Robigalia

Rust, seL4, and Persistent Caps

Corey Richardson

Clarkson University

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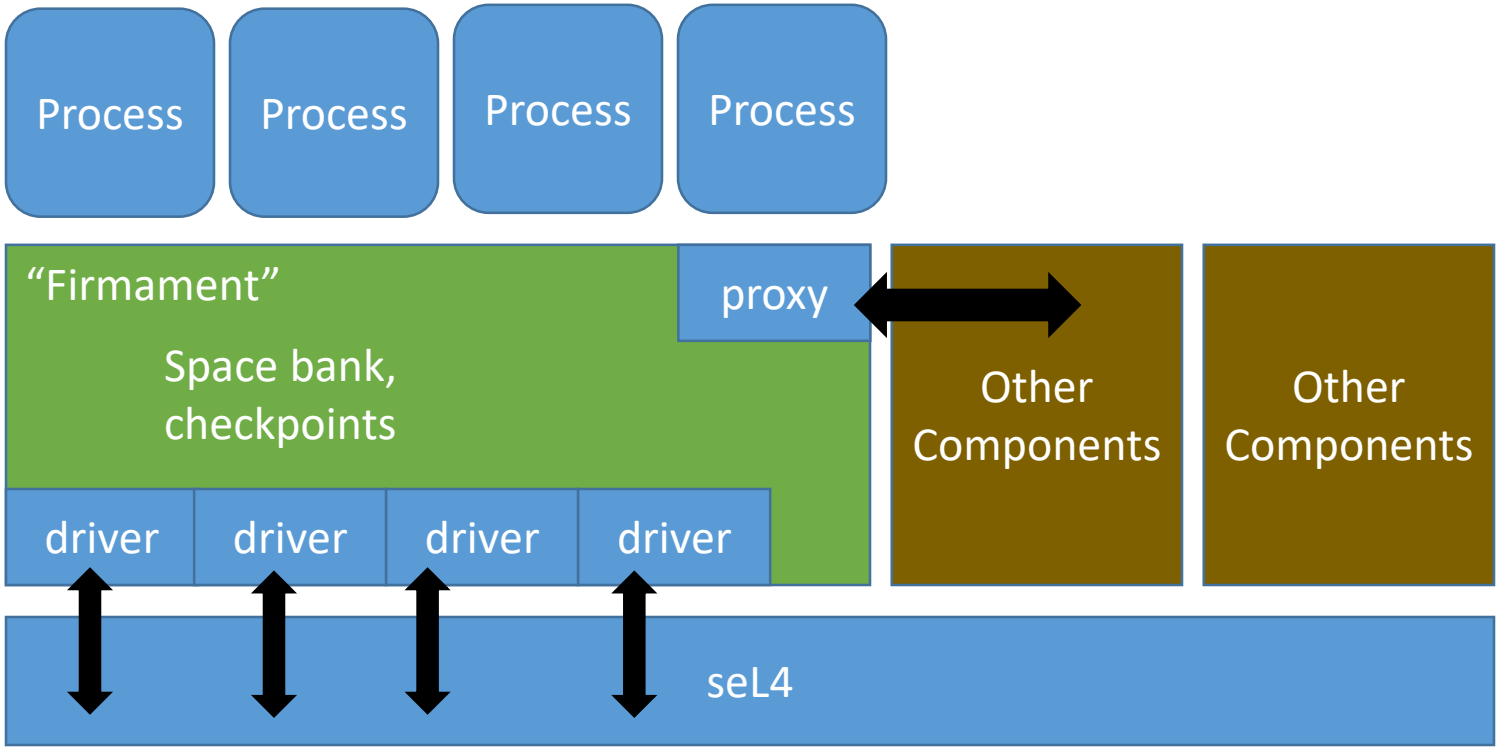
What?

- Create a reliable dynamic operating system
- Using Rust (some components will be implemented in C and formally verified)
- With seL4
- Initially targeting x86_64 workstation/server class HW.
- … but also aiming at RISC-V and some ARM boards, in the future.
- Primary target is eventual verified RISC-V implementations.
- Vaguely like Genode in scope, but more specific to seL4 for now.

System Structure



Why?

- I enjoy working on systems, and seL4 is a neat kernel
- Try to continue the legacy of KeyKOS, EROS, and Coyotos
- See how far Rust can be pushed as an OS implementation language

Who?

- Me, Corey Richardson
- Alex Elsayed
- https://robigalia.org/

Rust

- Rust is a recently developed language out of Mozilla Research
- “Safe, concurrent, fast: pick three”
- Implementation language for their new parallel web browser engine
- Advanced type system for managing concurrent access to data, while forbidding data races and memory unsafety
- … but for this talk, not terribly relevant!

Challenges

- Resource Accounting
- Extending seL4’s capability model
- System persistence
- Drivers

Resource Accounting

- Finite amount of storage capacity on a local system
- What processes get to use it?
- How does that come to pass?

- Finite amount of processing power on a local system
- What processes get to use it?
- How does that come to pass?

Space Banks for Resource Accounting

- Name ripped from EROS, but inspired by seL4's Untyped objects
- Intuitive, visceral understanding: the system manages all storage in a central bank. Can't use storage unless you pay for it.
- Can invoke a space bank to purchase address space, capability space, other seL4 objects.
- Space bank is primary trusted OS service.

Space Banks

- A space bank at runtime is an endpoint.
- Important piece of state: current quota
- Three management operations: revoke, create_child, and verify.
- Revoking a space bank revokes all seL4 objects created from the space bank, returning that storage to your quota.
- Creating a child space bank gives you a new space bank with its own (larger or smaller) quota.
- Verify lets clients ask their (trusted) space bank if it recognizes another capability (received from a potentially untrusted client) as a valid space bank.

Space Banks

- Can also do “auctions”. Allows processes to collaborate to exchange storage capacity.
- Can create a bid object from a space bank, and store objects in that bid. Objects stored in a bid are inaccessible until bid is destroyed.
- Can offer a bid into an auction, and send the auction cap (badged endpoint) to another thread which can offer its own bid.
- At any point, a thread can destroy its bid, which cancels the auction. **Important** to prevent malicious threads holding resources “hostage”.
- Once both threads agree to the auction, the space bank implementation swaps ownership of the objects between the source space banks, including properly adjusting their quotas to reflect this.

Space Banks

- Possibilities with auctions:
- Give another space bank more quota, from your own.
- Give another space bank a region of address space that you no longer need/use.
- … many more possibilities, not all useful. Very general mechanism.
- **Important:** once you auction off some quota, you can't get it back by revocation!
- But once the space bank that bought your quota is revoked, the storage returns to you.

Space Banks

- **Some important properties:**

- All bytes are always accounted for
- All owned storage can always be revoked, returning quota to the caller promptly
- Storage cannot be manufactured except for by the firmament (which is hopefully only in response to things like new disk inserted or memory hotplug)

??? for Time Accounting

- Still kicking around ideas for how to do this. Some initial ideas, nothing ready yet.
- Need to think hard about the new RT extensions and what properties we want.

Safe Revocation

- Revoking an untyped object which has some page tables mapped into it will cause gnashing of teeth for the process using those page tables.
- Need to *very carefully* design servers exposed to untrusted clients to both avoid resource DoS, resilience to revocation.
- How do you do it?

Bushels

- A **bushel** is the minimum granularity of isolation in a Robigalia system. Not a specific thing, but a design pattern for robust cooperation.
- Corresponds directly to a badged endpoint.
- Server manages a map from badge -> bushel.
- Few different ways to do this, but a nice one possible where state per client is fixed size is to use it as index into huge array of address space.
- Some more complex mappings possible that are robust to revocation.

Bushels

- Each bushel is associated with a single space bank, which is usually given by the client when creating the bushel.
- When receiving a message on and endpoint, server first inspects the badge and determines the bushel ID.
- Stores the bushel ID while servicing the request.
- **Only access memory that was allocated from that bushel's space bank**, or the server's own space bank (but be careful to avoid DoS!)
- If there is a fault while processing a request for a bushel, the fault handler will reset the server, which will then deallocate any other state corresponding to that particular bushel.

Bushels

- This is revocation-safe. If a thread non-cooperatively revokes its space bank that it gave to a server to service its requests, it can only hurt itself.
- Server still able to service requests by other clients.

- Does this scale? **Not necessarily**. Hard for mutually untrusting processes to collaborate to pool their resources for the server to use.
- Our hope is that this will be rare enough to allow per-case design of protocols for those cases.
- If not, some ideas of how to extend.

Extending seL4's IPC

- Desired features: large messages (> IPC buffer size)
- "Extended Virtual Message Registers"
- Two threads can agree to use some shared memory to act as extended storage for messages.
- Write first bit of message into IPC buffer, rest into shared memory, then send seL4 IPC. Minor isolation hole.

- Also a protocol for sending multiple different capabilities (very simple), but not atomic.
- Possibility: central trusted implementing bulk transfer of caps and data which does copying across address spaces. Closes isolation hole.

Persistence and Drivers

- Still working on a design for this.
- Eventual goal is to have ~all userspace processes able to be transparently persisted to secondary storage, with checkpointing and restore.

- Driver story is unfortunate. Currently working on things like ACPI and PCIe. virtio drivers soon.
- Hope to use rump kernel drivers in the short run.
- Long run: verified drivers for some devices.

Questions?