Mirage/kFreeBSD

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Mirage

What is Mirage...?

- *Mirage* is an exokernel which can be used for building secure, high-performance network application on top of various cloud and mobile platforms.
- Source code can be developed on arbitrary operating system, e.g. FreeBSD or GNU/Linux that could be then translated to a specialized standalone microkernel to be run on top of Xen.
- It is developed in OCaml, supplemented with some additional syntax constructs and libraries that is going to be mapped directly to the corresponding operating system primitives.
- Completely event-driven architecture, without preemptive thread scheduling... Yeah! :-)

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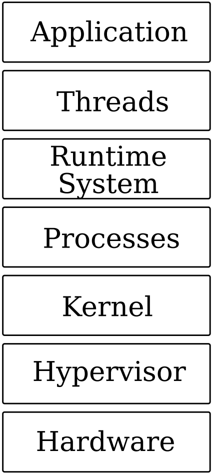
Caml

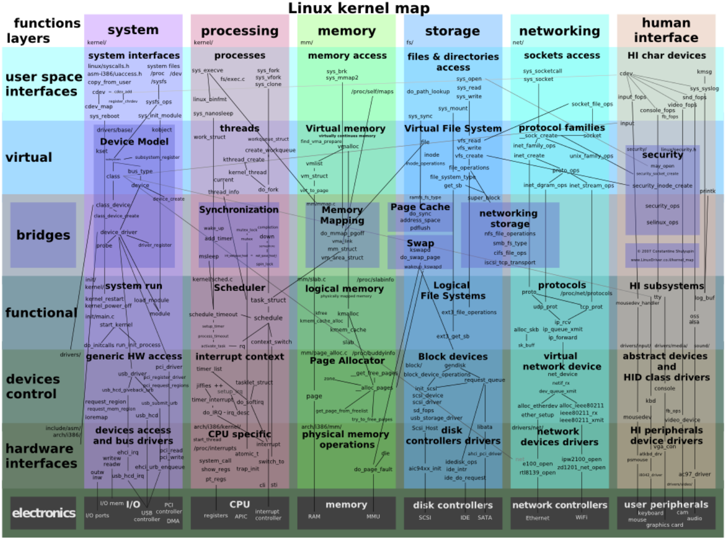
Why Mirage...?

There are way too many layers in today's systems...



Why Mirage...?

Complex and complicated (sometimes even bloated) source code...



How Mirage Can Help With This...?

- Static typing guarantees provided by, and different kind of domain-specific languages expressed in OCaml help to reduce the risk of potential (security) bugs.

- There are more possibilities to deploy compile-time optimizations, *„whole OS optimization”* – less layers are actually present in the resulting binary.

- Each of the systems are simple, easy-to-tackle – multiple cores are handled by the hypervisor.

(Hopefully) A Simple Example

```
let echo () =
  lwt mgr, mgr_t = Manager.create () in
  let src = None, 8081 in
  Flow.listen mgr (‘TCPv4 (src,
    (fun (addr, port) t ->
       Console.log "From %s:%d" (ipv4_addr_to_string addr) port;
       let rec echo () =
         lwt res = Flow.read t in
         match res with
         | None ->
            Console.log "Connection closed";
            return ()
         | Some data ->
            Flow.write t data >>= echo
       in
       echo ()
    )
  ))
```

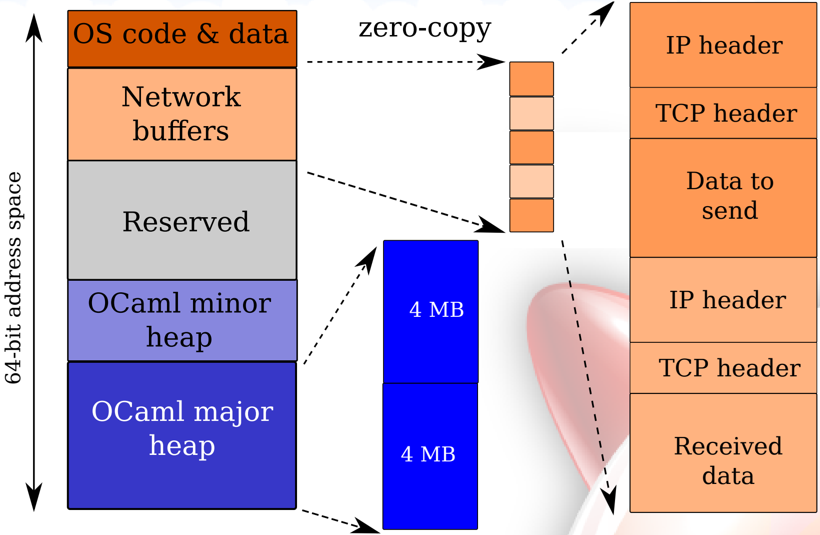
Mirage/Xen

```
$ ocamlopt -output-obj -o app.o echo.ml
```

By using the "Xen MiniOS", we can easily get a bootable kernel.

- It starts up in 64-bit mode, all the memory is available.
- Relatively small size, ab. 50 – 100 KB
- The implementation uses the `lwt` OCaml library, which implements cooperative threading and enables to create monadic blocks.
- Real concurrency is available through Xen (vCPUs).

Memory Management, Processing Network Buffers



Portability

Thanks to OCaml, Mirage is extremely portable. Some of the existing backends:

- **POSIX / TUNTAP**: Standard OCaml runtime + Ethernet tap
- **POSIX**: Standard socket interface via a TCP/UDP socket
- **Javascript**: `ocamljs` – WebSockets
- **Google AppEngine**: `ocamljava` – HTTP
- **Android, iMotes**: `ocamlopt` ARM backend

Further backends are in the works...!

Mirage/kFreeBSD

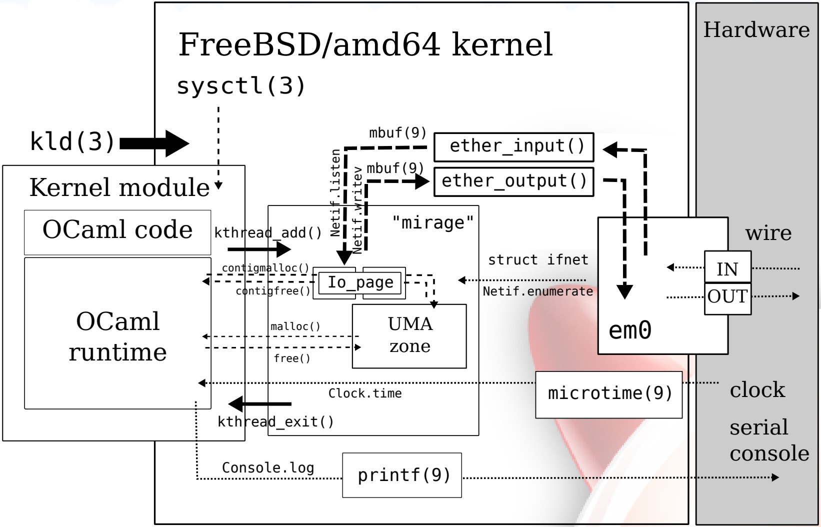
Mirage/kFreeBSD

A summer project at Cambridge University Computer Laboratory: porting Mirage to the FreeBSD kernel.

Objectives:

- Run Mirage-based applications *in* the FreeBSD kernel.
- Implement all the required system-level primivites:
  - Accept and send frames
  - Handle events, interaction with the kernel
  - Preserve „zero-copy” properties
- Study the performance of the generated OCaml code by DTrace.
- Detailed comparison of performance and maintainability of the Mirage network stack and the original FreeBSD network stack.

Current Architecture



Experiences, Challenges

- The OCaml standard library (of version 3.12.1) builds upon floating-point numbers – while the FreeBSD kernel does not really this.

- OCaml ports in the FreeBSD Ports Collection are getting stale. They may possibly need a new maintainer.

- The C compiler is more strict when building kernel modules, uses a different memory model, and it does not support PIC.

- Because of the hybrid C – OCaml solution, it is hard to debug sometimes – logging to serial console works though :-)

- FreeBSD DTrace port has some limitations (when working with kernel modules).

Further Reading

Some recommended links to study:

http://openmirage.org/
http://github.com/avsm/mirage/
http://github.com/mirage/
http://github.com/pgj/mirage-kfreebsd/
http://ocsigen.org/lwt/