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LTTng: The road to container awareness

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Who am I?

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What's LTTng?

- 2 tracers
  - Kernel : lttng-modules
  - Userspace : lttng-ust
- A trace format : CTF
- A common cli tool / library : lttng-tools
- A cli trace reader : babeltrace
- Multiple graphical trace readers

Why LTTng?

- Low overhead
- Combined kernel and userspace tracing
- Can be enabled / disabled at runtime
- Flexible storage usage
  - Network streaming
  - In memory ringbuffers

What’s a Linux container?

- There is no canonical concept of a container in the kernel
- Multiple implementations like Docker, rkt, LXD and many others
- All based on kernel namespaces, cgroups and other isolation and security systems

Current status

- The kernel tracer can be used on the host
  - No way to filter events per-container
- The userspace tracer can be used on the host and in the containers
  - One lttng instance on the host
  - One lttng instance per container
  - No context information to correlate traces between the host and the containers

What can we fix now?

- Add namespaces support to the kernel tracer
  - Add a context for each namespace type
  - Add namespace information to the statedump
- Build simple userspace statedump providers for container runtimes to do container-to-namespace mapping
- Add per-container views to current kernel analyses

Let’s write some patches

- Experimental tracer branches with a minimum viability implementation of the ns contexts and statedump
- Experimental lttng-tools branch with per context filtering
- A simple shellscript based container runtime statedump for Docker and LXD
- Experimental lttnganalyses branch with a per-container cputop and memtop analyses

Kernel Tracer

- Add a context for each namespace type
  - pid, user, cgroup, ipc, mnt, net, uts
- Add namespaces to the process statedump
  - Include hierarchical information for the nested namespace types (pid and user)

Kernel Tracer NS Contexts

- Syscalls and other kernel events with namespace contexts
  - tid: The unique process id on the host
  - vtid: The process id specific to this namespace
  - pid_ns: A unique identifier for this process pid namespace
- With this information, we can group processes into containers and do host to container process id mapping

```
[15:54:15.216386600] (+0.000006785) ns-contexts
syscall_entry_gettimeofday: { cpu_id = 1 }, { procname = "redis-server",
pid = 11734, vpid = 1, tid = 11734, vtid = 1, ppid = 11714, cgroup_ns =
4026531835, ipc_ns = 4026532571, net_ns = 4026532574, pid_ns =
4026532572, user_ns = 4026531837, uts_ns = 4026532570 }, { }
```

Kernel Tracer NS Statedump

- Process statedump events for namespaces
  - The process “tid” is the primary key, it’s unique in the kernel across containers
  - Pid namespace can be nested, one event per level with “ns_level” to track the order

```
[15:54:05.937411441] (+0.000000501) ns-contexts lttng_statedump_process_state:
{ cpu_id = 1 }, { tid = 1527, pid = 1527, ppid = 1353, name = "systemd", type = 0,
mode = 5, submode = 0, status = 5, cpu = 1 }
[15:54:05.937411834] (+0.000000393) ns-contexts
lttng_statedump_process_pid_ns: { cpu_id = 1 }, { tid = 1527, vtid = 1, vpid = 1,
vppid = 0, ns_level = 1, ns_inum = 4026532424 }
[15:54:05.937412212] (+0.000000378) ns-contexts
lttng_statedump_process_pid_ns: { cpu_id = 1 }, { tid = 1527, vtid = 1527, vpid =
1527, vppid = 1353, ns_level = 0, ns_inum = 4026531836 }
```

Userspace Tracer NS Contexts

- Add a context for each namespace type
  - pid, user, cgroup, ipc, mnt, net, uts

Userspace Tracer NS Contexts

- Userspace events with contexts will allow correlation with kernel events in the analyses
  - vtid: Same field in the kernel events, allows to match with system wide process ids
  - pid_ns: Same field in the kernel events, allows per container filtering

```
[22:51:19.896554347] (+1.000484100) master-cheetah ust_tests_hello:tptest: { cpu_id = 1 },
{ procname = "hello", vpid = 27486, vtid = 27486, pid_ns = 4026532298, user_ns =
4026532294 }, { intfield = 1, intfield2 = 0x1 }
```

Filtering Example

- Filter all syscalls from a docker container

```
# Get the pid of the docker container init process
$ pid=$(docker inspect --format '{{.State.Pid}}' my-container)

# Get the pid namespace id from this pid
$ pid_ns=$(lsns -n -t pid -o NS -p ${pid})

# Create a session and add the required contexts
$ lttng create my-container
$ lttng add-context -k -t procname -t pid -t vpid -t tid -t vtid -t
pid_ns

# Enable all the syscalls, filter by pid namespace for my-container
$ lttng enable-event -k --syscall -a --filter=”\$ctx.pid_ns == ${pid_ns}”
```

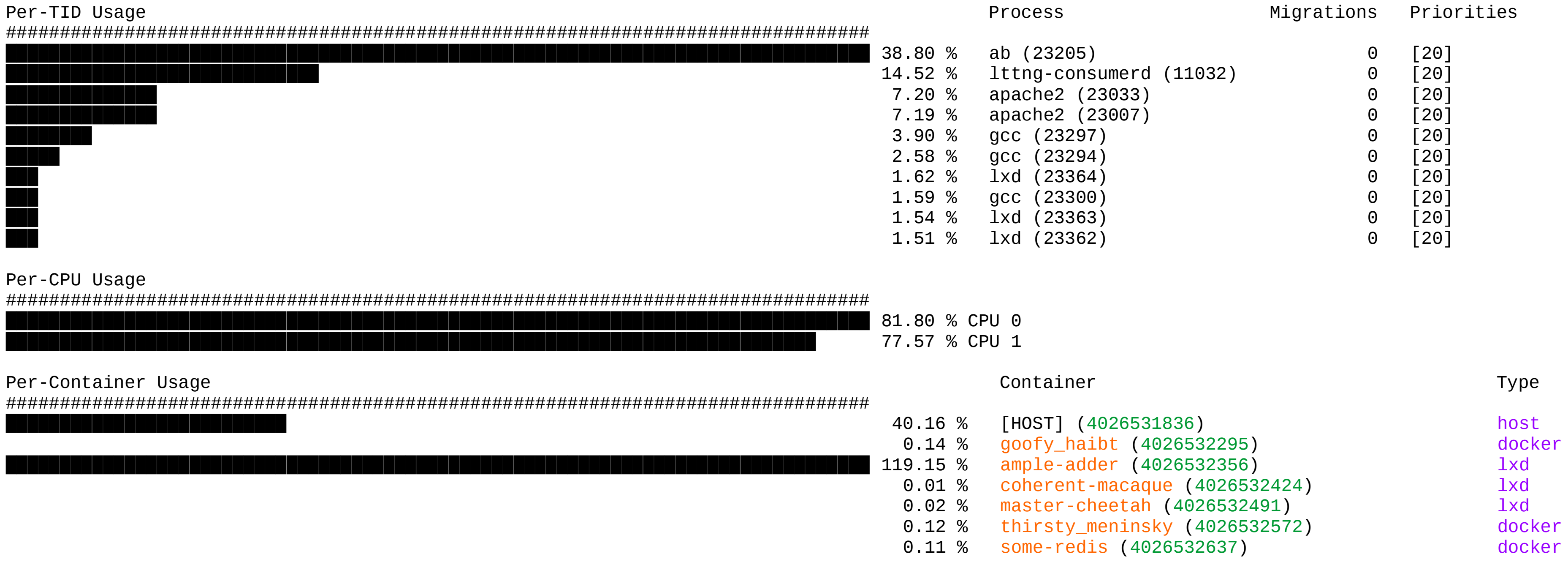
Container Runtimes Statedump

- We need to map the kernel ids to human readable names
- Use small userspace helpers to dump this information
- One implementation per container runtime

```
[15:54:10.128336926] (+0.000000670) ns-contexts
ust_container_statedump:lttng_statedump_container: { cpu_id = 0 }, { container_name = "ample-
adder", container_type = "lxd", pid_ns = 4026532354 }
[15:54:09.700828135] (+0.000000450) ns-contexts
ust_container_statedump:lttng_statedump_container: { cpu_id = 1 }, { container_name =
"goofy_haibt", container_type = "docker", pid_ns = 4026532295 }
```

Analyses

- Combine all this information to run kernel level analysis per container



```
Per-TID Usage                                                                              Process                   Migrations   Priorities
################################################################################
████████████████████████████████████████████████████████████████████████████████ 38.80 %   ab (23205)                         0   [20]
█████████████████████████████                                                    14.52 %   lttng-consumerd (11032)            0   [20]
██████████████                                                                    7.20 %   apache2 (23033)                    0   [20]
██████████████                                                                    7.19 %   apache2 (23007)                    0   [20]
████████                                                                          3.90 %   gcc (23297)                        0   [20]
█████                                                                             2.58 %   gcc (23294)                        0   [20]
███                                                                               1.62 %   lxd (23364)                        0   [20]
███                                                                               1.59 %   gcc (23300)                        0   [20]
███                                                                               1.54 %   lxd (23363)                        0   [20]
███                                                                               1.51 %   lxd (23362)                        0   [20]

Per-CPU Usage
################################################################################
████████████████████████████████████████████████████████████████████████████████ 81.80 % CPU 0
███████████████████████████████████████████████████████████████████████████      77.57 % CPU 1

Per-Container Usage                                                                         Container                                     Type
################################################################################
██████████████████████████                                                        40.16 %   [HOST] (4026531836)                           host
                                                                                   0.14 %   goofy_haibt (4026532295)                      docker
████████████████████████████████████████████████████████████████████████████████ 119.15 %   ample-adder (4026532356)                      lxd
                                                                                   0.01 %   coherent-macaque (4026532424)                 lxd
                                                                                   0.02 %   master-cheetah (4026532491)                   lxd
                                                                                   0.12 %   thirsty_meninsky (4026532572)                 docker
                                                                                   0.11 %   some-redis (4026532637)                       docker
```

Analyses

```
Timerange: [2017-11-23 15:23:40.280154476, 2017-11-23 15:23:46.943948421]
Per-Container Memory Allocations                                                                Container                                     Type
################################################################################
                                                                                      0 pages   some-redis (4026532637)                       docker
                                                                                      0 pages   thirsty_meninsky (4026532572)                 docker
                                                                                      0 pages   master-cheetah (4026532491)                   lxd
                                                                                      0 pages   coherent-macaque (4026532424)                 lxd
                                                                                    676 pages   ample-adder (4026532356)                      lxd
                                                                                      0 pages   goofy_haibt (4026532295)                      docker
████████████████████████████████████████████████████████████████████████████████ 232768 pages   [HOST] (4026531836)                           host

Per-Container Memory Deallocations                                                              Container                                     Type
################################################################################
                                                                                      0 pages   some-redis (4026532637)                       docker
                                                                                      1 pages   thirsty_meninsky (4026532572)                 docker
                                                                                      0 pages   master-cheetah (4026532491)                   lxd
                                                                                      0 pages   coherent-macaque (4026532424)                 lxd
                                                                                     85 pages   ample-adder (4026532356)                      lxd
                                                                                      0 pages   goofy_haibt (4026532295)                      docker
████████████████████████████████████████████████████████████████████████████████ 231060 pages   [HOST] (4026531836)                           host


Total memory usage:
- 233444 pages allocated
- 231146 pages freed
```

Scenario

- Run a kernel and userspace tracer on the host
  - Output to a remote relayd
  - Enable namespace contexts on syscalls
  - Enable statedump with namespace information
  - Periodically run container runtime statedump
- Run a userspace only tracer in the containers
  - Output to a remote relayd
  - Enable namespace contexts on application specific ust tracepoints
  - This in-container tracer doesn’t need to be the same version as the host tracer, it can be deployed according to a different release cycle
- Run offline analysis that can correlate information from both sources

What's next?

- Merge a finalized version of the patches upstream
- Add cgroups contexts and statedump

Longer Term Improvements

- Instrument container runtimes
  - Add events to track container lifetime
    - Kernel ids for namespace are ephemeral
  - Viewers and analyses could track containers across restart
- Add container support to control tools
  - For example, “lttng filter --container container-name”

What do you need?

- We are interested in your needs and use cases

Questions

?

LTTng Project

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