OCaml on the ESP32 chip

Well typed lightbulbs await

Lucas Pluvinage – ENS Paris

OCaml Workshop – ICFP 2018

Context

- A language: OCaml

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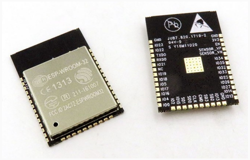
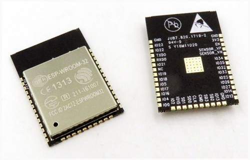
- A platform: ESP32

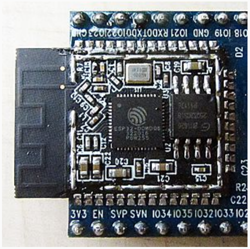
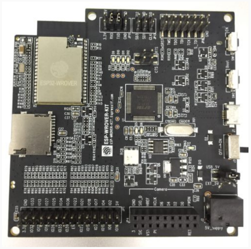


Context

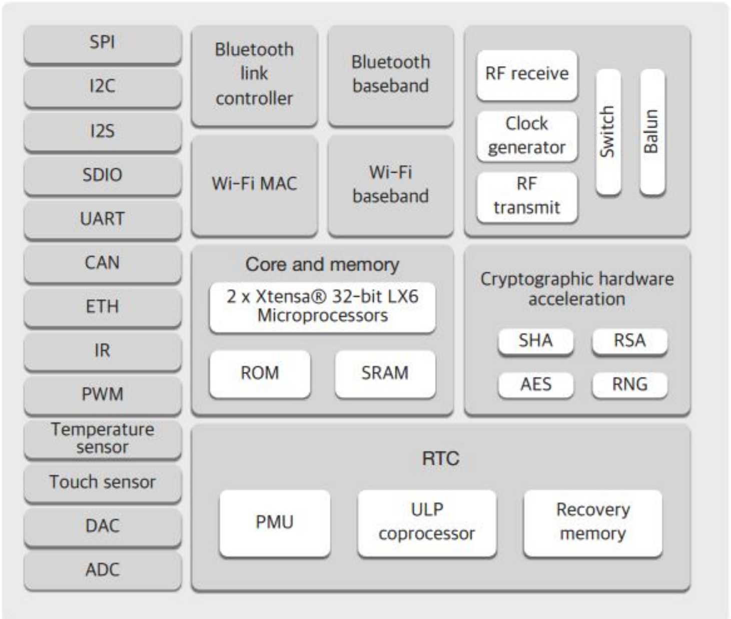
- A language: OCaml
- A platform: ESP32
- An application library: Mirage



ESP32 microcontrollers

ESP32 microcontrollers – hardware



ESP32 microcontrollers – software

- Espressif IoT Development Framework (ESP-IDF)
- FreeRTOS (Real-Time Operating System)
- Written in C – Xtensa backend for GCC
- MicroPython port available

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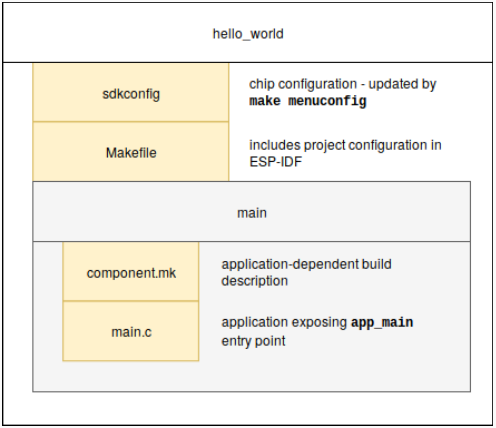
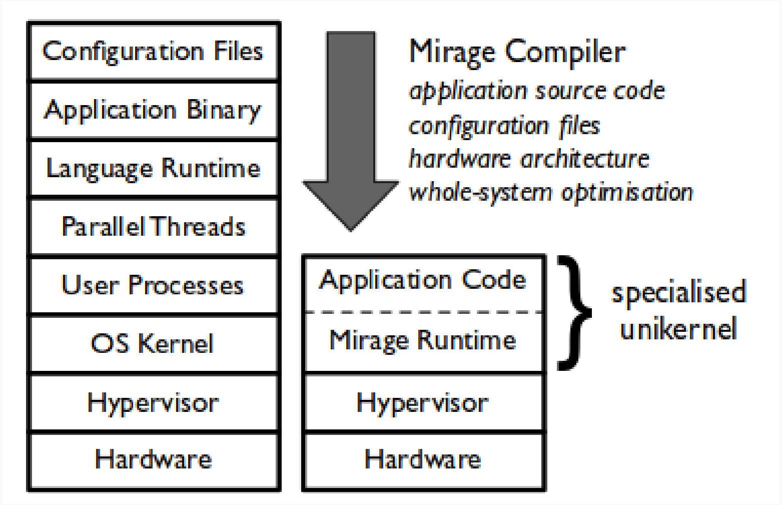

hello_world
sdkconfig
chip configuration - updated by **make menuconfig**
Makefile
includes project configuration in ESP-IDF
main
component.mk
application-dependent build description
main.c
application exposing **app_main** entry point

Mirage unikernel framework

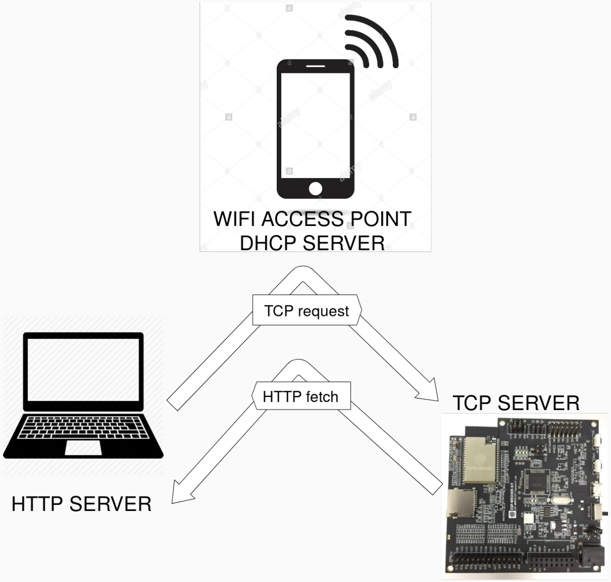
What is an unikernel ?



Picture from *Unikernels: Library Operating Systems for the Cloud*

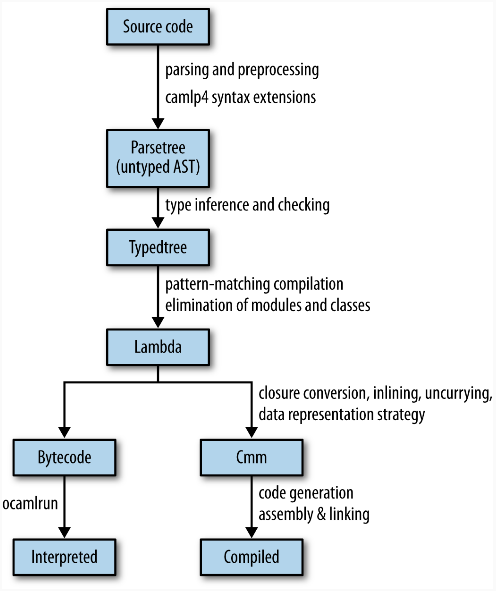
Time for a demonstration

Time for a demonstration



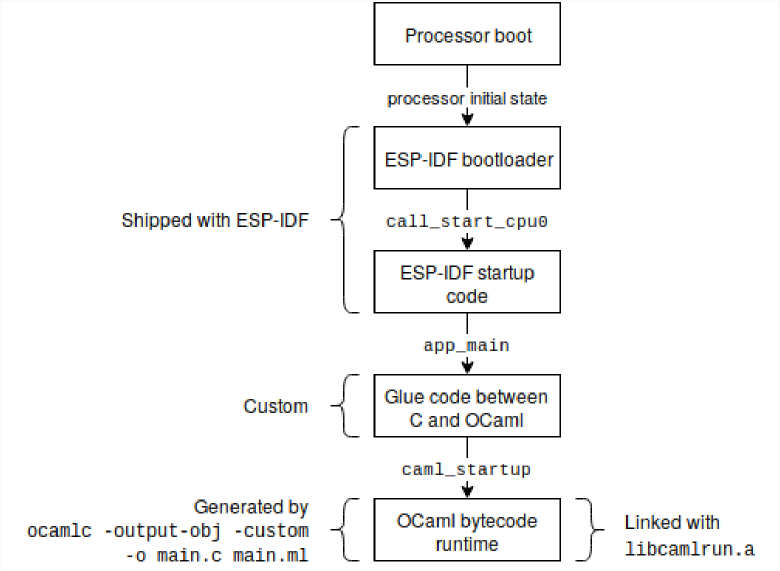
Compiling OCaml for ESP32

Compilation paths


Source code
parsing and preprocessing
camlp4 syntax extensions
Parsetree (untyped AST)
type inference and checking
Typedtree
pattern-matching compilation
elimination of modules and classes
Lambda
closure conversion, inlining, uncurrying,
data representation strategy
Bytecode
Cmm
ocamlrun
code generation
assembly & linking
Interpreted
Compiled

Picture from `https://dev.realworldocaml.org/compiler-frontend.html`

Bytecode execution path on ESP32



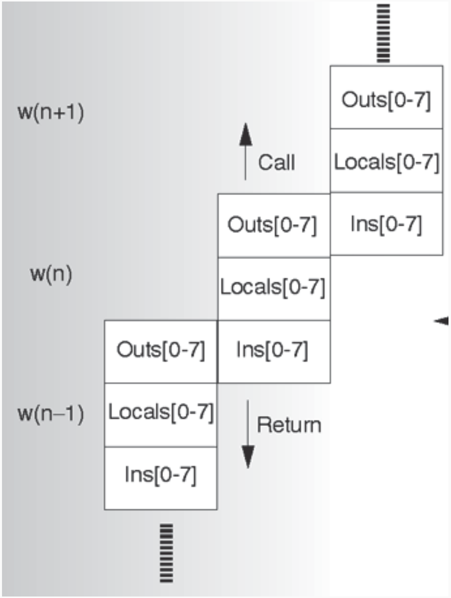
Native compilation support for Xtensa processors

OCaml compiler backend

- `asmcomp/xtensa/`
    - `proc.ml`: processor and calling conventions
    - `arch.ml`: architecture
    - `emit.mlp`: assembly emission
- `asmrun/xtensa.S` runtime interface between OCaml and C

No interference with the OCaml compiler code !

Register windowing and calling conventions

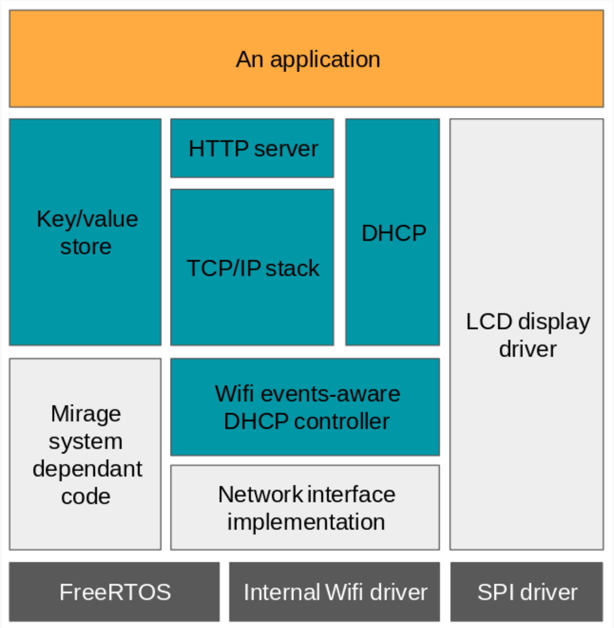


Cross-compiling for ESP32 microcontrollers

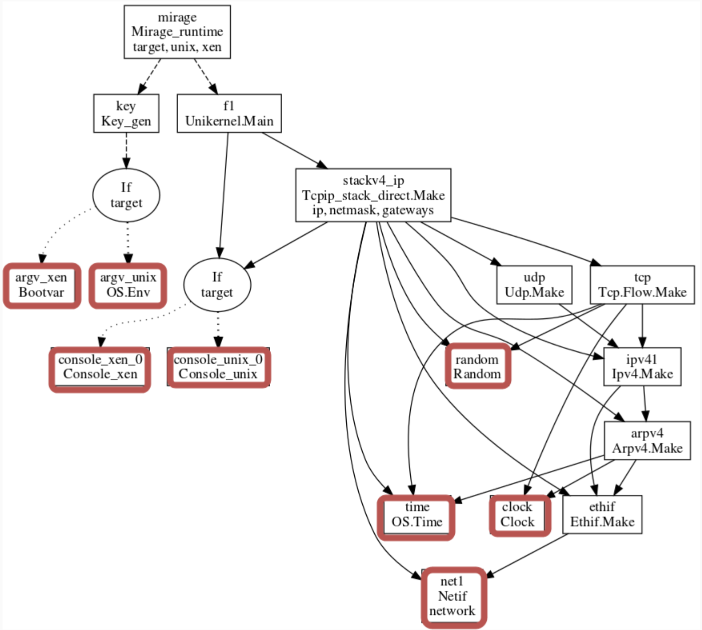
- Integration with build systems: from a single parameter to more extensive tweaking.
- Integration with opam:
    - OCaml 4.06.0+32bit switch
    - Cross-compiler in `[switch root]/esp32-sysroot`
    - This allows to access both host and target packages.
- `opam-cross-esp32`: 127 packages ported for cross-compilation.

Unikernels for embedded applications

Unikernels and the Mirage project



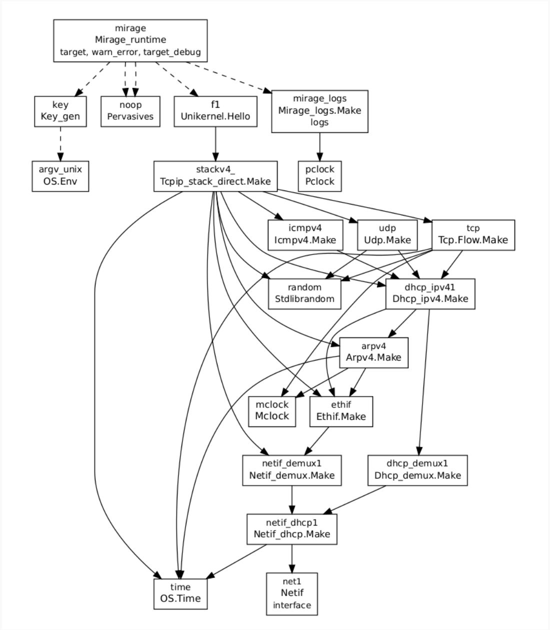
What to you need to build a standalone application ?



`OS.Main.run: unit Lwt.t -> unit`

- Collaborative threading with Lwt library:
  ```
  bind: 'a Lwt.t -> ('a -> 'b Lwt.t) -> 'b Lwt.t
  return: 'a -> a Lwt.t
  join: unit Lwt.t list -> unit Lwt.t
  pick: 'a Lwt.t list -> 'a Lwt.t
  ```
- Timer feature:
  ```
  Time.sleep_ns: int64 -> unit Lwt.t
  ```
- Event system:
  ```
  Event.wait_for_event: int -> unit Lwt.t
  ```

Porting network features



Porting network features

- Netif:
    - `write: t -> buffer -> (unit, error) result Lwt.t`
    - `listen: t -> (buffer -> unit io) -> (unit, error) result Lwt.t`
    - `mac: t -> macaddr`
    - `get_stats_counters`, `reset_stats_counters`
- Netif_DHCP: input a Netif and outputs a Netif and a DHCP module. Acts as a multiplexer.

Results

Applications

- LCD screen control
- Wifi AP/Station mode/both
- HTTPS
- DHCP
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Application	Code	Magic (LTO)	Rodata	Dynamic RAM
Hello world	764K	270K	151K	133K
AP - DHCP server	1058K	405K	256K	270K
STA - DHCP client	1217K	446K	289K	215K
HTTP fetch	2366K	1083K	622K	600K
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LCD canvas over HTTP	2368K	1038K	592K	700K

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LTO is fantastic! See PR#608 in `ocaml/ocaml`

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Overview

- Lot of exploration that resulted in a great proof of concept
- Opportunity for further research in the field of unikernels for embedded devices
- Very pleasant team and lab!

Resources and conclusion

- `well-typed-lightbulbs` Github organization.
- `https://www.lortex.org/esp32/` blog posts.

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Götz Salzmann
@gtz42

Suivre

Wow, this makes me want to finally learn ocaml:

Justin Cormack @justincormack
Really excited by Mirage unikernels on ESP32 microcontrollers lortex.org/posts/mirage/e… #unikernelsarenotaboutvirtualmachines

Traduire le Tweet

19:00 - 30 août 2018

4 J'aime

4