UNIVERSITY OF CAMBRIDGE

Turning down the LAMP

Software Specialisation for the Cloud

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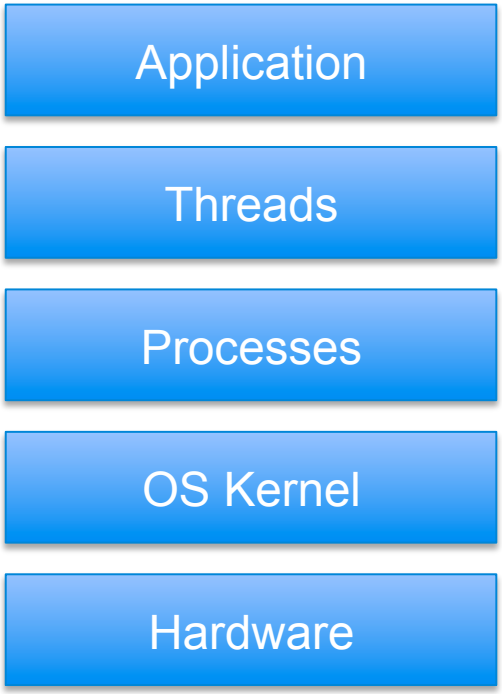
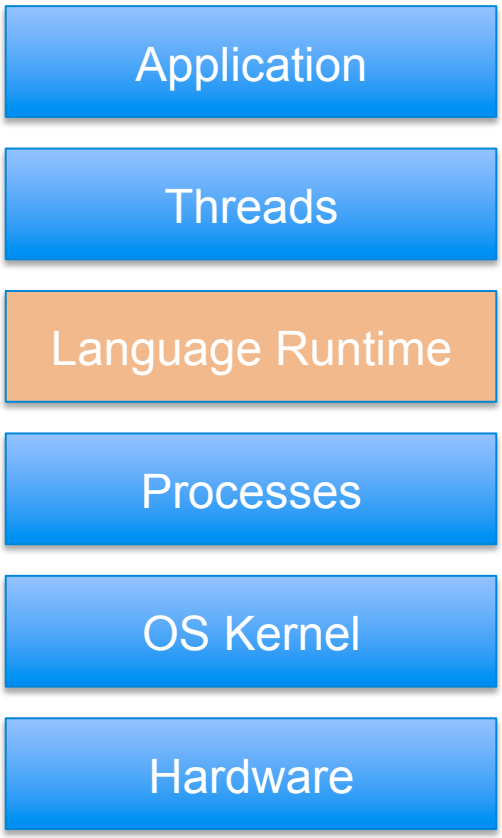
Motivation: Layers



Motivation: Layers



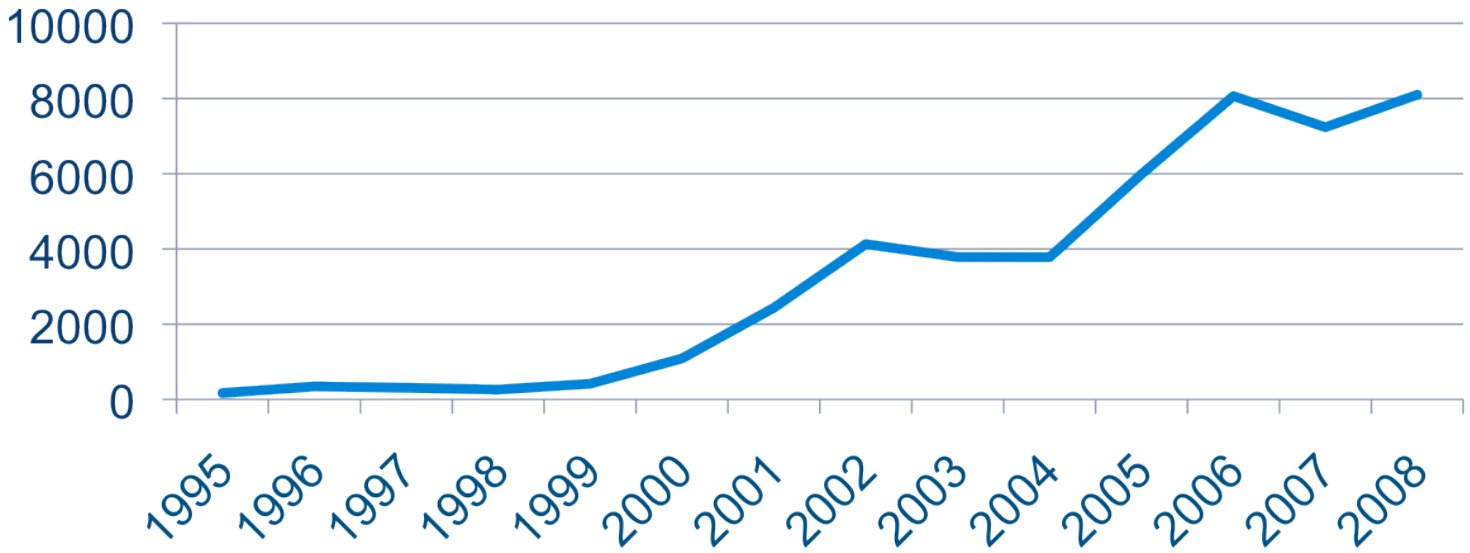
Motivation: Layers

- Application
- Threads
- Language Runtime
- Processes
- OS Kernel
- Hypervisor
- Hardware

Motivation: Security

- **Linux Kernel**
  - *Mar 1994:* 176,250 LoC *May 2010:* 13,320,934 LoC

Most core Internet services still written in C / C++



Approach: Reconstruct

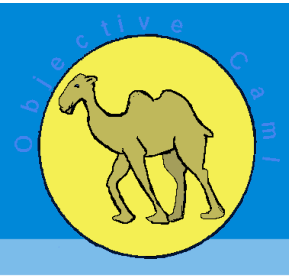
- Most layers are in place **for compatibility**
  - **Xen:** to run operating systems
  - **Linux:** to run POSIX applications
  - **Processes:** to protect C applications

- **If we start again, how much can things be improved?**

Language

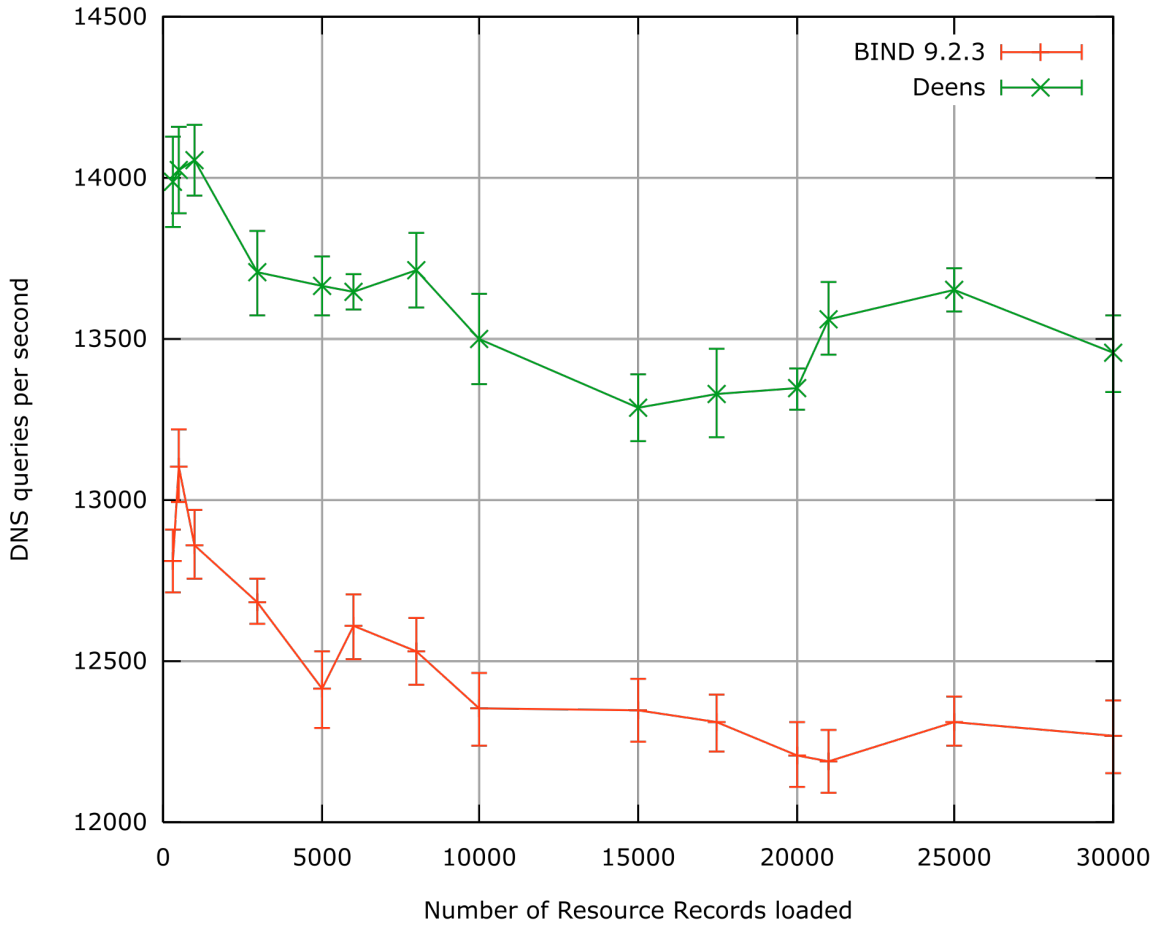
- Choose a **new implementation language** that:
  - Has **strong static typing**
    - This improves performance (more work at compile time)
    - Reduces run-time bugs (memory safety)
  - Has a **simple run-time system**
    - Essential for a low-level systems language
  - Is **extensible**, e.g. for new methods of parallelization

Language: Objective Caml

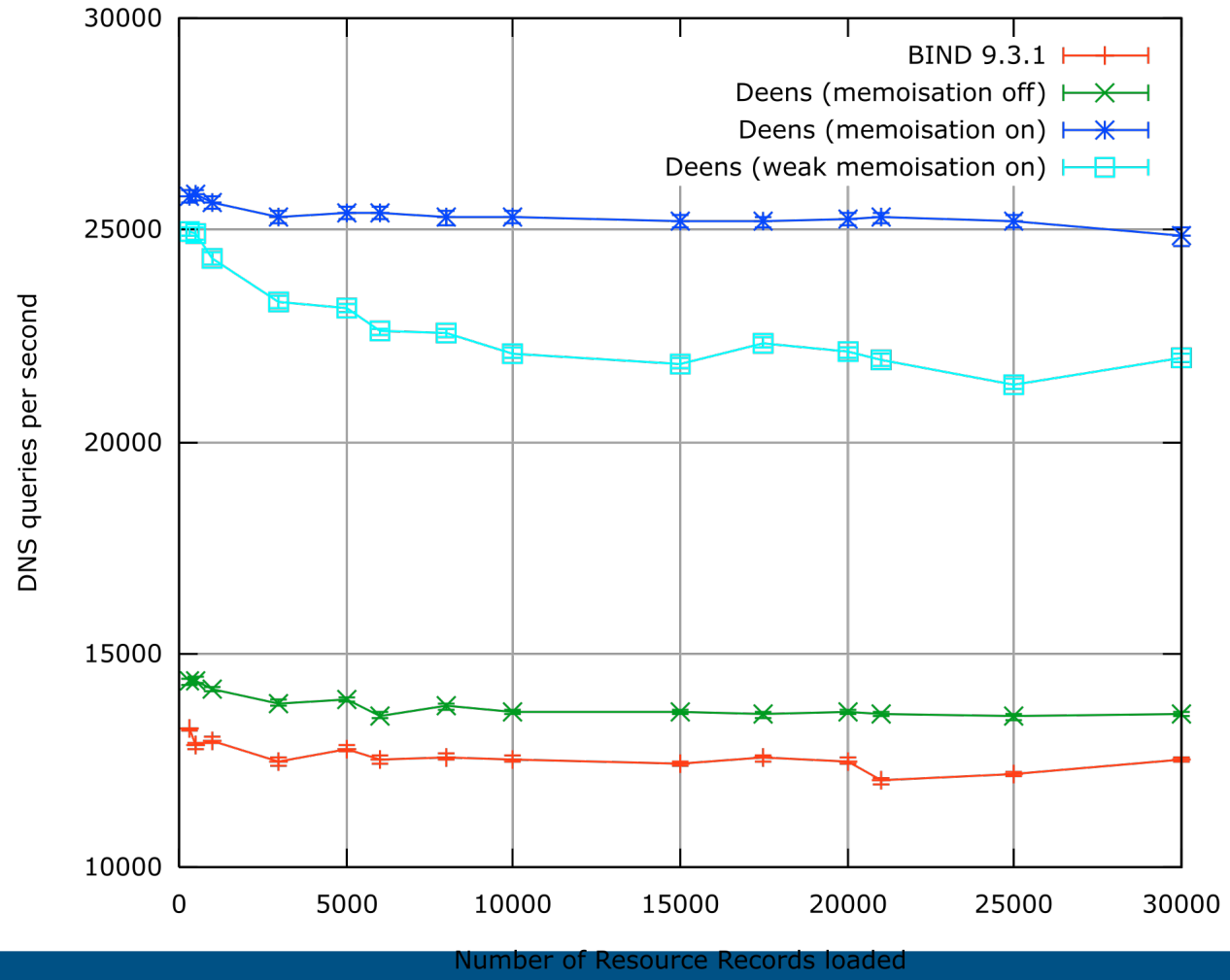


- Developed since 1996 in INRIA, France.
- Based on the ML type-system: **type inference**, **static typing**
- Proven in **industry**:
  - Citrix XenServer (virtualization)
  - Jane Street Capital (finance)
  - Skydeck, MLState (web)
- **Extensible** type-system and grammar (FlowCaml, JoCaml, HashCaml)

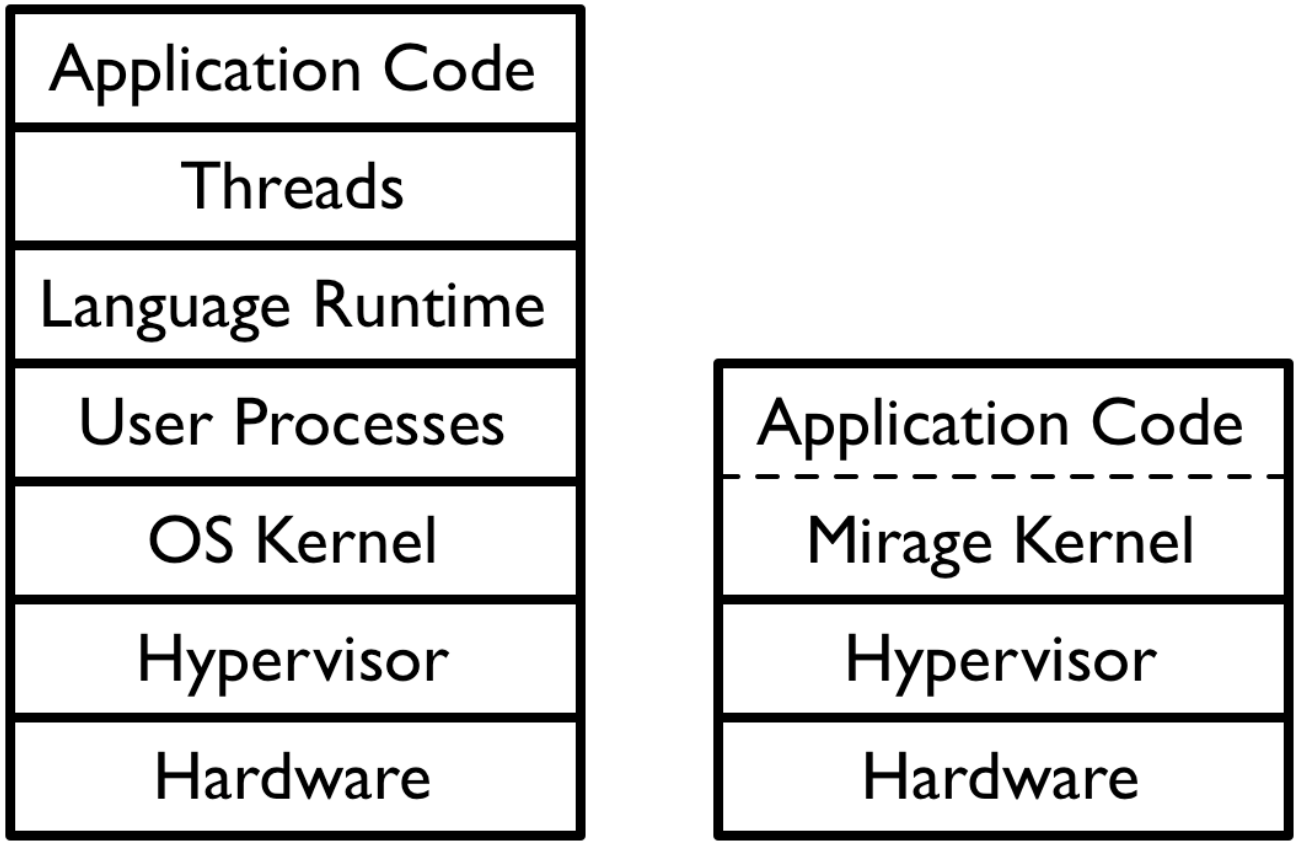
DNS: Performance of BIND (C) vs Deens (ML)



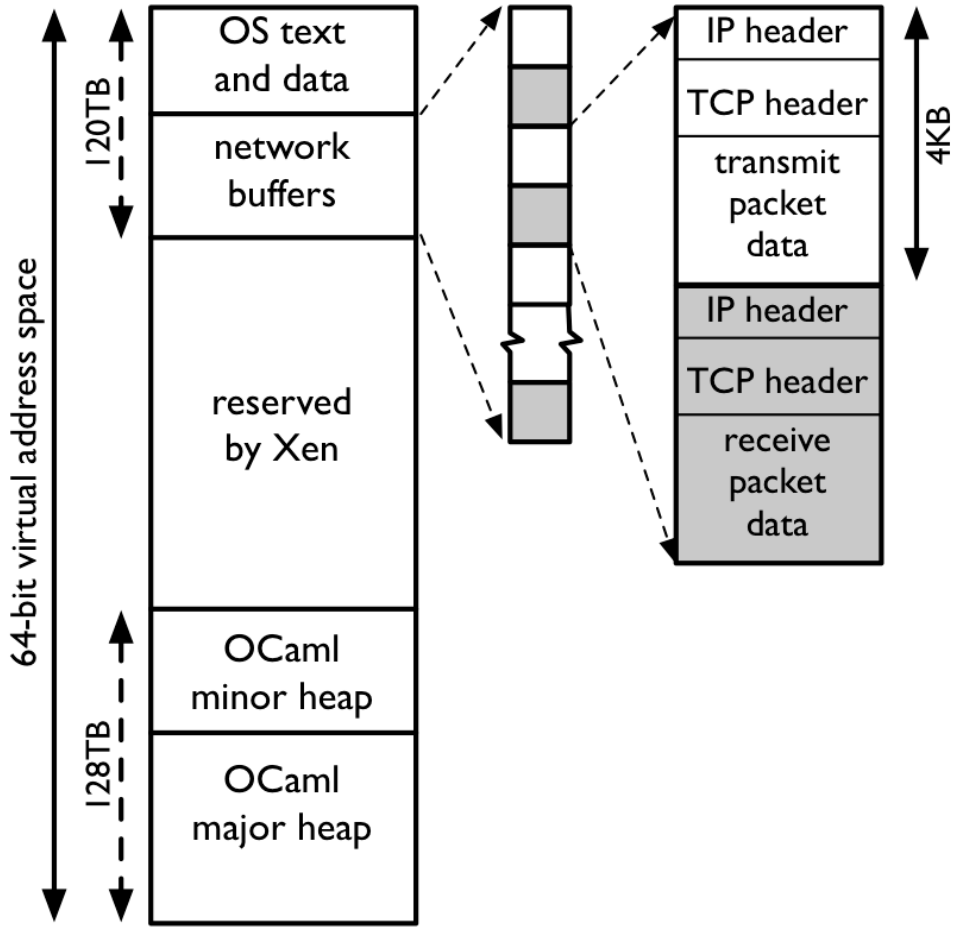
DNS: with functional memoisation



MirageOS: Specialised application kernels



MirageOS: memory layout, concurrency



Memory

- 64-bit PV layout
- Single process
- Zero-copy I/O to Xen
- 4MB super page mappings

Concurrency

Cooperative threading and events
Fast inter-domain communication
Works across **cores and hosts**

Mirage: storage

Language-integrated storage:

```
type t = { name: string; age: int }

let me = { name = “Anil”; age=31 }

let save () = t_save db me

let get () = t_get ~age:(`Gt 30) db
```

Advantage: SQLite is fast and simple

Downside: interoperability. Object SCSI (Panassus) ?

Mirage: concurrency

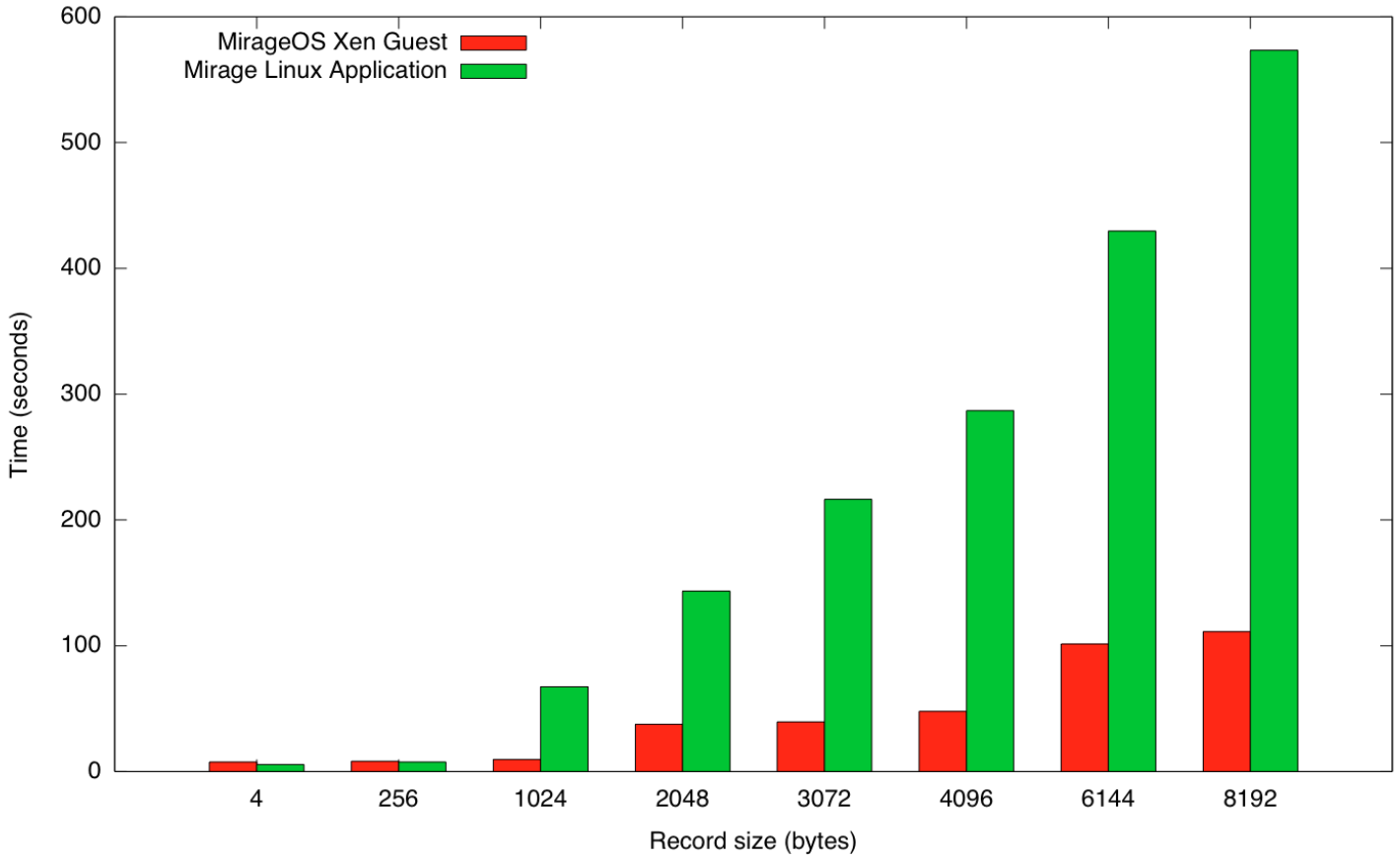
Language-integrated concurrency:

```
let rec loop () =
    printf “hello!\n”;
    lwt s = sleep 2.5 in
    loop ()
# val loop : unit -> Lwt.t unit = <fun>
```

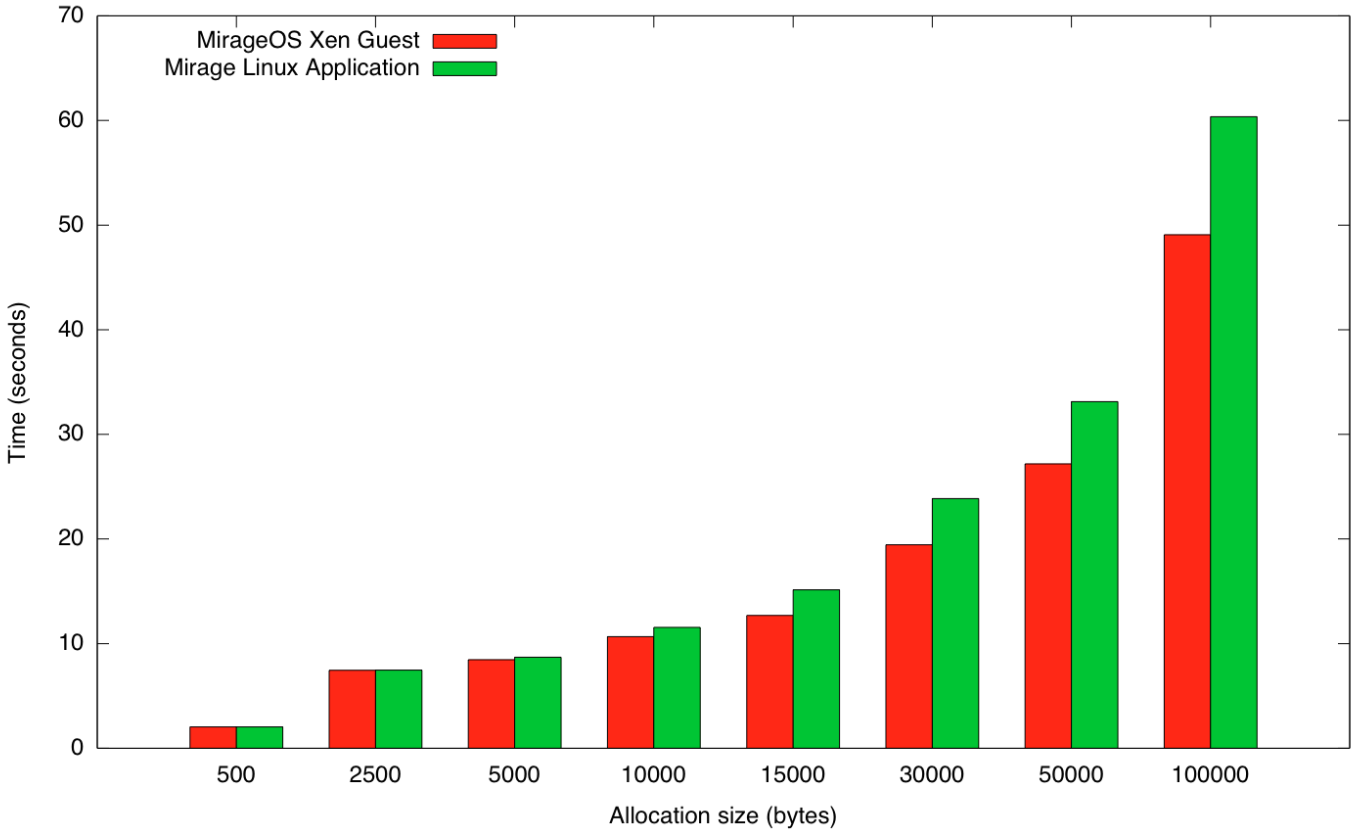
Advantage: Blocking functions have a special type **Lwt.t**

Downside: Extra function call overhead

MirageOS: SQL performance vs PV Linux



MirageOS: memory performance vs PV Linux



The Future: Multi-scale Operating System

- We produce **highly optimized kernels** from a **portable functional language** code base which can **adapt** to the local hardware.
- Same source code runs efficiently on:
  - **mobile phone** environment (e.g. using Cadmium or ARM)
  - **desktop OS** for development (e.g. using Eclipse IDE)
  - **cloud** for cheap scalability (using Xen kernel backend)
  - and soon GPGPU? FPGA? Intel SCC?

Applications

- **Dust Clouds**
  - Thousands of tiny virtual machines (~100k each)
  - Same price as a few conventional “large” virtual machines
  - Sprinkle them world-wide to run Tor anonymity nodes
- **Self-scaling Services**
  - As load spikes, request more resources dynamically from cloud
  - Detect resource imbalance and “migrate” globally on demand
- **All requires low-latency, high-reliability cloud APIs**

Observations

- Static address space layouts permit **multiple language runtimes** to run simultaneously in one VM container.
  - Alternative to Facebook compiling PHP to C++ using HipHop
- **Partial evaluation** has the potential save huge amounts of energy
  - Already used in systems, e.g. libc/arch/x86_64
- Thinking **multi-scale** instead of **multi-core** is important for OS and language design:
  - Newer multi-core look like multiple hosts in many ways (failure, coherency, communication latency).

Questions?

Open-source:

http://github.com/avsm/melange
http://github.com/avsm/mirage
http://github.com/mirage

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avsm