Ironclad

A formally verified OS kernel written in SPARK and Ada.

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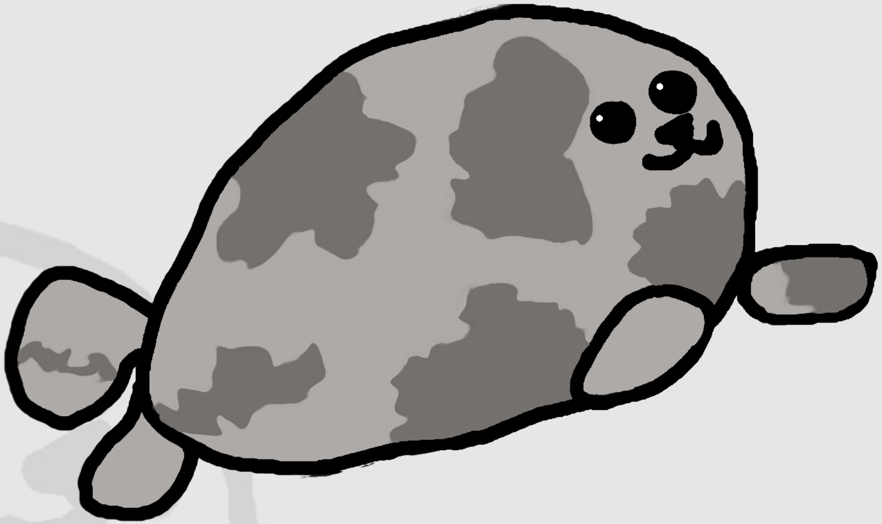
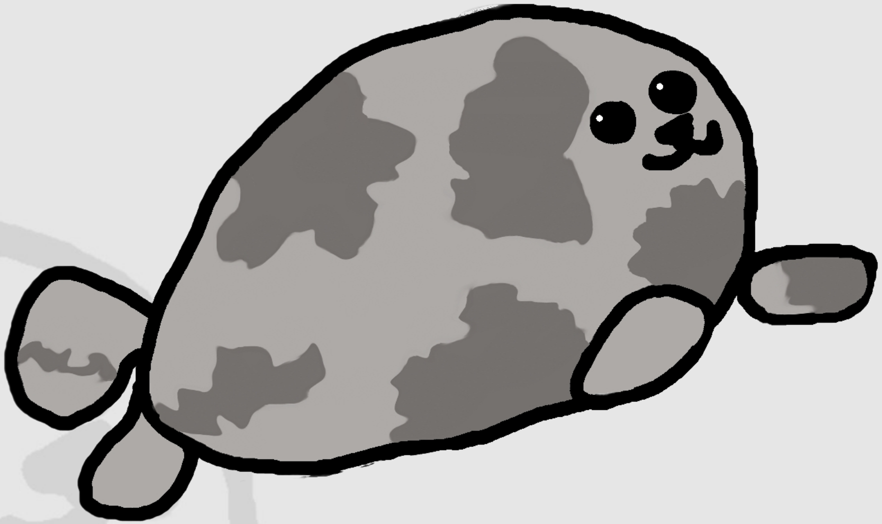
So what is Ironclad?

- POSIX-compatible formally-verified (to an extent) kernel.
- Hard real-time facilities and flexible scheduling.
- Highly portable.
- Free as in freedom.

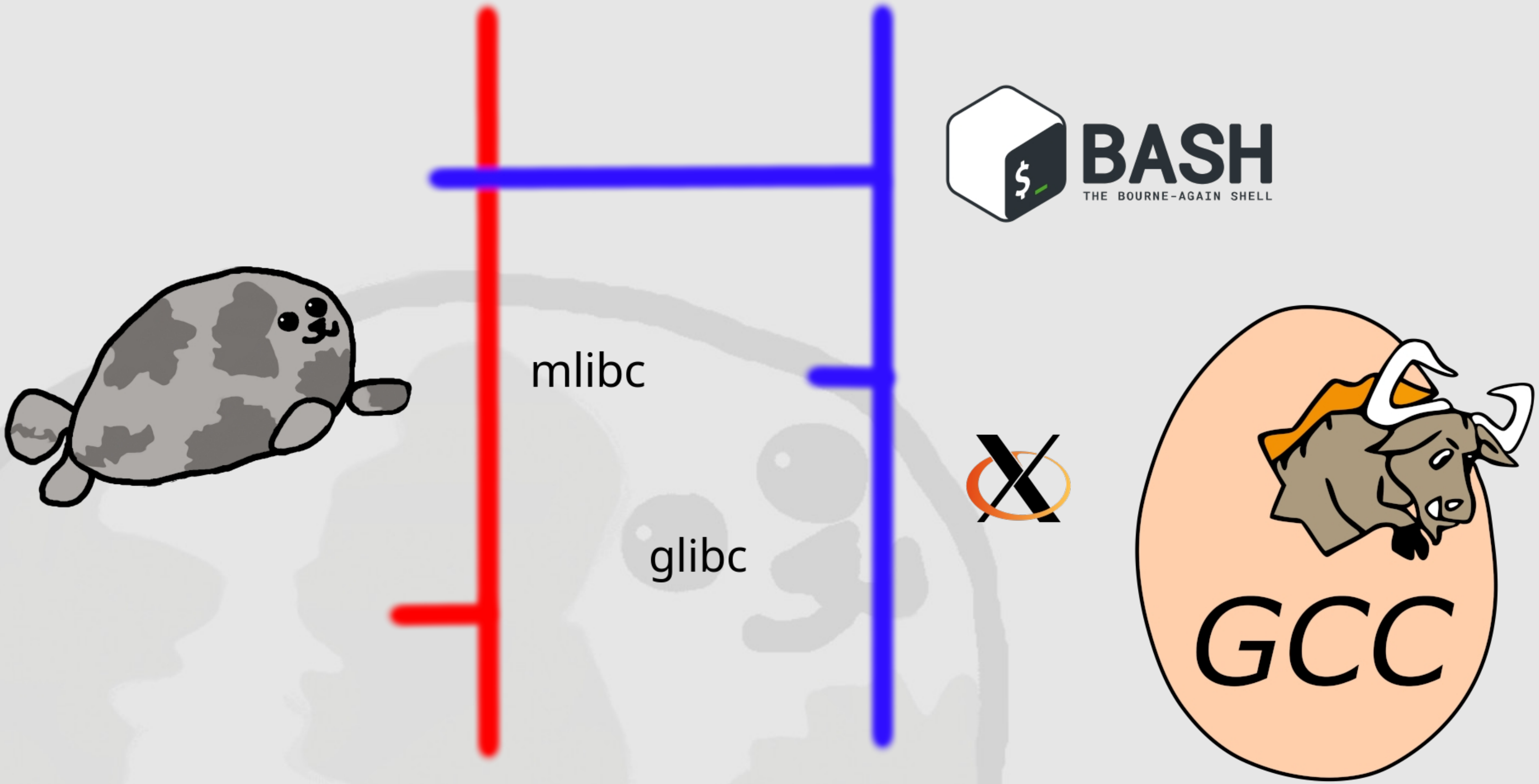


What are the goals of Ironclad?

- A highly secure architecture.
- Hard real-time suitability without compromising general purpose computing.
- Doing so keeping in mind POSIX compatibility.

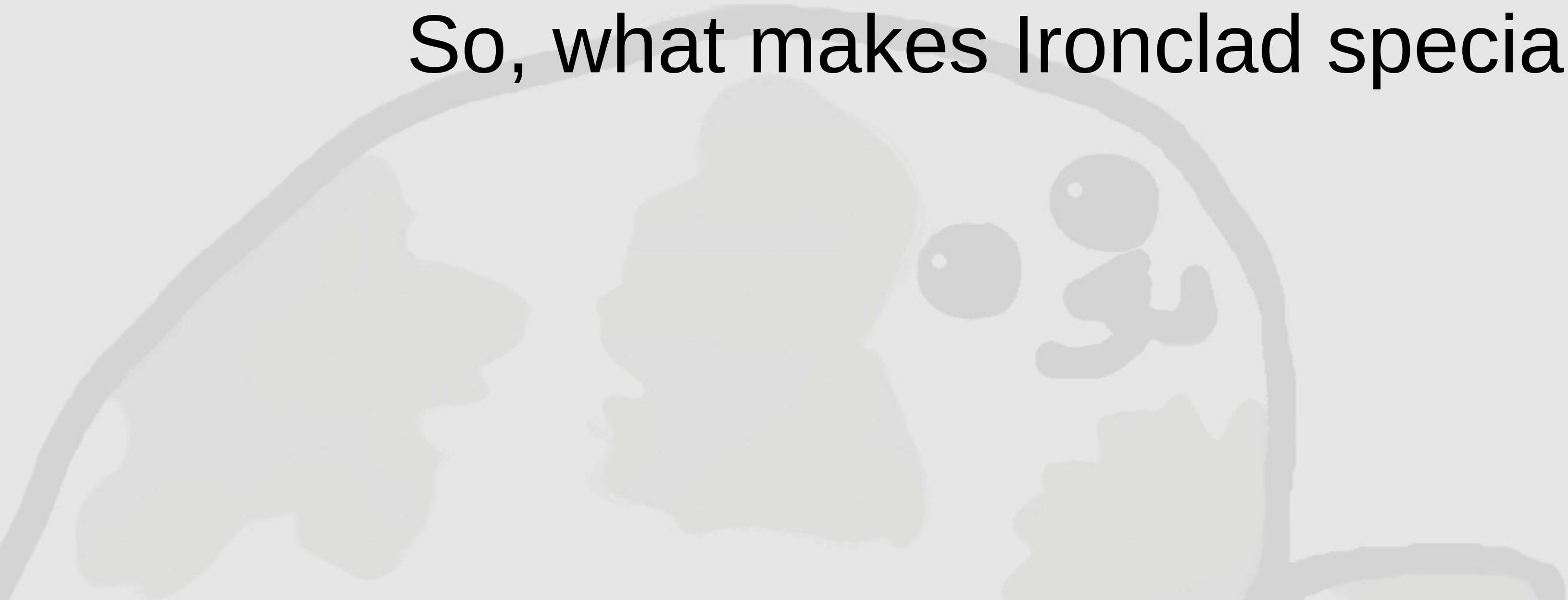


Operating system architecture

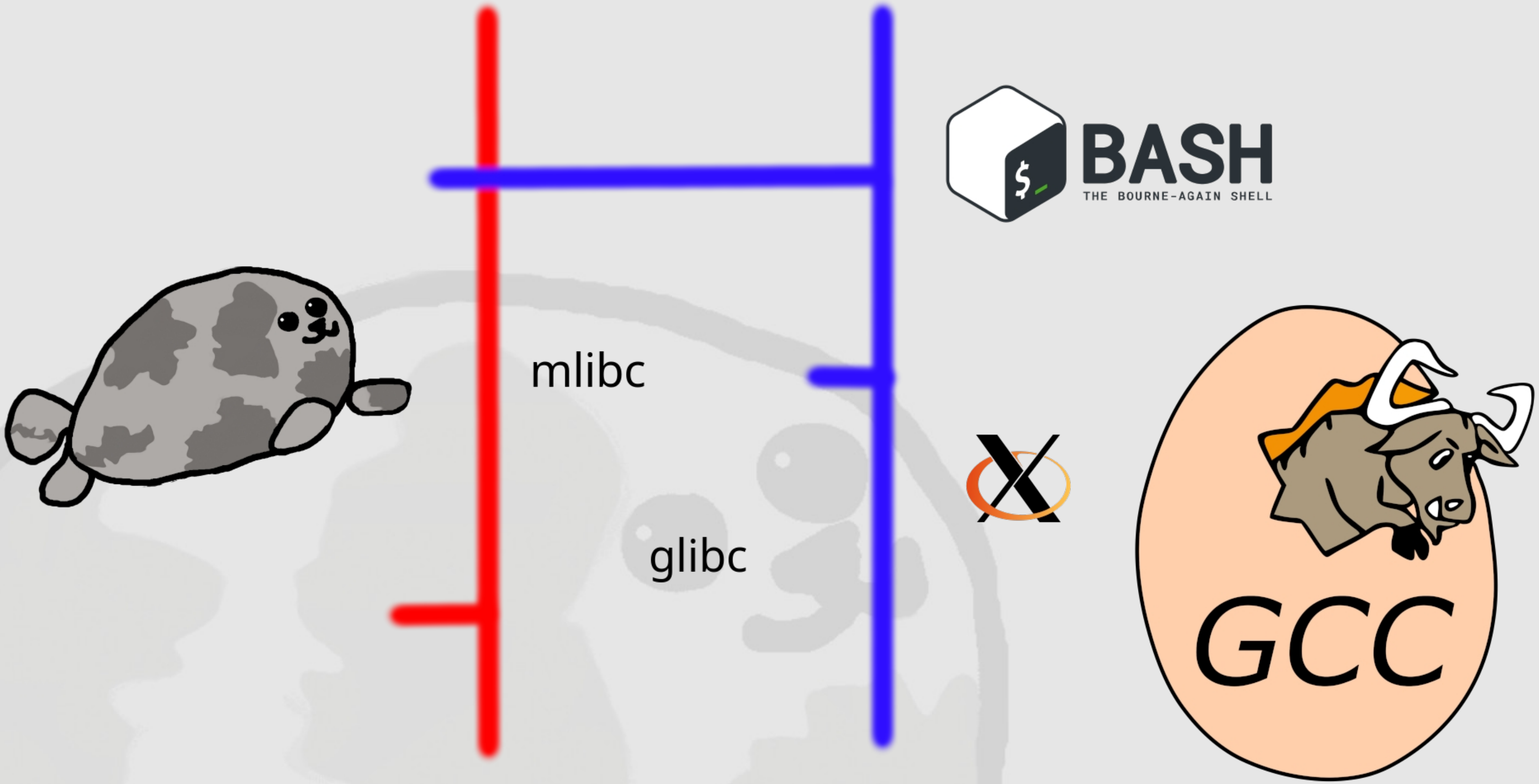


Operating system architecture

So, what makes Ironclad special?



Mandatory Access Control (MAC)



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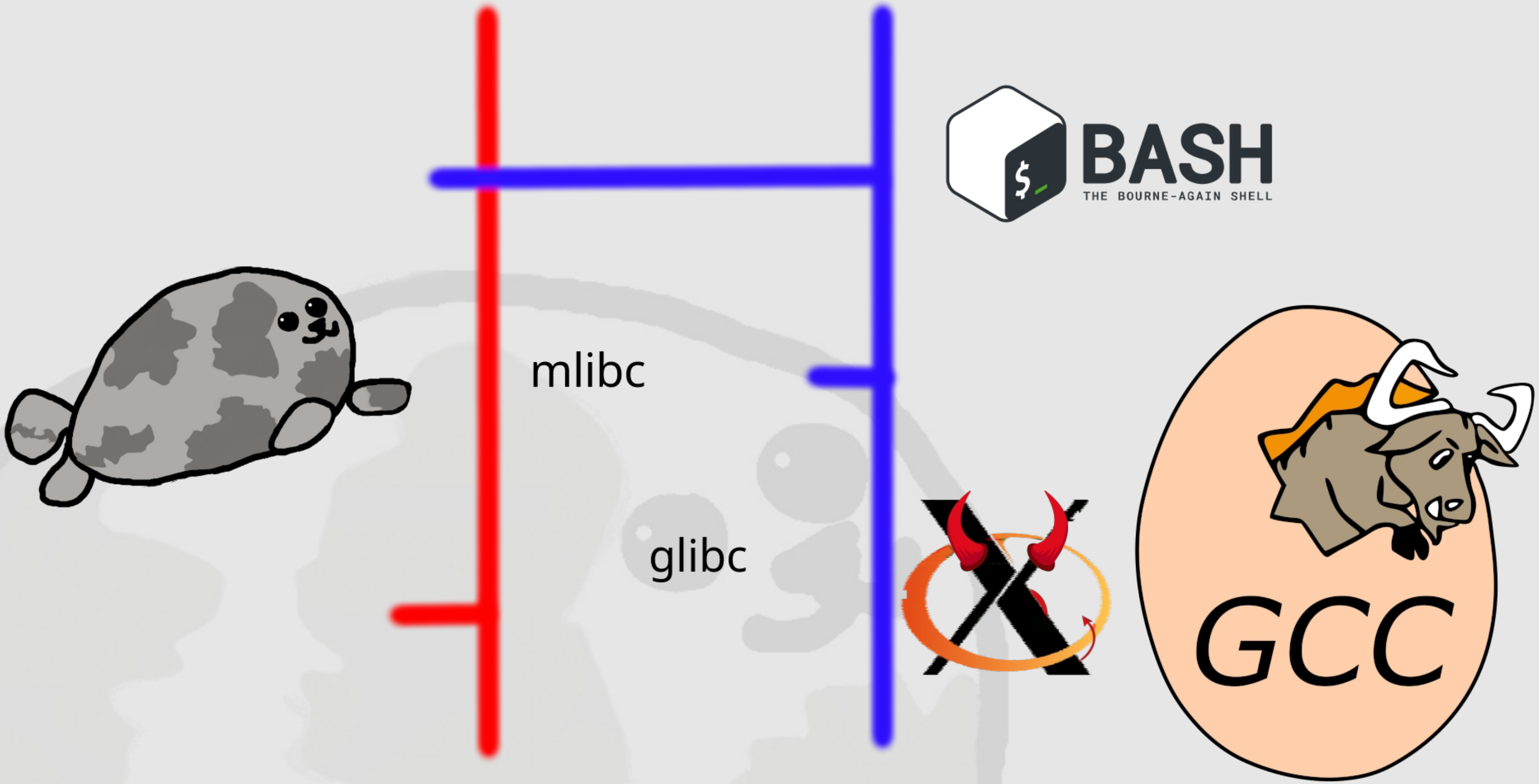

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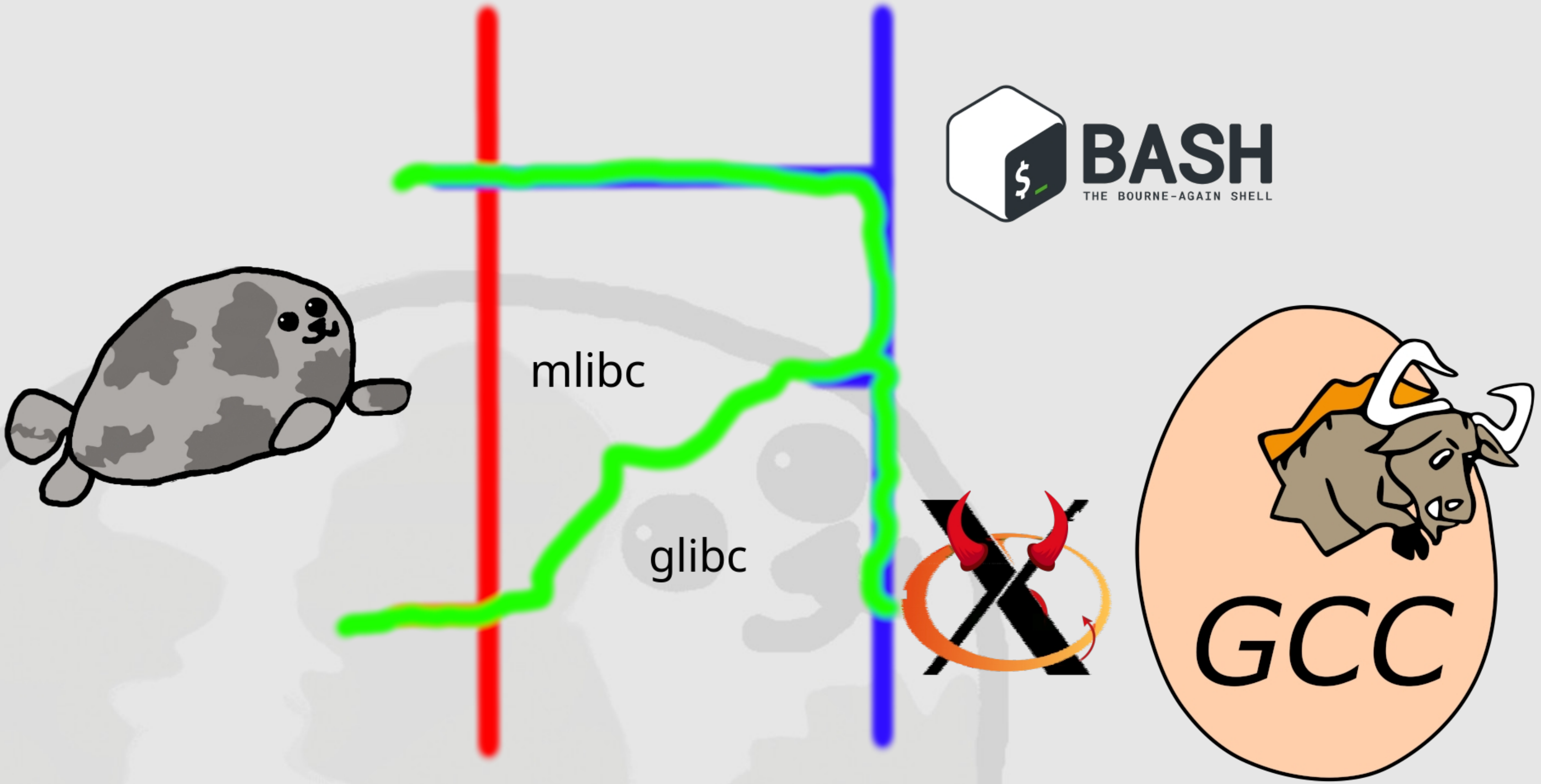

Mandatory Access Control (MAC)

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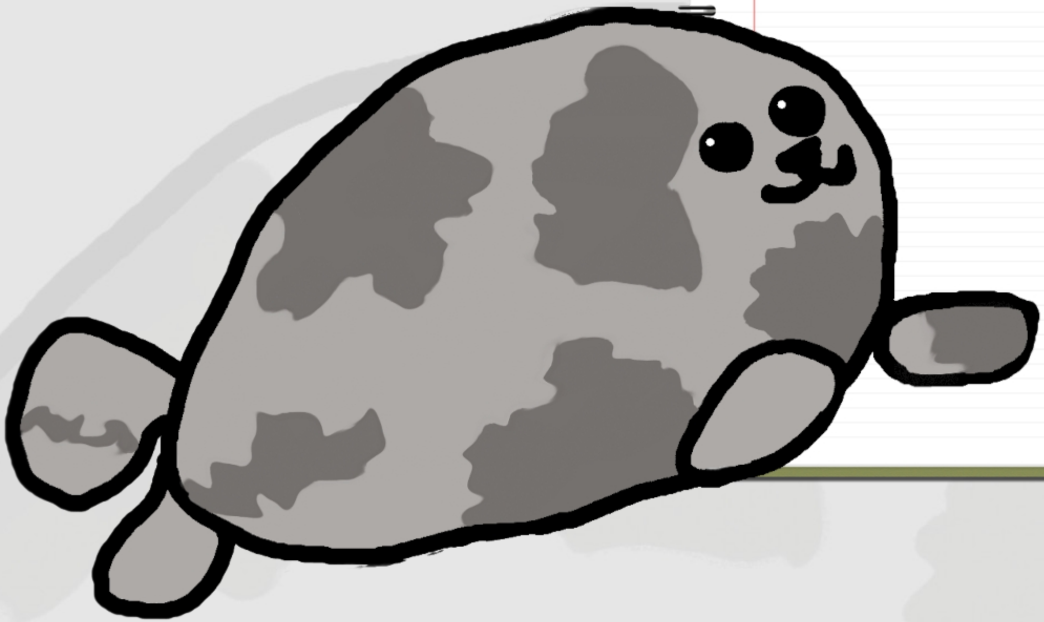
Things X can do:
- Allocate memory
- Do inter process communication
- Access entropy resources
- Open files read only.



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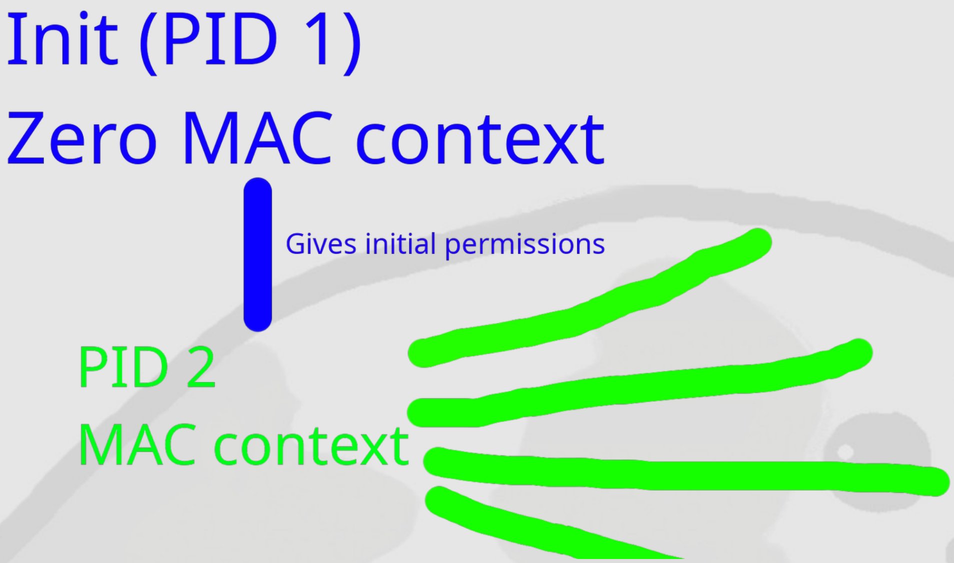



```
type Capabilities is record
   Can_Change_Scheduling : Boolean;
   Can_Spawn_Others      : Boolean;
   ...
end record;

type Context is record
   Action  : Enforcement;
   Caps    : Capabilities;
   Limits  : Limit_Arr;
   Filters : Filter_Arr (1 .. 30);
end record;
```

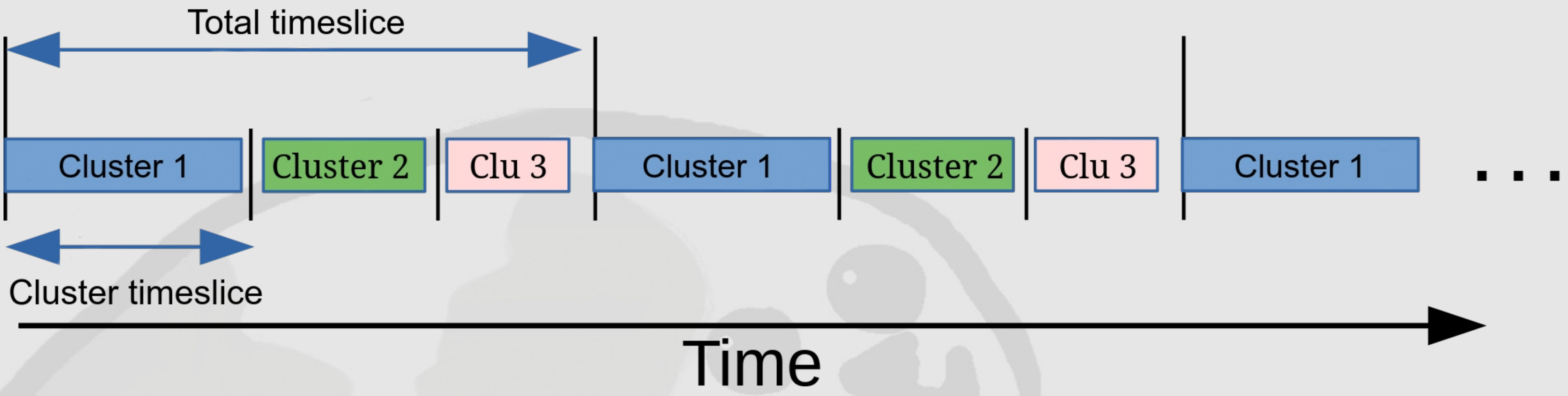
Scheduling

- Processes: Owns a memory map, threads, open files.

- Thread-cluster: Groups threads regardless of process and coordinates them.

- Threads: Basic unit of processor execution, has a set of registers and stack.

Scheduling


Total timeslice
Cluster 1
Cluster 2
Clu 3
Cluster 1
Cluster 2
Clu 3
Cluster 1
. . .
Cluster timeslice
Time

Formal verification

- 3 tiers.
- Architectural code that is difficult to verify or can be reasonably verified to a lesser standard.
- Easily verifiable architecture-independent code.

Formal verification

```
--  Set the user id associated with a process.
procedure Set_UID (Proc : PID; UID : Unsigned_32)
with Global => (In_Out => (Proc_Lock, Proc_Registry),
     Pre    => Is_Valid (Proc) and UID >= 1000,
     Post   => Get_UID (Proc) = UID;
```

```
procedure Set_UID (Proc : PID; UID : Unsigned_32) is
begin
   Registry (Proc).User := UID;
end Set_UID;
```

How do these benefits extend to userland?

```c
// Set the real and effective user Ids
// to 1000.
int err = setuids(1000, 1000);
```

```asm
mov $59, %rax
mov $1000, %rdi
mov $1000, %rsi
syscall # <- Straight to Ironclad!
```

- We never have to leave formally verified code!

Limitations of POSIX and userland verification

```
ssize_t read(int fd, void *buffer, size_t count);
```

Global state is not properly encapsulated!

Limitations of POSIX and userland verification

```
ssize_t read(int fd, void *buffer, size_t count);
                    // FD is a socket.
                    // FD is non blocking, so no waiting.
                    // And this goes all the way up the chain...
```

Global state is not properly encapsulated!

What’s next for Ironclad

- Finishing the last bells and wistles to get Xorg and a proper desktop environment to run.
- Do a port to riscv-based boards, like the visionfive series.
- Expand the existing networking to more network cards.

Follow the progress, check the source code, or download distributions at https://ironclad.cx

Thanks to

AdaCore

Thanks to

- Mintsuki <https://github.com/mintsuki>
- Lucretia <https://github.com/lucretia>
- Ineiev <https://savannah.gnu.org/users/ineiev>