UNSW SYDNEY | Australia's Global University

School of Computer Science & Engineering

Trustworthy Systems Group

seL4 Microkit

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TS

So, what is Microkit?

- An operating systems framework for building systems on seL4.
- Primary motivation is to lower the barrier the entry to developing on seL4.
- While making seL4 easier to use, we still want to uphold performance, security, and memory efficiency.
    - This means providing few, minimal, abstractions over seL4 primitives.
- Targeted at cyber-physical embedded systems, with a static architecture.

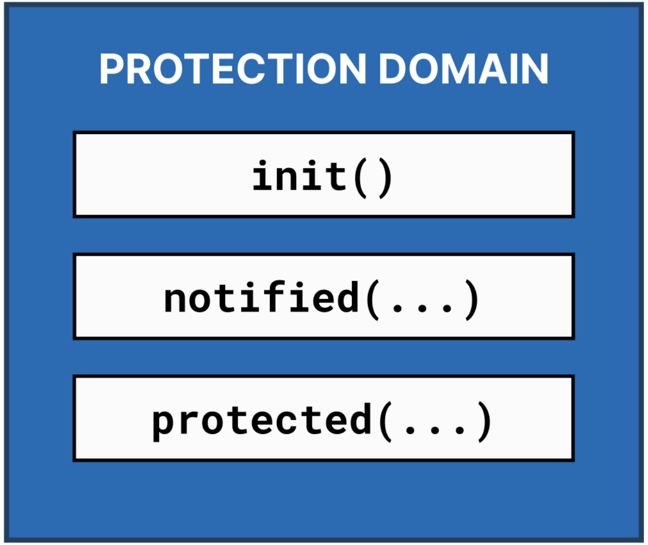
Why the name change?

- The “Core” in seL4 Core Platform makes it look like *the* only framework to build seL4 systems on which is **not** true.
- For those already referring to “seL4 Core Platform”:

  -
    ```
    sed –i 's/sel4cp/microkit/g'
    ```
  - Just kidding…
- If you spot anything not renamed yet that should be, please let us know! File an issue on GitHub or post on the mailing list.

Abstractions – Protection Domains

- An environment for executing user-level code.
- Single-threaded with its own address-space.
  - In seL4 terms, each PD contains its own CSpace, VSpace, and TCB.
- By default, all it can execute is its own code and *nothing* else.
- Execution is event-based.



PROTECTION DOMAIN

`init()`

`notified(...)`

`protected(...)`

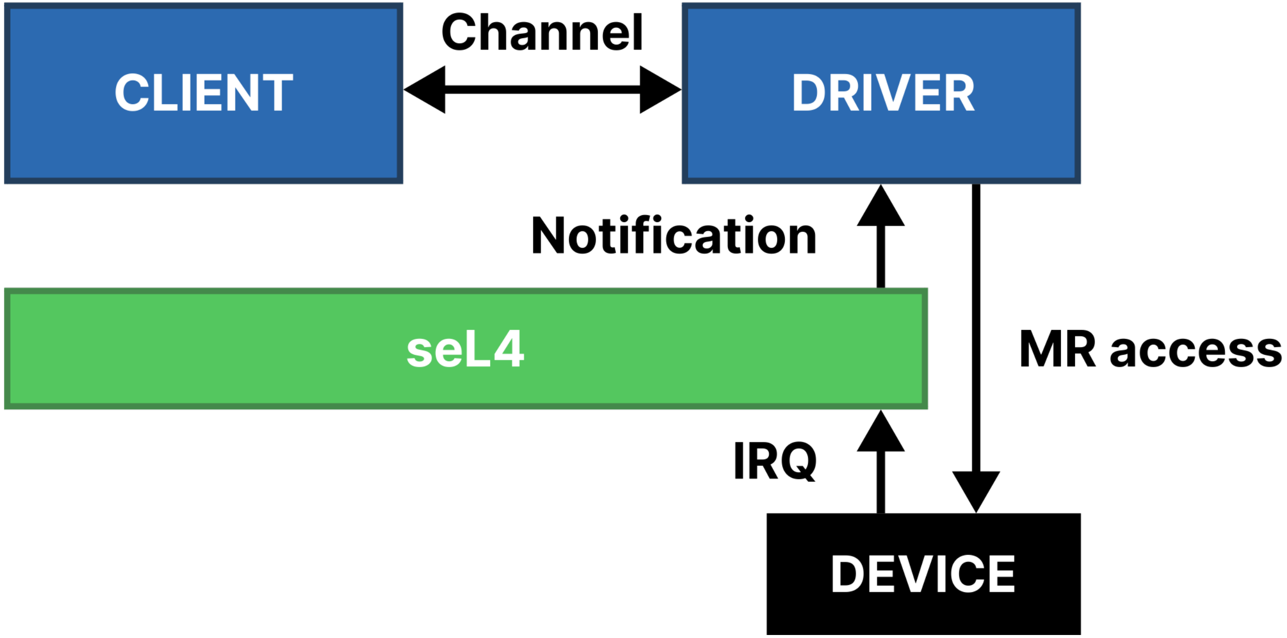
Abstractions – Memory Regions

- MRs represent a contiguous block of physical memory.
    - Regular memory.
    - Device memory (for implementing device drivers).
- May be mapped into one or more PDs.
    - Allows for shared buffers between PDs.
    - Enables zero-copy communication.
    - Specify caching attributes and permissions.

Abstractions – Communication Channels

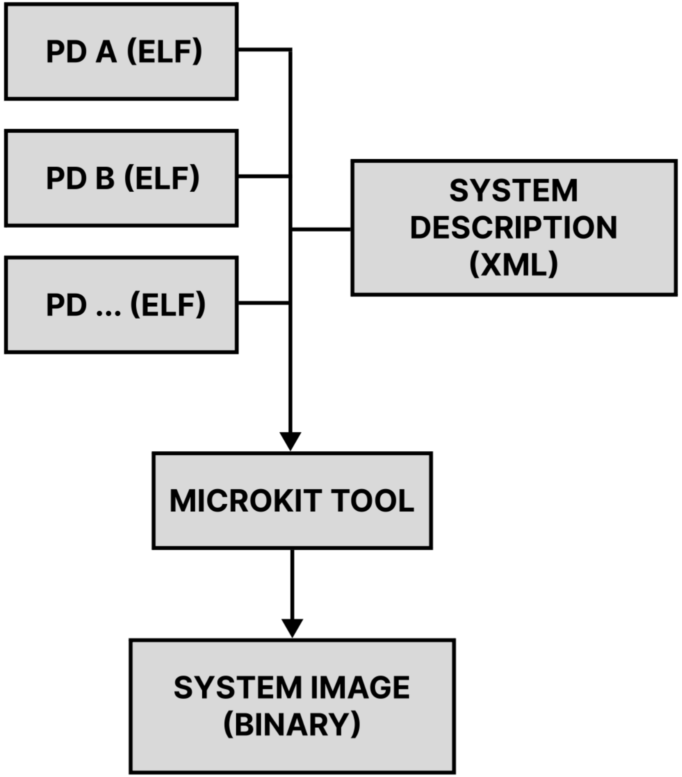
- Allows for bi-directional communication between a pair of PDs.
- Allows for synchronous and asynchronous communication.
- Notifications are used for asynchronous communication:
  - A PD “notifies” another to signal that some event has occurred.
  - Interrupts from hardware are also delivered as notifications.
- Protected Procedure Calls (PPC) are used for synchronous communication:
  - Enables a PD to execute code in a different PD.
  - For example, a client invoking some service in a server that returns a result.

Abstractions – Summary



Microkit design

- All the PDs, MRs, and CCs are described in a System Description Format (SDF) written in XML.
  - This is deliberate, it allows trivial parsing as well as auto-generation.
- In addition to the SDF, the Microkit tool expects the ELFs of all PDs in the system.
  - It intentionally does not provide a build-system.
  - Each PD is linked with `libmicrokit`.
- Microkit is distributed as an SDK.



Status of Microkit

- After much discussion, the Microkit RFC has been **approved** by the seL4 Foundation.
- Microkit is now an official seL4 project: `github.com/seL4/microkit`!
- Development over the past year includes:
  - Limited dynamicism (stopping, restarting, late-loading PDs).
    - Static architecture remains.
  - New abstraction - virtual machines.
  - Support for other architectures such as RISC-V and x86-64 and more hardware platforms.
  - CapDL integration to (eventually) connect Microkit to existing seL4 proofs.
  - An implemented verification story now exists.
- The process of upstreaming all the changes has started.
- You can follow the status of upstreaming here `github.com/seL4/microkit/issues/61`.

What’s next for Microkit?

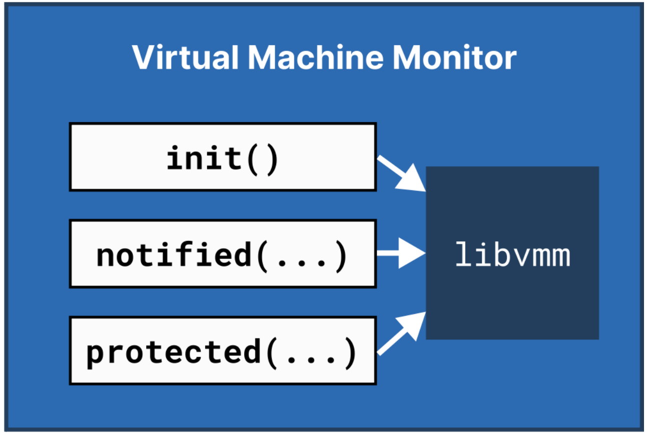
- Development is most certainly not done!
- Enhancing the eco-system:
  - Virtual Machine Monitor (VMM)
  - Proper debugging support
  - Performance profiling
  - System visualisation tools
- Building a non-trivial example system using Microkit (PoS system).

Virtual machines on Microkit

- Why?
  - To avoid porting existing or implementing new device drivers for seL4.
  - Invoking legacy software.
- Main goals:
  - Secure and performant virtual machines.
  - Lower the barrier to entry for using virtual machines with seL4.
    - Having documentation and lots of examples is a priority!

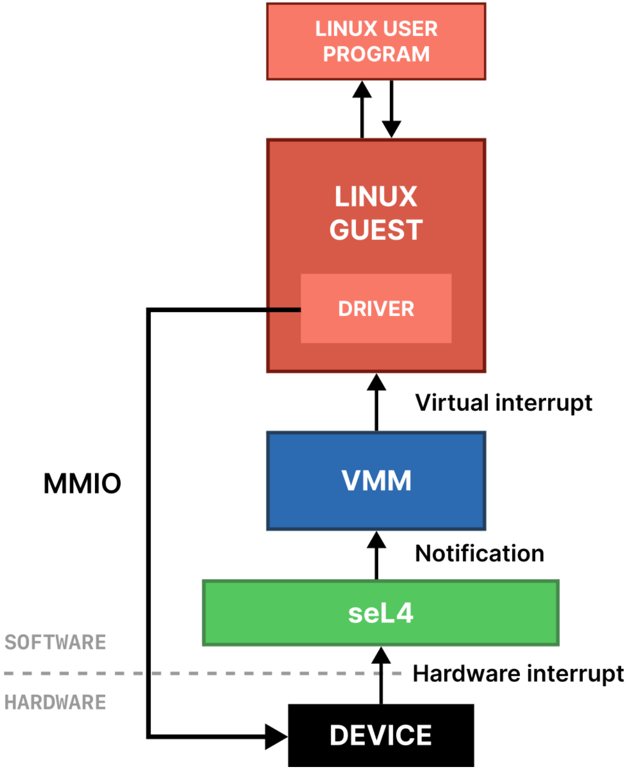
Virtual machines – VMM as a library

- A ”one-size fits all” VMM is not ideal.
- The library allows people to build their own VMM, with their own control-flow.
- Supports AArch64, RISC-V in-progress.
- Examples of using the VMM library in C, Zig, and Rust already exist.
    - Each of these is ~100-150 SLOC.
    - About 2300 SLOC involved to boot a Linux guest with `libvmm`.



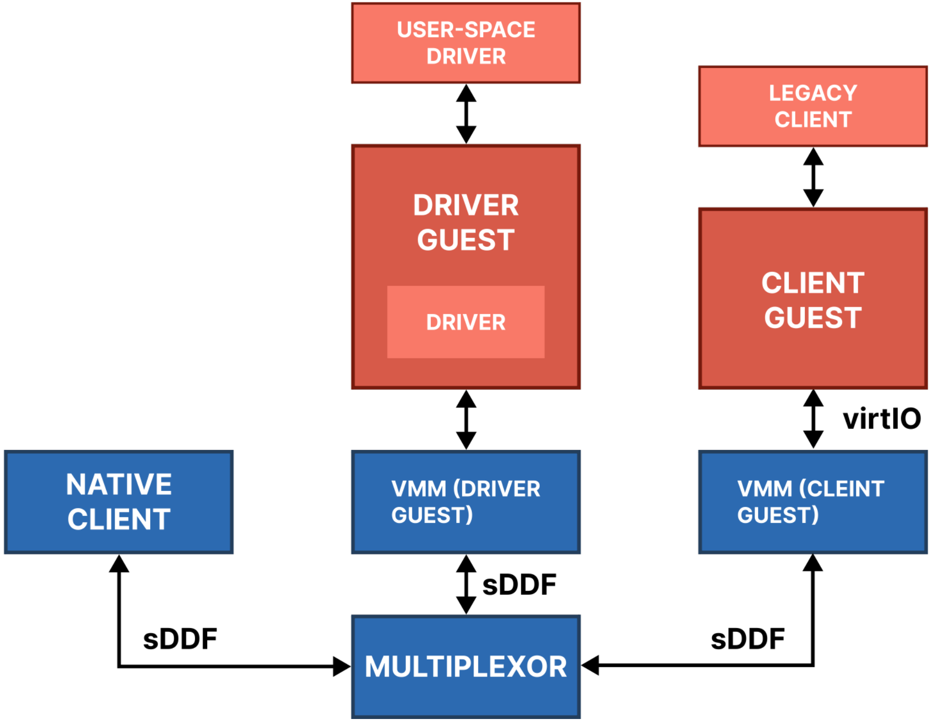
Virtual machines – Pass-through devices

- The easiest way to get I/O in a virtual machine is “pass-through”.
- This gives the guest full access to a certain device.
- In Microkit, this is trivial to do by creating a memory region and mapping it into the virtual machine.



Virtual machines – Device sharing

- We need to be able to share devices.
- Using and extending the sDDF transport layer, we can allow native clients and other virtual machines to make use of the same device.
- sDDF allows us to transparently swap out a virtualised driver with a native driver.
- We are working towards graphics and networking support.

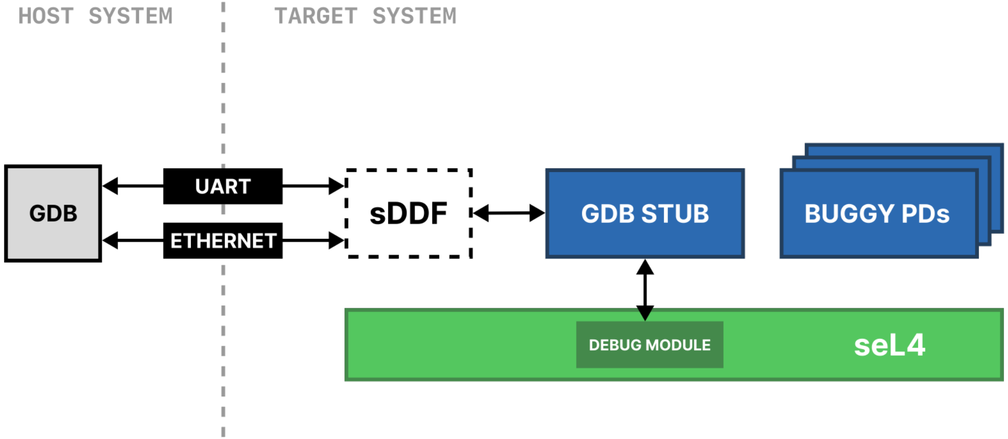


Virtual machines - Summary

- Sufficient for development and experimentation, but not production ready yet.
  - Proper performance and security analysis needed.
  - Highly-used features such as SMP guests and virtIO are still in-progress.
- Not just for Microkit! The project should be able to be used in other seL4 environments.
  - The library depends on few seL4 invocations.

Proper debugging

- When running on real-hardware, using only `printf` debugging is quite limiting.
- Adding GDB support to Microkit to provide the ability to:
  - set breakpoints (both in software and hardware).
  - single-step code.
  - inspect kernel state, such as dumping a CSpace.
- Also want to provide stack traces for faults, such a virtual memory fault.
- Mostly a work-in-progress at this stage.



A performance profiler

- Current profiling on seL4 is limited.
  - Good for getting an idea of cache misses, kernel entries etc.
  - For non-trivial systems, we need a more systematic way of tracking performance.
- Goal is to have a statistical sampling user-level profiler to track performance of each PD in the system.
- Allow analysis of data by existing tools such as perf.
- Export data over serial, network, block.
- One potential problem is that kernel changes are required, conflicting with simply attaching the profiler to a deployed and running system.
- Again, mostly a work-in-progress at this stage.

Community input

- As the main developers of Microkit, there are only so many use-cases we have considered.
  - This means we are bound to miss some use-cases and there may still be holes.
- While we do try to give users of Microkit the best user experience, there will almost certainly be gaps and mistakes as the project matures.
  - Ranging from documentation, to error messages, to workflow, etc.
- It is vital for the community using our software to tell us what needs improving!

Thanks! Questions?