BKK19-419: Debugging with OP-TEE

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OP-TEE
.org

Agenda

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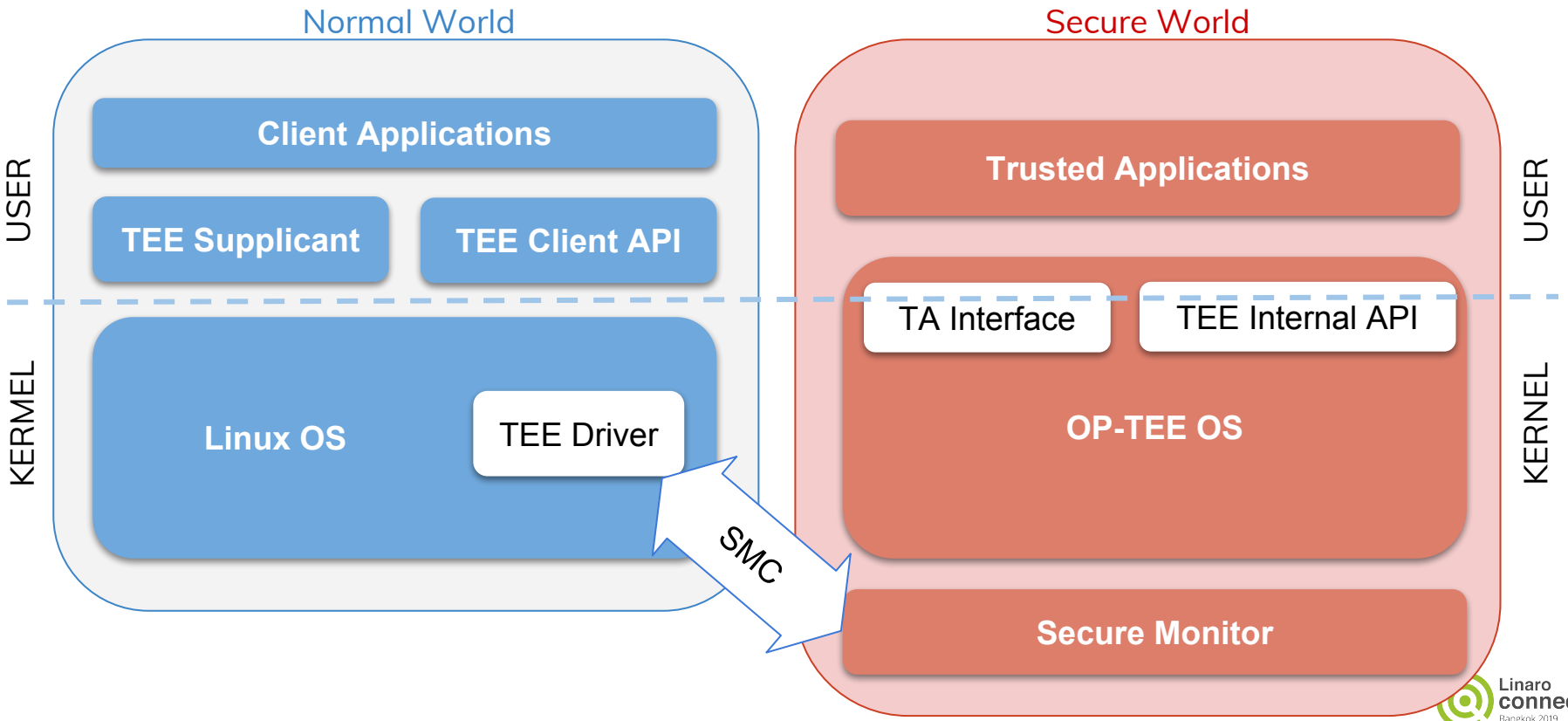
Brief OP-TEE background



Basics for debugging OP-TEE

Basics: GlobalPlatform return code origins

Name	Value	Comment
TEEC_ORIGIN_API [1]	0x00000001	The return code is an error that originated within the TEE Client API implementation.
TEEC_ORIGIN_COMMS [1]	0x00000002	The return code is an error that originated within the underlying communications stack linking the rich OS with the TEE.
TEEC_ORIGIN_TEE [1]	0x00000003	The return code is an error that originated within the common TEE code.
TEEC_ORIGIN_TRUSTED_APP	0x00000004	The return code originated within the Trusted Application code. This includes the case where the return code is a success.

Source: https://globalplatform.org/specs-library/?filter-committee=tee

Basics: Print log levels

OP-TEE uses a secure UART to dump all the debug prints. So OP-TEE provides following log levels which can be enabled during compilation:

- CFG_TEE_CORE_LOG_LEVEL
- CFG_TEE_TA_LOG_LEVEL

Levels:

- 0: none
- 1: error
- 2: error + info
- 3: error + info + debug
- 4: error + info + debug + flow

Default value for log levels is “1: error”.

Abort dumps / call stack

In case of any abort, information is dumped onto secure UART.

Abort dump types:

- Data or prefetch abort exception
- Call to TEE_Panic()
- TEE core fatal error

```
E/TC:0 TA panicked with code 0x0
E/TC:0 Status of TA 484d4143-2d53-4841-3120-4a6f636b6542
(0xe07ba50) (active)
E/TC:0  arch: arm  load address: 0x101000  ctx-idr: 1
E/TC:0  stack: 0x100000 4096
E/TC:0  region 0: va 0x100000 pa 0xe31d000 size 0x1000 flags rw-
E/TC:0  region 1: va 0x101000 pa 0xe300000 size 0xf000 flags r-x
E/TC:0  region 2: va 0x110000 pa 0xe30f000 size 0x3000 flags r--
E/TC:0  region 3: va 0x113000 pa 0xe312000 size 0xb000 flags rw-
E/TC:0  region 4: va 0 pa 0 size 0 flags ---
E/TC:0  region 5: va 0 pa 0 size 0 flags ---
E/TC:0  region 6: va 0 pa 0 size 0 flags ---
E/TC:0  region 7: va 0 pa 0 size 0 flags ---
E/TC:0 Call stack:
E/TC:0  0x001044a8
E/TC:0  0x0010ba59
E/TC:0  0x00101093
E/TC:0  0x001013ed
E/TC:0  0x00101545
E/TC:0  0x0010441b
E/TC:0  0x00104477
```

Symbolize call stack addresses

OP-TEE provides a helper script called symbolize.py (<optee_os>/scripts/symbolize.py) to symbolize call stack addresses.

```
Example usage:
$ cat dump.txt | ./optee_os/scripts/symbolize.py -d ./optee_examples/*/ta
<snip>
E/TC:0 Call stack:
E/TC:0  0x001044a8 utee_panic at optee_os/lib/libutee/arch/arm/utee_syscalls_a32.S:74
E/TC:0  0x0010ba59 TEE_Panic at optee_os/lib/libutee/tee_api_panic.c:35
E/TC:0  0x00101093 hmac_sha1 at optee_examples/hotp/ta/hotp_ta.c:63
E/TC:0  0x001013ed get_hotp at optee_examples/hotp/ta/hotp_ta.c:171
E/TC:0  0x00101545 TA_InvokeCommandEntryPoint at optee_examples/hotp/ta/hotp_ta.c:225
E/TC:0  0x0010441b entry_invoke_command at optee_os/lib/libutee/arch/arm/user_ta_entry.c:207
E/TC:0  0x00104477 __utee_entry at optee_os/lib/libutee/arch/arm/user_ta_entry.c:235
<snip>
```

Usage details: https://optee.readthedocs.io/debug/abort_dumps.html

GDB using QEMU

GDB can use the debug stubs built into QEMU to perform full symbolic debug of OP-TEE. Steps to debug OP-TEE on QEMU using GDB:

 # Launch QEMU for OP-TEE (using build repo)

$ cd <qemu-project>/build

$ make run

 # Launch GDB in another console

$ cd <qemu-project>/toolchains/aarch64/bin

$ ./aarch64-linux-gnu-gdb -q

 # Connect to QEMU GDB server, load symbols from tee.elf, ta.elf and set breakpoints to debug

(gdb) target remote localhost:1234

(gdb) symbol-file <qemu-project>/optee_os/out/arm/core/tee.elf

(gdb) add-symbol-file <path-to-ta-elf>/<uuid>.elf <load-address>

(gdb) b tee_entry_std

(gdb) b TA_InvokeCommandEntryPoint

(gdb) c

Profiling in OP-TEE

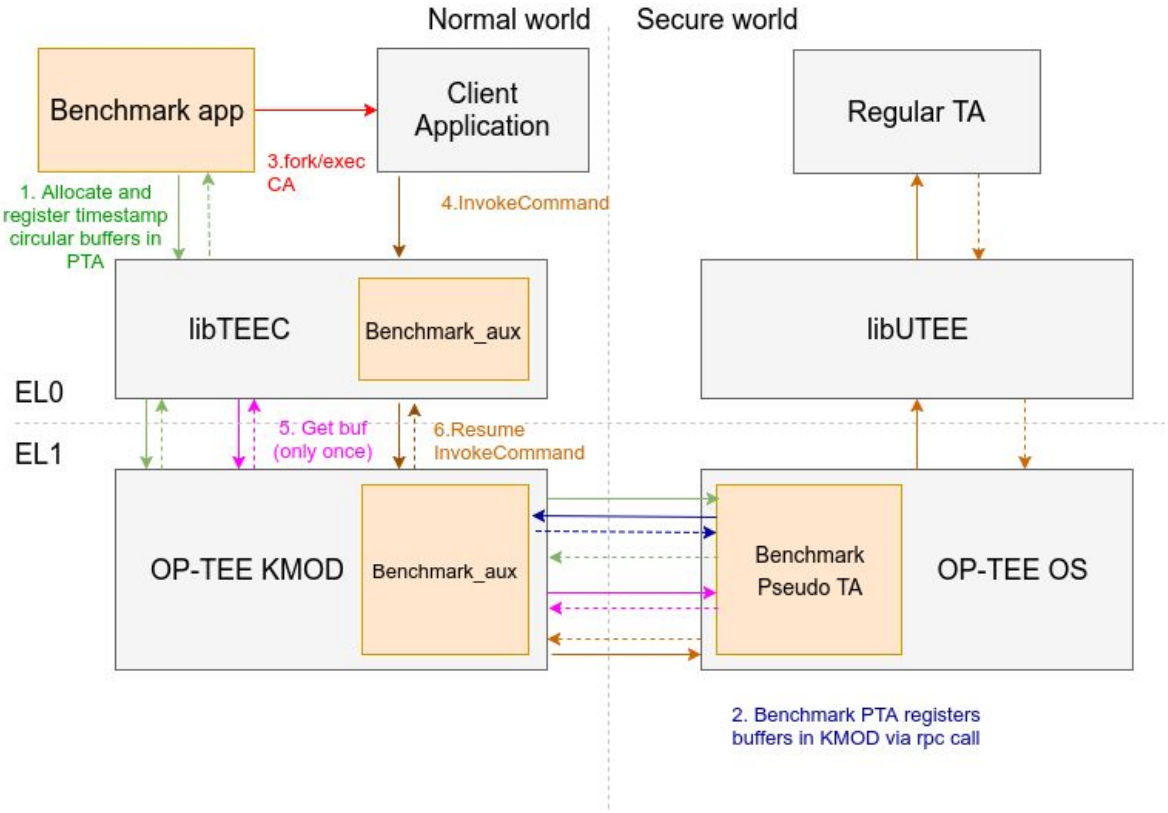
Profiling: Benchmark framework

OP-TEE provides a framework to measure latency values for various architectural layers involved during runtime operation as below:

- Round-trip time from a Client Application to a Trusted Application.
- Latency to go through each layer:
  - libTEEC -> Linux TEE driver
  - Linux TEE driver -> OP-TEE OS core
  - OP-TEE OS core -> TA entry point (not supported yet)
  - The same way back

Usage details: https://optee.readthedocs.io/building/gits/optee_benchmark.html#optee-benchmark

Profiling: Benchmark framework design



Profiling using gprof

OP-TEE supports profiling of user Trusted Applications with gprof. Details of profiling data collected are as follows:

- Call graph information
  - Records a pair of program counters (caller and callee). Also, records count for particular arc of the call graph being invoked.
- PC distribution over time
  - TEE core samples TA program counter (PC) during interruption of TA execution like normal world interrupts etc.

Usage details: https://optee.readthedocs.io/debug/gprof.html

Function Tracing (ftrace)

ftrace - Function tracing

GCC compilation with -pg option inserts a special function _mcount() for every function entry.

In case of ftrace, this API could be used for various purposes like:

- To record caller and callee functions.
- To record entry and exit point for every function.
- To record function execution time.

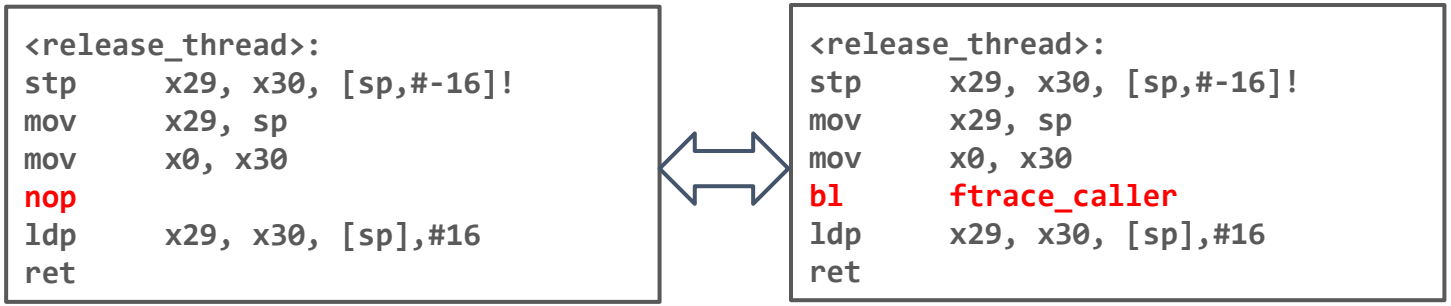
Code compiled with -pg

```
<release_thread>:
stp     x29, x30, [sp,#-16]!
mov     x29, sp
mov     x0, x30
bl      ffff000008092ea0 <_mcount>
ldp     x29, x30, [sp],#16
ret
```

ftrace for Linux TEE driver

Linux provides ability for dynamic function tracing (`CONFIG_DYNAMIC_FTRACE=y`)

Linux can dynamically enable/disable tracing



For detailed view of Linux ftrace, refer to training here: http://bit.ly/linux-ftrace-training

ftrace for Linux TEE driver: usage

Example usage of function graph for TEE driver apis:

```
# Mount debugfs to access ftrace
$ mount -t debugfs nodev /sys/kernel/debug
$ cd /sys/kernel/debug/tracing/

# Set filter for TEE driver apis
$ echo "optee_do_call_with_arg" > set_ftrace_filter
$ echo "optee_open_session" >> set_ftrace_filter
$ echo "optee_close_session" >> set_ftrace_filter
$ echo "optee_invoke_func" >> set_ftrace_filter

# Enable the function_graph tracer
$ echo "function_graph" > current_tracer
```

Output after running xtest

```
# tracer: function_graph
#
# CPU  DURATION                  FUNCTION CALLS
# |     |   |                     |   |   |   |
 22)               |  optee_open_session() {
 22) + 65.910 us   |    optee_do_call_with_arg();
 22) + 75.340 us   |  }
 22)               |  optee_invoke_func() {
 22) # 1922.170 us |    optee_do_call_with_arg();
 22) # 1935.320 us |  }
 22)               |  optee_close_session() {
 22) + 71.560 us   |    optee_do_call_with_arg();
 22) + 81.230 us   |  }
...
```

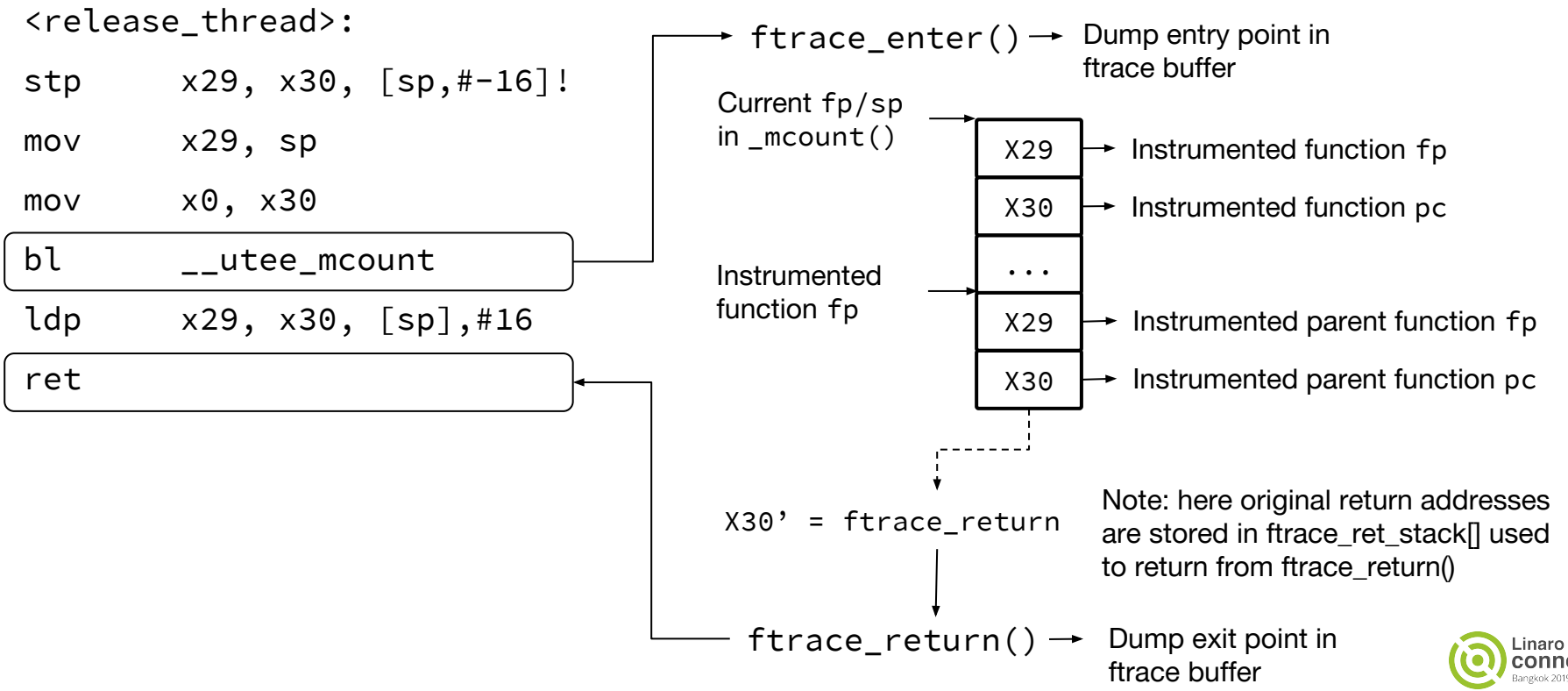
Function tracing in OP-TEE?

Ftrace in OP-TEE seems to be a promising feature providing enhanced debugging capabilities. Especially function graph trace which could be used:

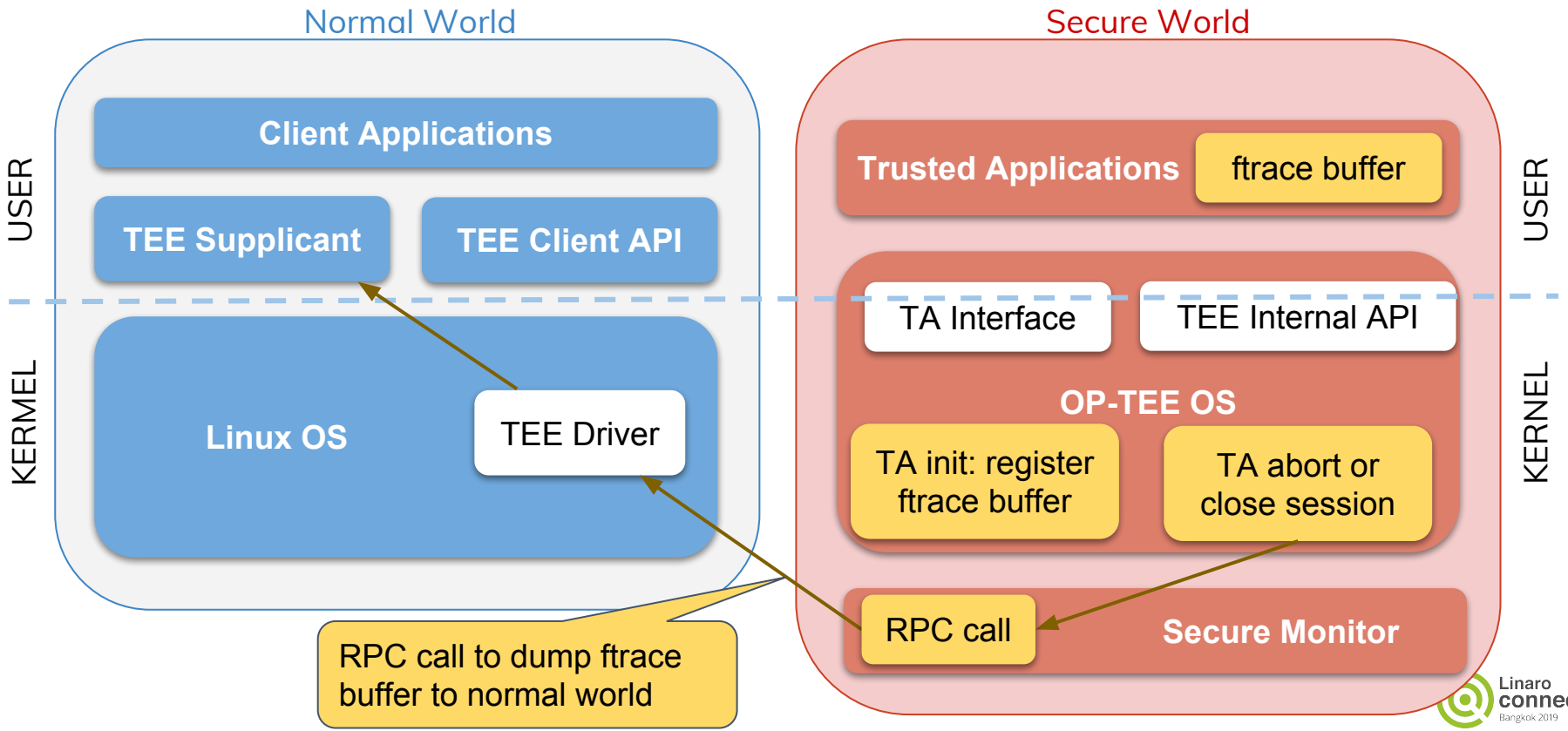
- To get in-depth view of runtime TA execution flow.
- To get useful information during abort dumps.

```
# Example hello world TA function graph
Call graph:
<snip>
 TA_CreateEntryPoint();
 TEE_Malloc() {
  malloc() {
   bget();
   }
  }
 ta_header_get_session();
 __utee_to_param();
 memcpy();
 TA_OpenSessionEntryPoint();
 __utee_from_param();
 memset();
 __utee_entry() {
  ta_header_get_session();
  __utee_to_param();
  memcpy();
  TA_InvokeCommandEntryPoint() {
   TEE_Panic() {
```

OP-TEE: ftrace mechanism

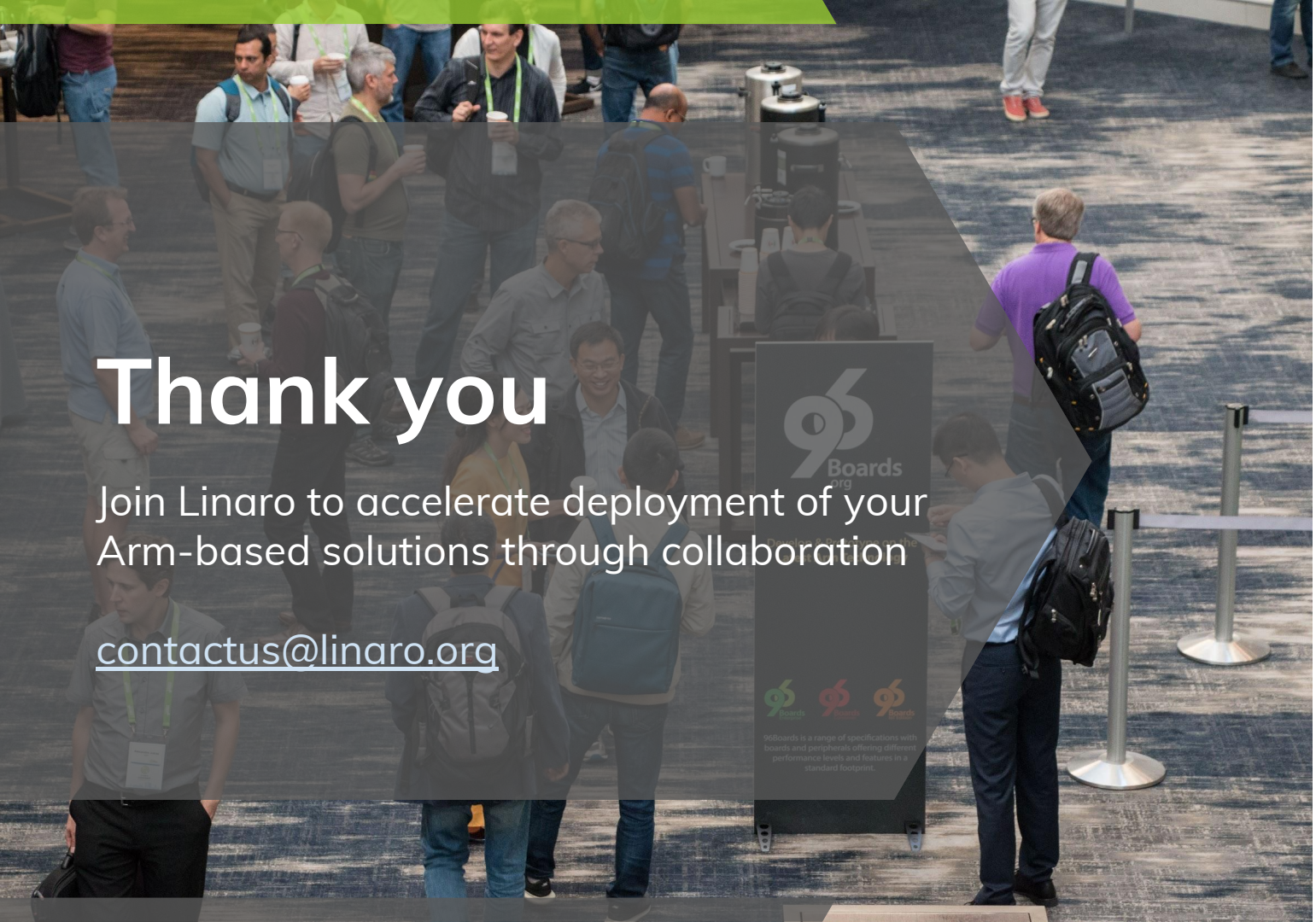


OP-TEE: ftrace implementation



OP-TEE ftrace: next steps...

- Create patch-set for upstream review from this ftrace PoC work.
- Extend TA ftrace buffer dump to include syscall function graph from OP-TEE OS.
- Implement ftrace for OP-TEE OS core.



Thank you

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