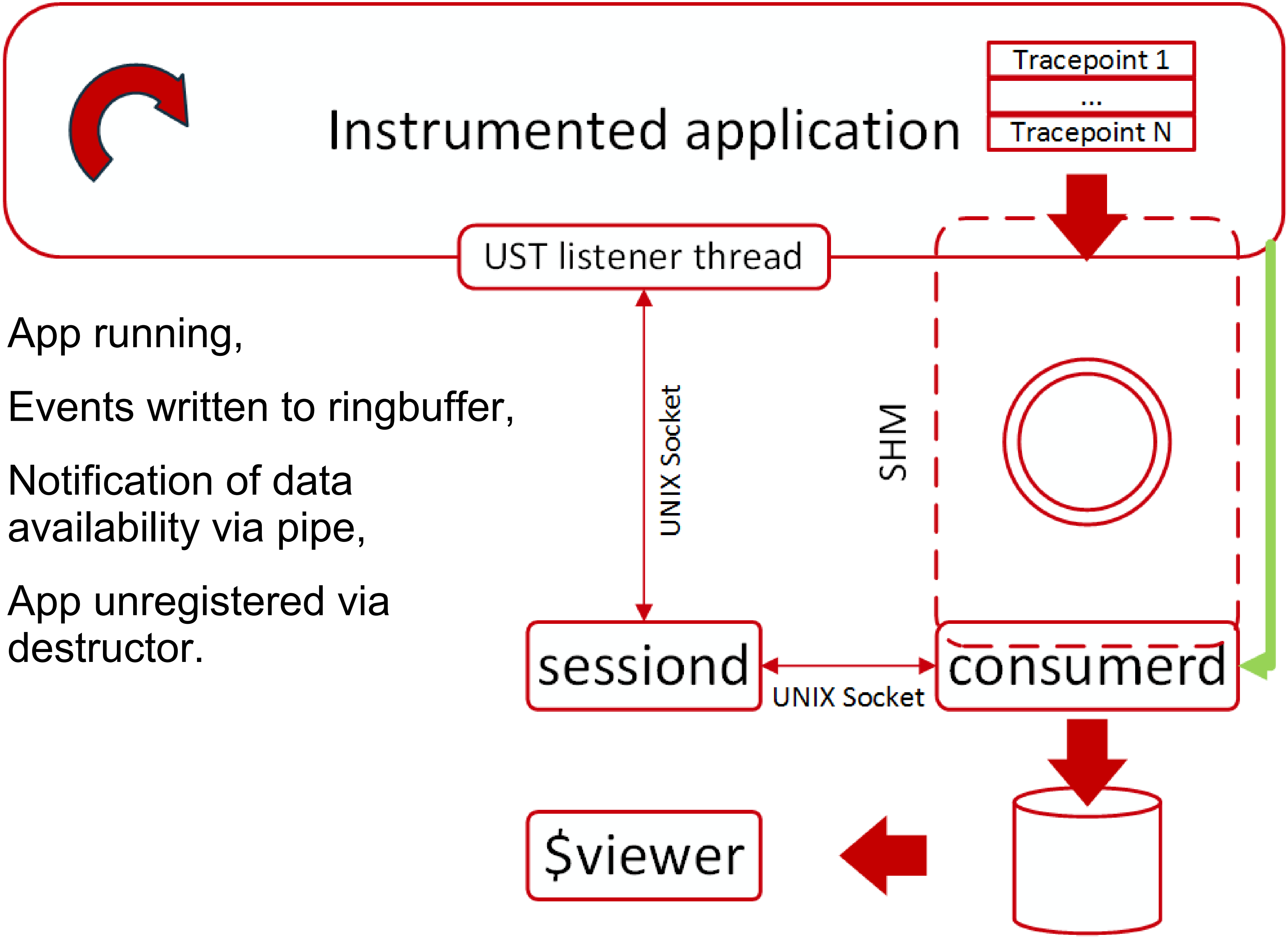
Tracing session - A wild app appears



- Listener thread spawned via constructor (GCC extension),
- App registration,
- Send SHM and wait fd.

Tracing session – App. execution & teardown

- App running,
- Events written to ringbuffer,
- Notification of data availability via pipe,
- App unregistered via destructor.



User-space instrumentation sources

Tracepoints - Declaration

```
TRACEPOINT_EVENT(
    /* Provider name */
    ust_tests_hello,

    /* Tracepoint name */
    tptest,

    /* Type, variable name */
    TP_ARGS(int, anint,
            long *, values,
            float, floatarg),

    /* Type, field name, expression */
    TP_FIELDS(ctf_integer(int, intfield, anint),
              ctf_array(long, arrfield1, values, 3),
              ctf_float(float, floatfield, floatarg))
)
```

Tracepoints - Invocation

```
void function(void)
{
    int i = 0;
    long vals[3] = { 0x42, 0xCC, 0xC001CAFE };
    float flt = M_PI;

    [...]
    tracepoint(ust_tests_hello,
               tptest,
               i,
               &vals,
               flt);
    [...]
}
```

SystemTAP SDT Providers

- Integration result of Collaboration Summit 2011 discussions,

- ✓ Compatibility with SystemTAP SDT,
  - Users can use SystemTAP with tracepoint() instrumented code.

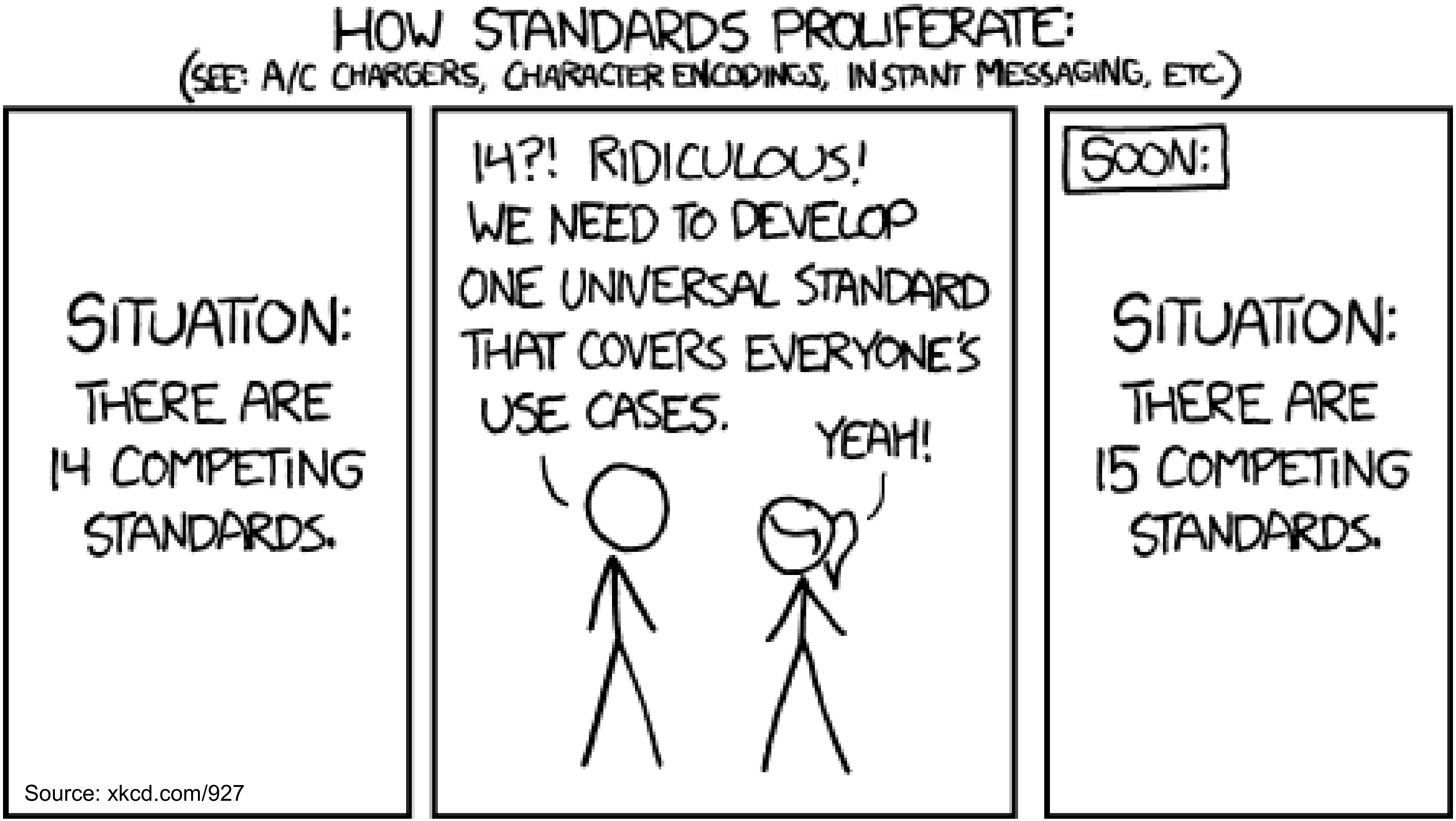
Uprobes

- Kernel patchset merged in 3.5,

- LTTng integration:
  - Initial lttng-modules patchset proposed [4],
  - Need usability improvement
  - Interface not exported by kernel

Trace format standardisation efforts

Trace format standardisation efforts

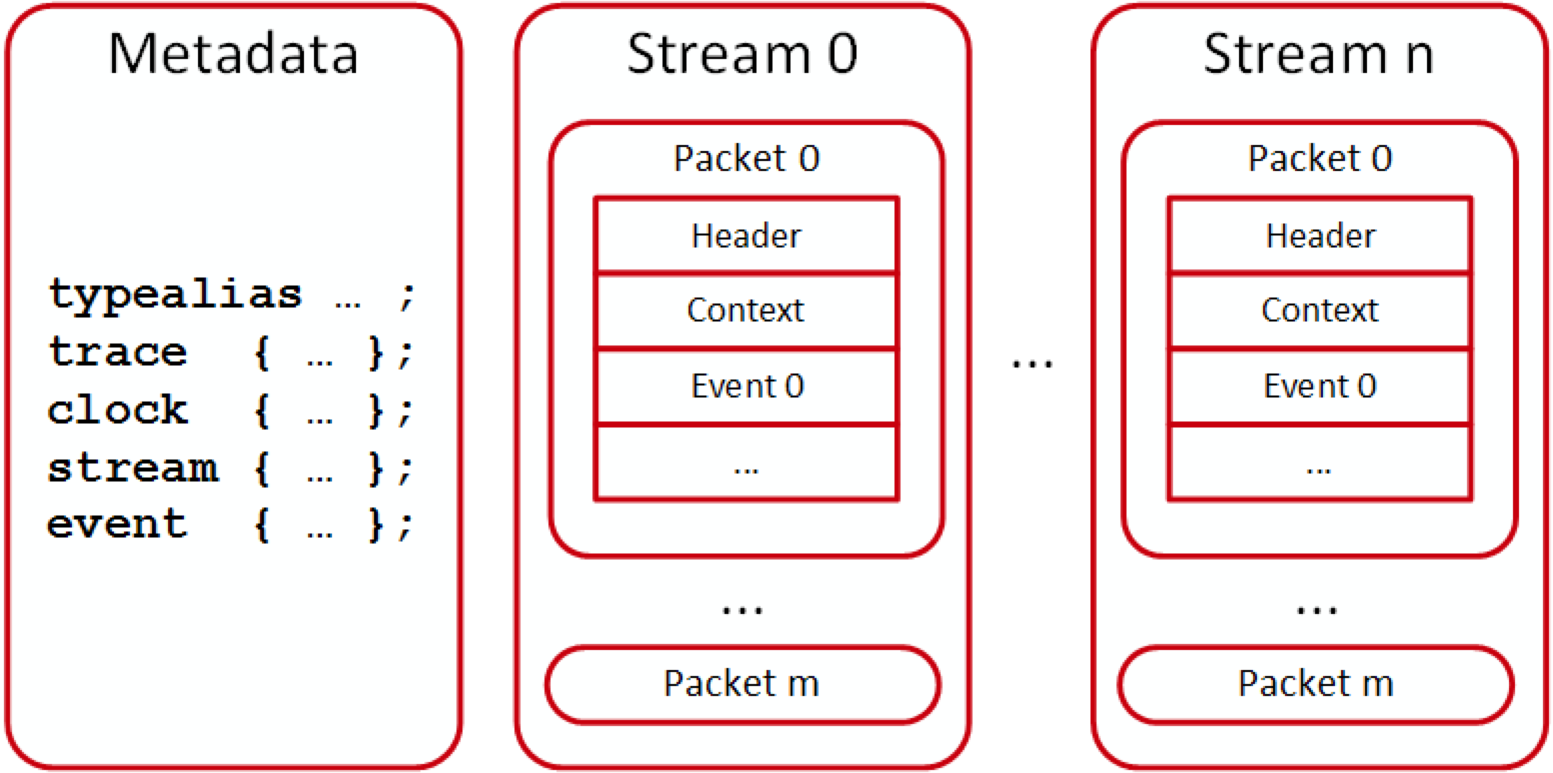

HOW STANDARDS PROLIFERATE:
(SEE: A/C CHARGERS, CHARACTER ENCODINGS, INSTANT MESSAGING, ETC)
SITUATION: THERE ARE 14 COMPETING STANDARDS.
14?! RIDICULOUS! WE NEED TO DEVELOP ONE UNIVERSAL STANDARD THAT COVERS EVERYONE'S USE CASES.
YEAH!
SOON:
SITUATION: THERE ARE 15 COMPETING STANDARDS.

Source: xkcd.com/927

Trace format standardisation efforts

- Joking aside: We need a common open format,
- Collaboration: Multicore Association, Ericsson,
- Goals of the Common Trace Format (CTF):
  - Common format for SW and HW traces,
  - Portable,
  - Compact,
- Tools based on CTF:
  - LTTng 2.x, Babeltrace, Eclipse LTTng plugin
  - GDB (save trace to CTF) [3],
  - Javeltrace

Common Trace Format



Self-described, packet-based format.

Common Trace Format – More info.

“Interoperability Between Tracing Tools with the Common Trace Format”,

- Mathieu Desnoyers at Linux Plumbers 2012 [5]

Common Trace Format (CTF) Specification [6],

Common Trace Format compliance testsuite [7].

Tales from a user-space tracer

Non-intrusive handling of SIGPIPE

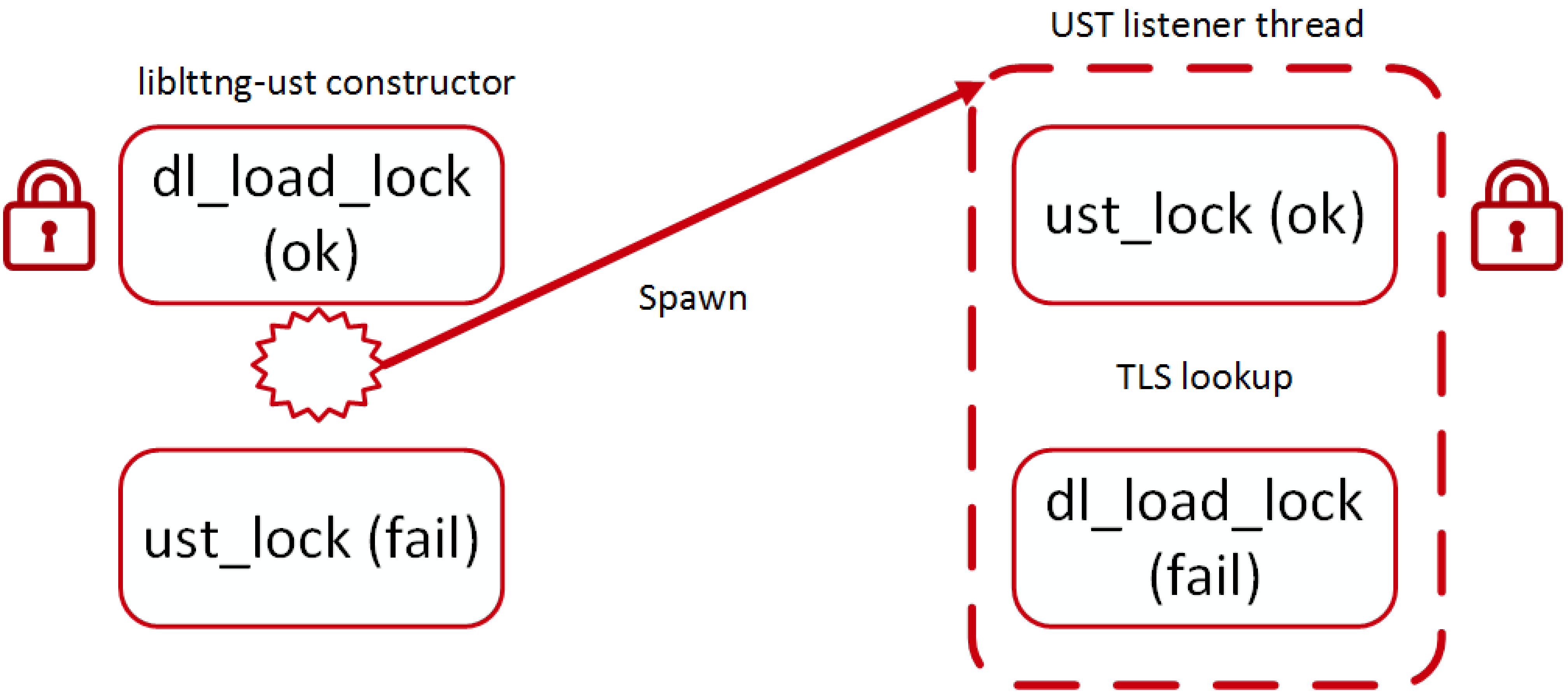
- Ringbuffer delivery notification use a pipe,
  - Traced applications can receive SIGPIPE if consumer end dies abruptly.

- ✖ Suppress SIGPIPE only in our lib without affecting signal handling for the rest of the process [8].

TLS & constructors

- Thread Local Storage (TLS) variable storage in dynamically libs. allocated when first used [9],
- Rely on internal glibc mutex to protect against dynamic linker,
- Same mutex is held while running ctor/dtor,

TLS & constructors (cont.)



liblttng-ust constructor

dl_load_lock (ok)

ust_lock (fail)

Spawn

UST listener thread

ust_lock (ok)

TLS lookup

dl_load_lock (fail)

TLS & constructors (cont.)

- Take mutex within constructors while TLS fixup performed,

⚠ Deadlock!

- Workaround: Force TLS fixup within lib ctor.

Tracing of apps closing all fds

Close all the things

- When daemonizing, some apps close all available fds,

Tracing of apps closing all fds

- When daemonizing, some apps close all available fds,

⚠ No communication == No tracing.

- Fix: None for the moment.

Recent features & future work

Recent features

✓ 2.1 (Basse Messe)

Network streaming over TCP,

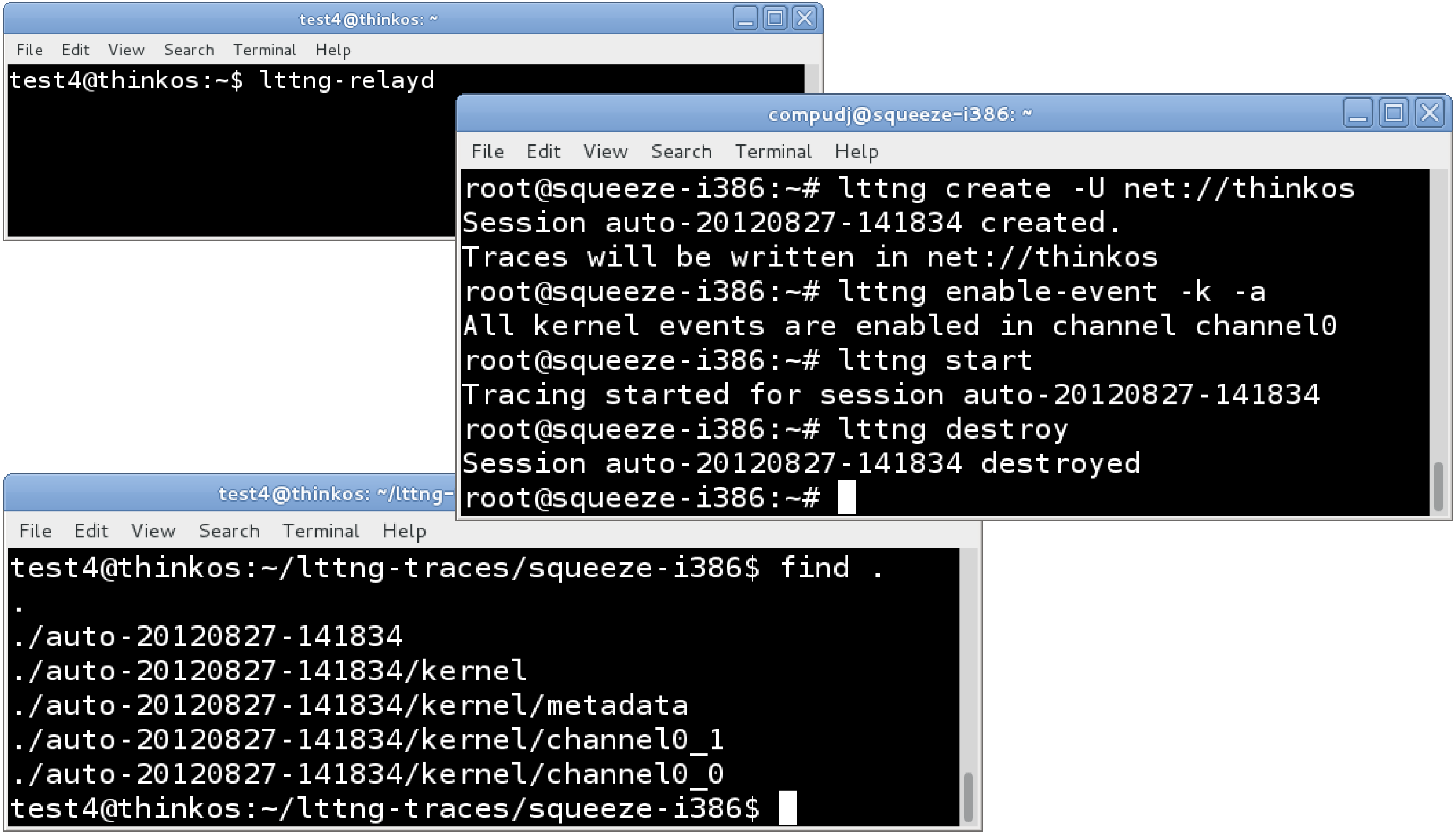
- Introduce lttng-relayd, receive traces from remote consumers.

Filtering before data collection,

- C-like syntax, bytecode interpreter.
- UST only for the moment.

Session daemon health monitoring API.

Network streaming over TCP



test4@thinkos: ~
File Edit View Search Terminal Help

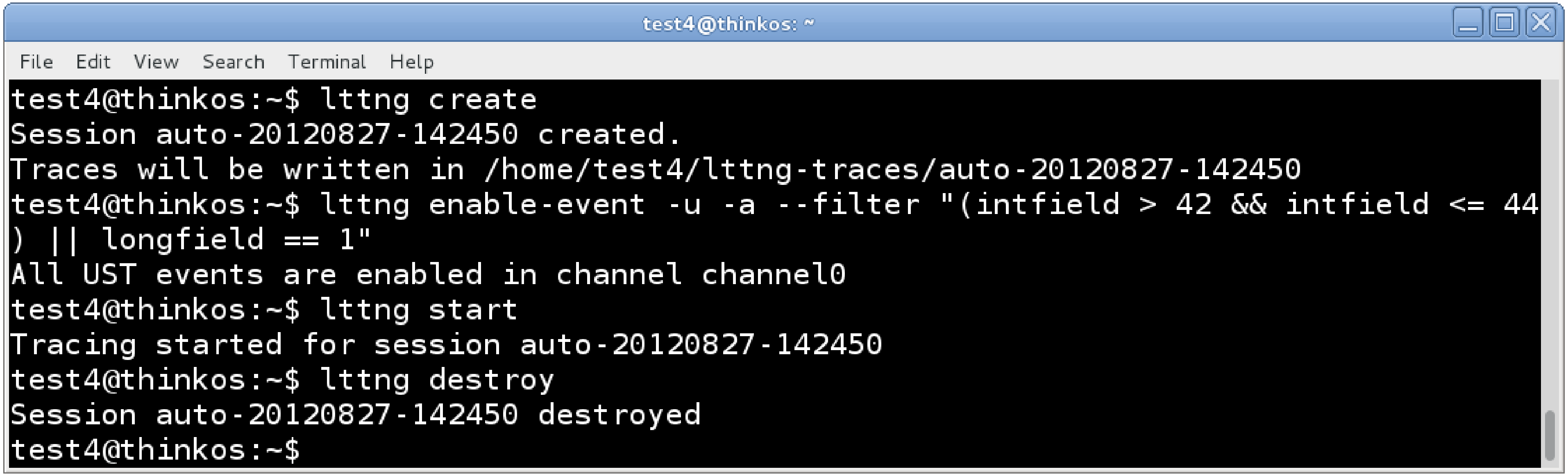
```
test4@thinkos:~$ lttng-relayd
```

compudj@squeeze-i386: ~
File Edit View Search Terminal Help

```
root@squeeze-i386:~# lttng create -U net://thinkos
Session auto-20120827-141834 created.
Traces will be written in net://thinkos
root@squeeze-i386:~# lttng enable-event -k -a
All kernel events are enabled in channel channel0
root@squeeze-i386:~# lttng start
Tracing started for session auto-20120827-141834
root@squeeze-i386:~# lttng destroy
Session auto-20120827-141834 destroyed
root@squeeze-i386:~#
```

```
test4@thinkos:~/lttng-traces/squeeze-i386$ find .
.
./auto-20120827-141834
./auto-20120827-141834/kernel
./auto-20120827-141834/kernel/metadata
./auto-20120827-141834/kernel/channel0_1
./auto-20120827-141834/kernel/channel0_0
test4@thinkos:~/lttng-traces/squeeze-i386$
```

Filtering (1)

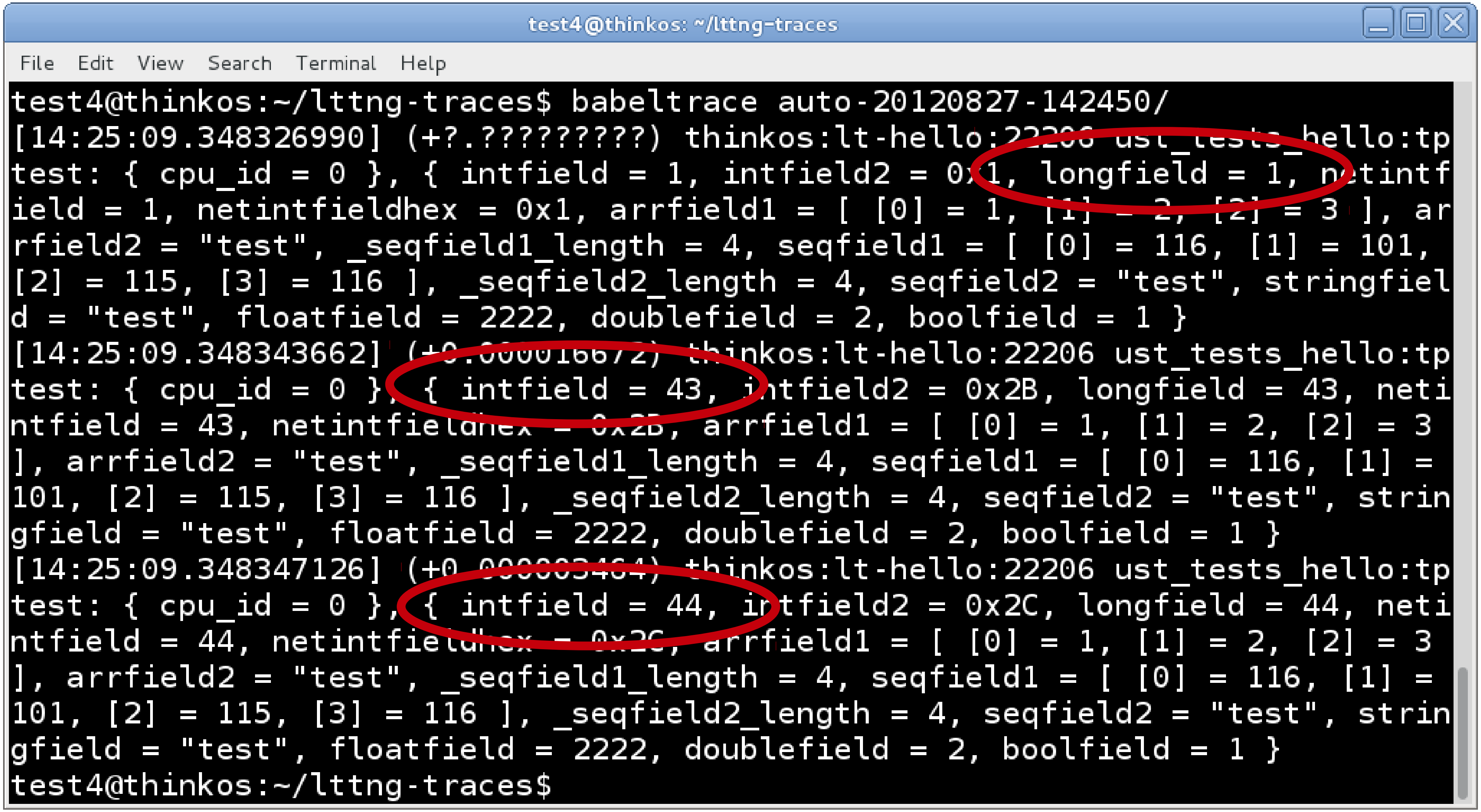


```
test4@thinkos:~$ lttng create
Session auto-20120827-142450 created.
Traces will be written in /home/test4/lttng-traces/auto-20120827-142450
test4@thinkos:~$ lttng enable-event -u -a --filter "(intfield > 42 && intfield <= 44
) || longfield == 1"
All UST events are enabled in channel channel0
test4@thinkos:~$ lttng start
Tracing started for session auto-20120827-142450
test4@thinkos:~$ lttng destroy
Session auto-20120827-142450 destroyed
test4@thinkos:~$
```

Filter:

“(intfield > 42 && intfield <= 44) || longfield == 1”

Filtering (2)


test4@thinkos: ~/lttng-traces
File Edit View Search Terminal Help

```
test4@thinkos:~/lttng-traces$ babeltrace auto-20120827-142450/
[14:25:09.348326990] (+?.?????????) thinkos:lt-hello:22206 ust_tests_hello:tp
test: { cpu_id = 0 }, { intfield = 1, intfield2 = 0x1, longfield = 1, netintf
ield = 1, netintfieldhex = 0x1, arrfield1 = [ [0] = 1, [1] = 2, [2] = 3 ], ar
rfield2 = "test", _seqfield1_length = 4, seqfield1 = [ [0] = 116, [1] = 101,
[2] = 115, [3] = 116 ], _seqfield2_length = 4, seqfield2 = "test", stringfiel
d = "test", floatfield = 2222, doublefield = 2, boolfield = 1 }
[14:25:09.348343662] (+0.000016672) thinkos:lt-hello:22206 ust_tests_hello:tp
test: { cpu_id = 0 }, { intfield = 43, intfield2 = 0x2B, longfield = 43, neti
ntfield = 43, netintfieldhex = 0x2B, arrfield1 = [ [0] = 1, [1] = 2, [2] = 3
], arrfield2 = "test", _seqfield1_length = 4, seqfield1 = [ [0] = 116, [1] =
101, [2] = 115, [3] = 116 ], _seqfield2_length = 4, seqfield2 = "test", strin
gfield = "test", floatfield = 2222, doublefield = 2, boolfield = 1 }
[14:25:09.348347126] (+0.000003464) thinkos:lt-hello:22206 ust_tests_hello:tp
test: { cpu_id = 0 }, { intfield = 44, intfield2 = 0x2C, longfield = 44, neti
ntfield = 44, netintfieldhex = 0x2C, arrfield1 = [ [0] = 1, [1] = 2, [2] = 3
], arrfield2 = "test", _seqfield1_length = 4, seqfield1 = [ [0] = 116, [1] =
101, [2] = 115, [3] = 116 ], _seqfield2_length = 4, seqfield2 = "test", strin
gfield = "test", floatfield = 2222, doublefield = 2, boolfield = 1 }
test4@thinkos:~/lttng-traces$
```

“(intfield > 42 && intfield <= 44) || longfield == 1”

Recent features (cont.)

✓ 2.2 (Cuda, Currently in RC)

- Per-uid buffers in UST,

- Context filtering,
  - '$ctx.procname == “demo*”',
  - '$ctx.vpid > 9000'.

- Trace file size limits,

Future work

- ✈ Flight recorder mode tracing (2.3),

- ϟ Trace data extracted on core dump (2.3),

- ☕ Java tracing.

Future work (cont.)

- Tracer triggers actions on specific events & filters
- Compressed, encrypted streaming and storage,
- LTTng accepted in Google Summer of Code [10].
  - Dynamic instrumentation support in UST,
  - Android port.

Conclusion

✓ Usability of user space tracing in production

Questions ?

?

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References

- [1] – Userspace tracing in small footprint devices – Jason Wessel
- [2] – lttng-modules README -
- [3] – [lttng-dev] [lttng-modules PATCH] Add uprobes support – Yannick Brosseau
- [4] – [PATCH v3 00/15] CTF Support – Yao Qi
- [5] - "Interoperability Between Tracing Tools with the Common Trace Format" - Mathieu Desnoyers , Linux Plumbers 2012
- [6] - Common Trace Format (CTF) Specification
- [7] - Common Trace Format compliance testsuite
- [8] – LTTng-UST – 2C44F5B9 - Fix UST SIGPIPE handling
- [9] – ELF Handling for Thread-Local Storage – Ulrich Drepper (page 8)
- [10] – LTTng GSoC 2013 Ideas list