NEC

Unikernels Made Easy

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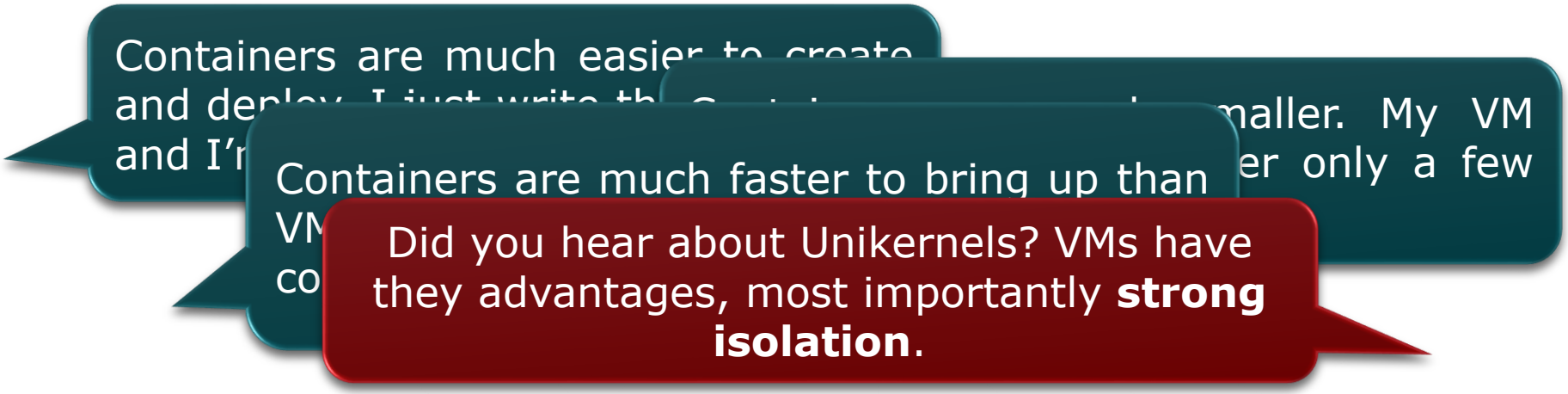
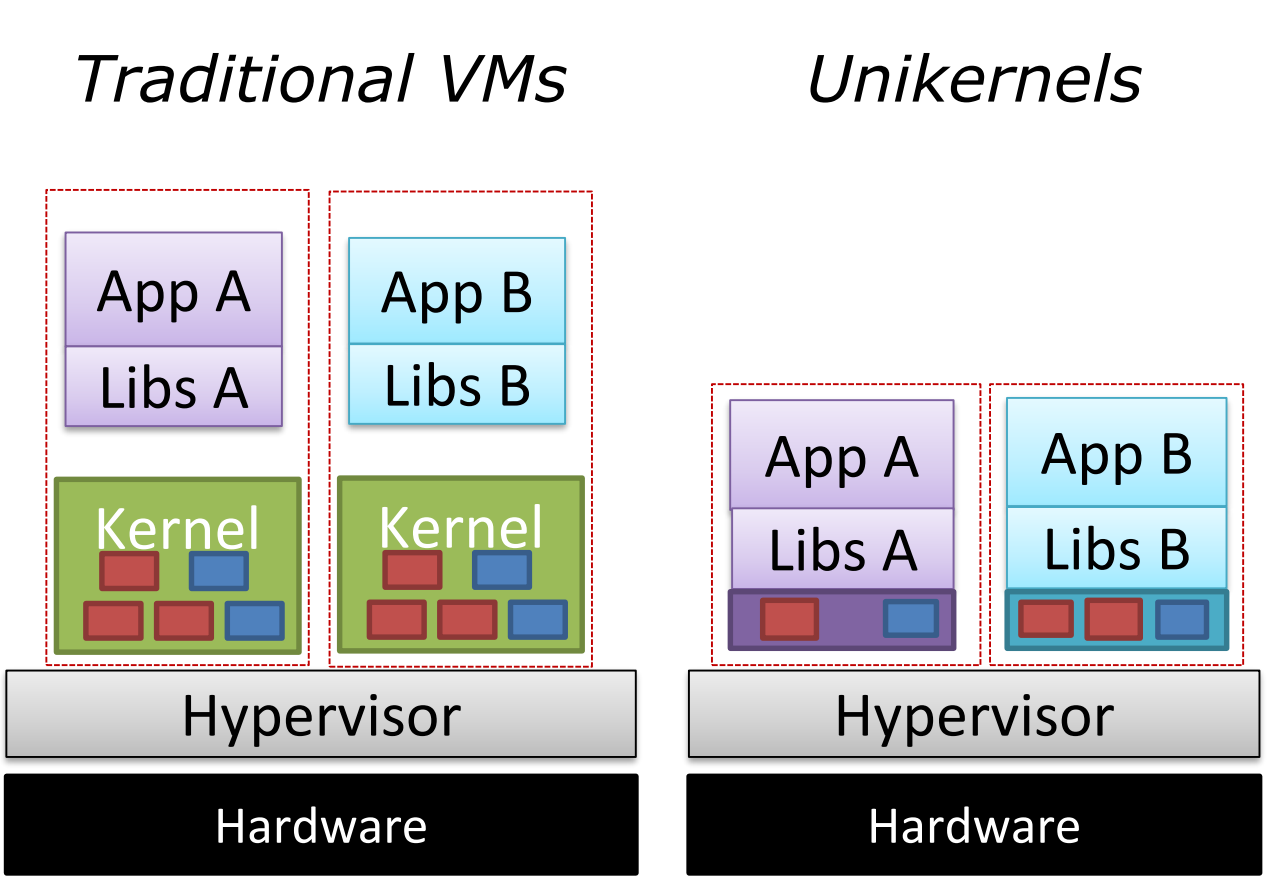
VMs vs Containers

- VMs have been around for a long time
  - They allow consolidation, isolation, migration, …
- Then containers came and many people LOVED them. Why?



Unikernels as VMs



- Unikernels are purpose-built
  - Thin kernel layer, *only what application needs*
  - Single *monolithic* binary containing OS and application
- No isolation within Unikernel needed, done with hypervisor
  - One application → Flat and single address space
- Further advantages from specialization

Unikernel Advantages

- Fast instantiation, destruction and migration time
  - 10s of milliseconds

- Low memory footprint
  - Few MB of RAM

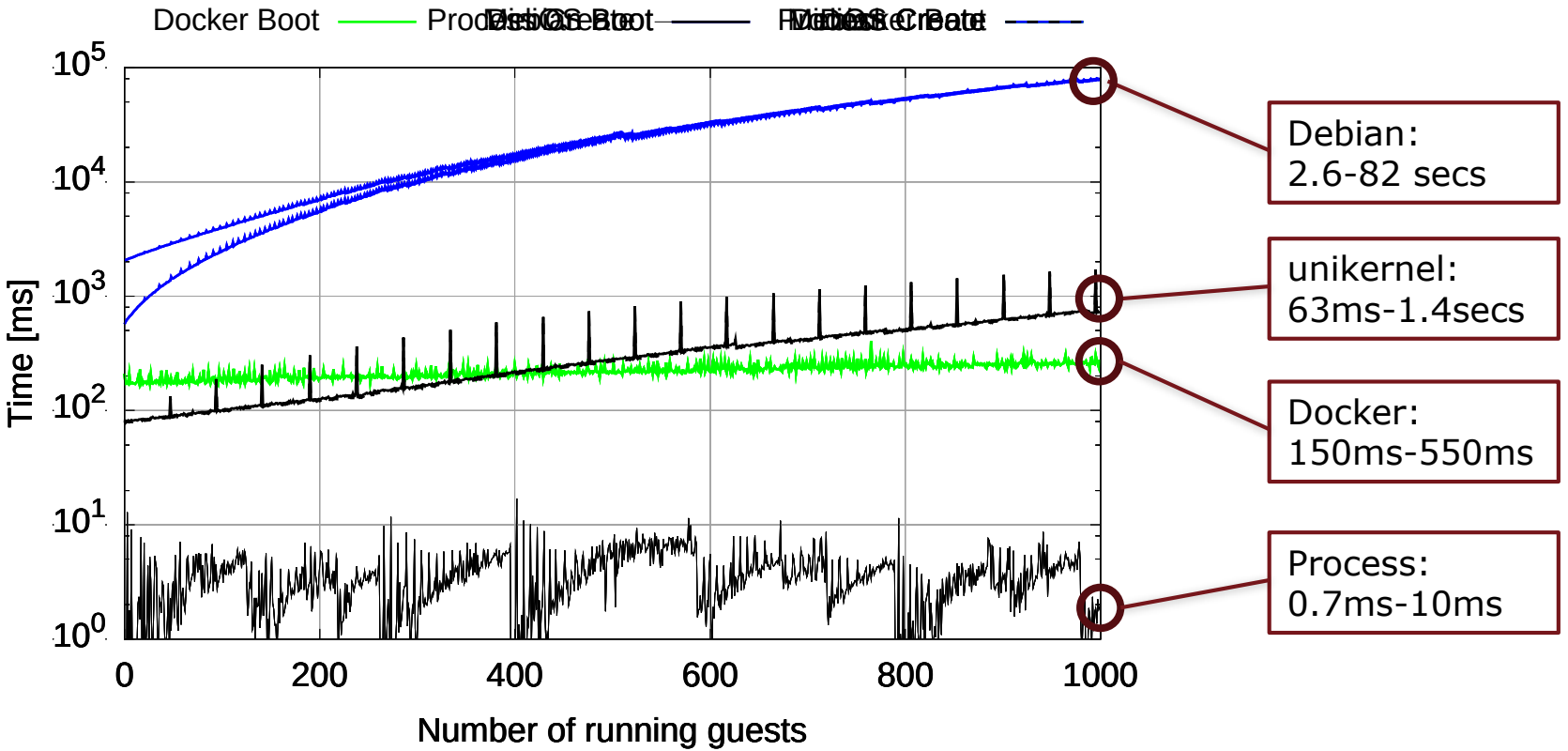
- High density
  - 10k guests on a single server node

- High Performance
  - 10-40Gbit/s throughput
  - 5-6x more req/s than standard nginx

- Reduced attack surface
  - Less components exist in Unikernel
  - Strong isolation by hypervisor

LightVM [Manco SOSP 2017], Elastic CDNs [Kuenzer VEE 2017], Superfluid Cloud [Manco HotCloud 2015] , ClickOS [Martins NSDI 2014]

In Numbers: Instantiation Times



Server: Intel Xeon E5-1630 v3 CPU@3.7GHz (4 cores), 128GB DDR4 RAM, Xen/Linux versions 4.8

Application Domains

Minimal SW Stack

Reactive vNFs,
Serverless,
…

Fast boot, migration, destroy

Resource efficient

Minimal SW Stack

Serverless,
(Per-customer) vNFs,
IoT,
MEC,
…

Specialization

NFV,
MEC,
…

High performance

Mission critical

Small code base
→ Low attack surface
→ Cheaper verification

Automotive,
IoT,
…

The Devil is in the Details

So, Unikernels:

- Give similar speed and size of containers
- But add **strong isolation** with *virtualization* and increase **security** due to *smaller code base*

The problem is *Unikernel development:* Optimized Unikernels are manually built

- Building takes several months or even longer
  - *We've done it before, multiple times*
- Potentially repeat the process for each target application
  - *We've done that too…*

That's not an effective way of doing things!

Unikraft: A Unikernel Framework

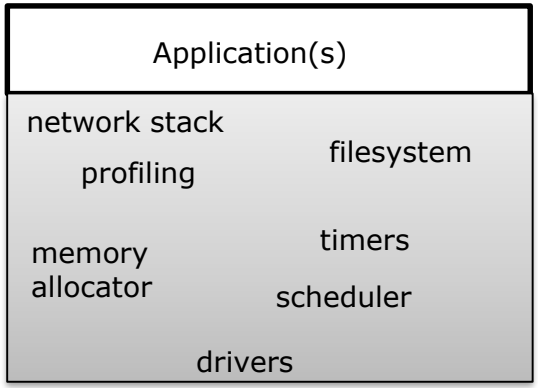
Motivation

- Support wide range of use cases
- Simplify building and optimizing
- Common and shared code base for Unikernel creators
- Support different hypervisors and CPU architectures

Unikraft

- Concept:
  "Everything is a library"
  - Decomposed OS functionality
- Unikraft's two components:
  - Library Pool
  - Build Tool

The Unikraft Way: Everything is a library



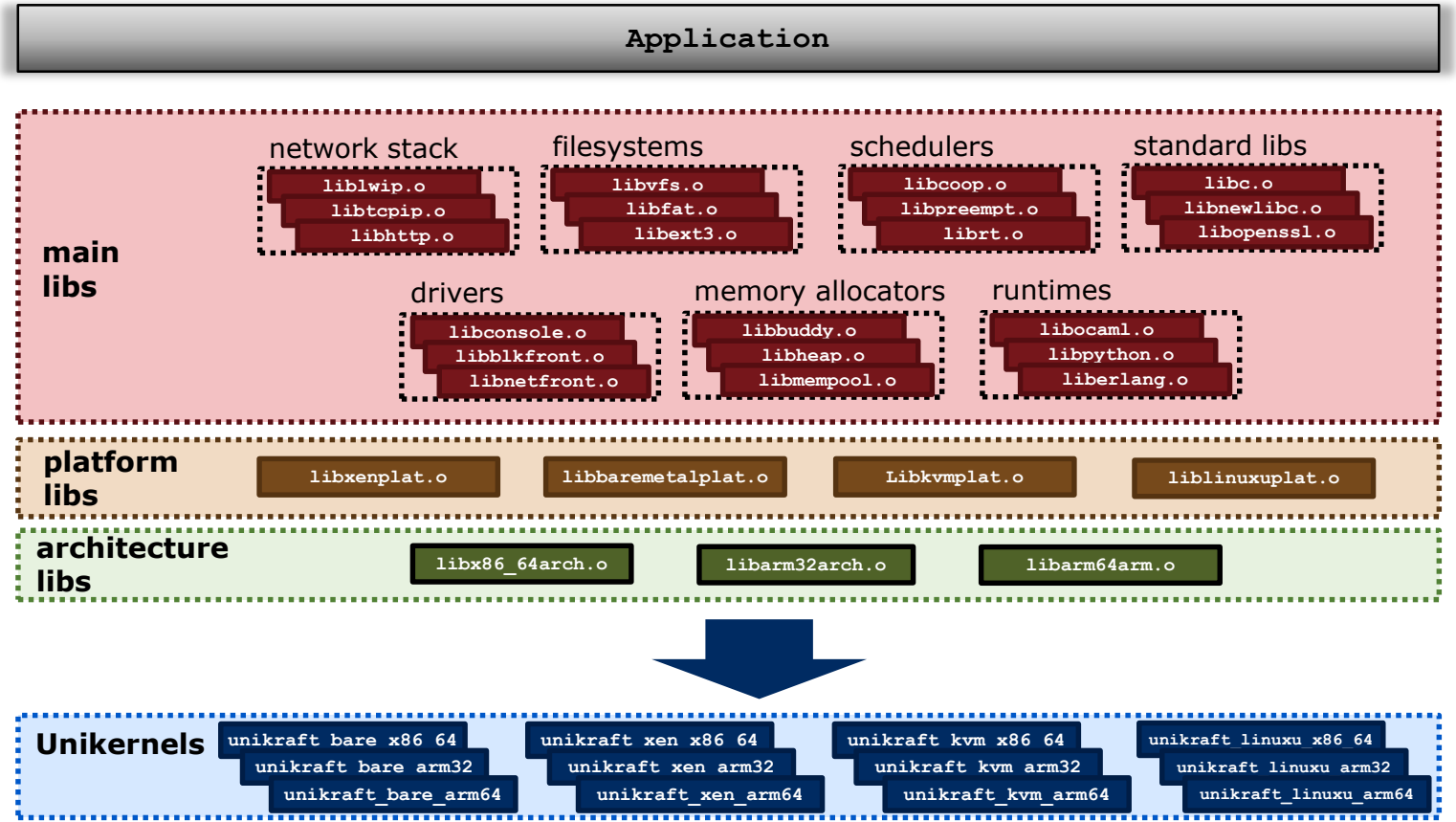
The Unikraft Way: Everything is a library

Decompose OS into a set of libraries

Unikraft

Overview

Unikraft Component 1: Library Pool



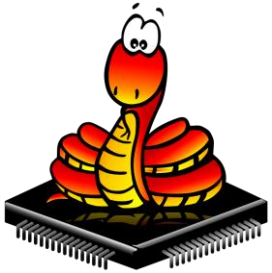
1. **Select/Create Application**
2. **Select and Configure libraries**
3. **Build**
4. **Run**

Example Library Selection

Micropython Unikernel for KVM on x86_64

My Python App	libmicropython.o
liblwip.o	libvfscore.o
libschedcoop.o	liballocbbuddy.o
libkvmplat.o	libx86_64arch.o

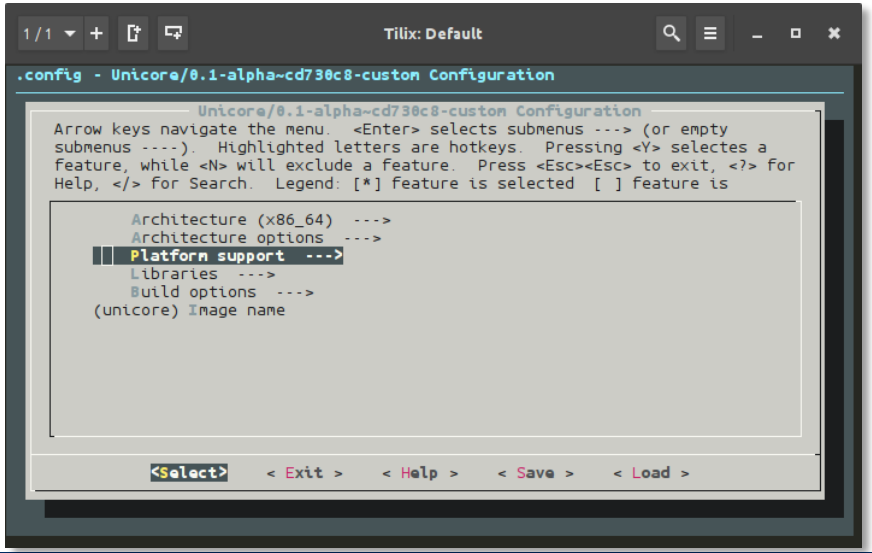
=



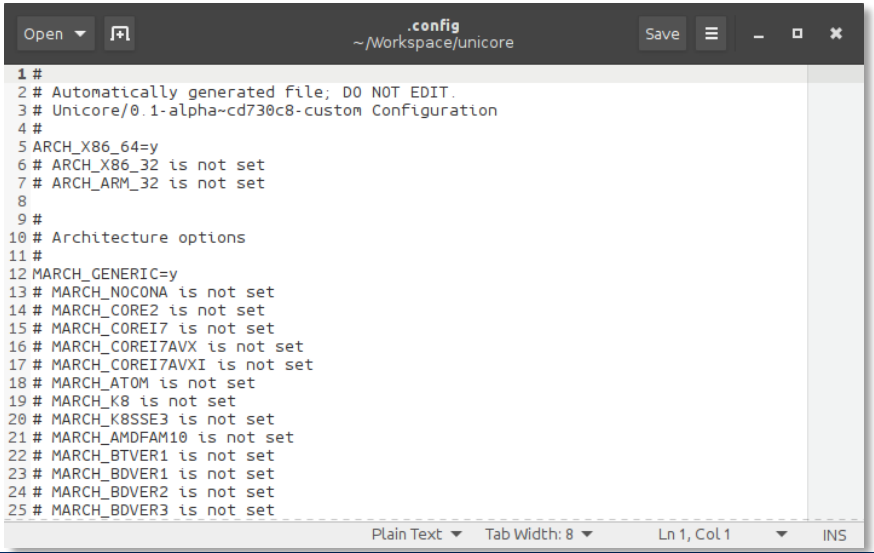
Unikernel

Unikraft Component 2: Build Tool

- Kconfig/Makefile based
- `make menuconfig`
  - Choose options in the menu that you want for your application
  - Choose your architecture and target platform(s) (currently: Xen, KVM, Linux)
- Save config and `make`



.config



Unikraft

Current Status

Available Libraries

Core Libraries

- libfdt
  - Flat device tree parser
- libnolibc
  - A tiny libc replacement
- libukalloc
  - Memory allocator abstraction
- libukallocbbuddy
  - Binary buddy allocator
- libukargparse
  - Argument parser library
- libukboot
  - Unikraft bootstrapping
- libukdebug
  - Debug and kernel printing
  - Assertions, hexdump
- libuksched
  - Scheduler abstraction
- libukschedcoop
  - Cooperative scheduler
- libukbus
  - abstraction for device buses, e.g., PCI
- libuklock
  - mutexes and semaphores
- libukmpi
  - message-passing interface
- libuknetdev
  - network device support
- libukswrand
  - pseudo-RNG interface
- libuktimeconv
  - time calculation/conversion
- libvfscore
  - basic file descriptor management / mapping / handling

External Libraries

- libnewlib
  - libc originally aimed at embedded devices
- liblwip
  - lightweight TCP/IP stack

Architecture Libraries

- libarmmath
  - 64bit arithmetic on Armv7
- libx86ctx
  - Scheduling/context switch support for x86

Platform Libraries

- libxenplat
  - Xen (PV)
  - x86_64, ARMv7
- libkvmplat
  - QEMU/kvm
  - x86_64, ARM64, virtio-net support
- liblinuxuplat
  - Linux userspace
  - x86_64, ARMv7

Current work in the pipeline: Upstream soon

Core Libraries

- libukschedpreempt
  - Pre-emptive scheduler

External Libraries

- libclick
  - Click modular router (e.g., for NFV)
- libaxtls
  - TLS support aimed at embedded devices
- libstdc++
- libmicropython
  - Python implemented for microcontrollers

Architecture Libraries

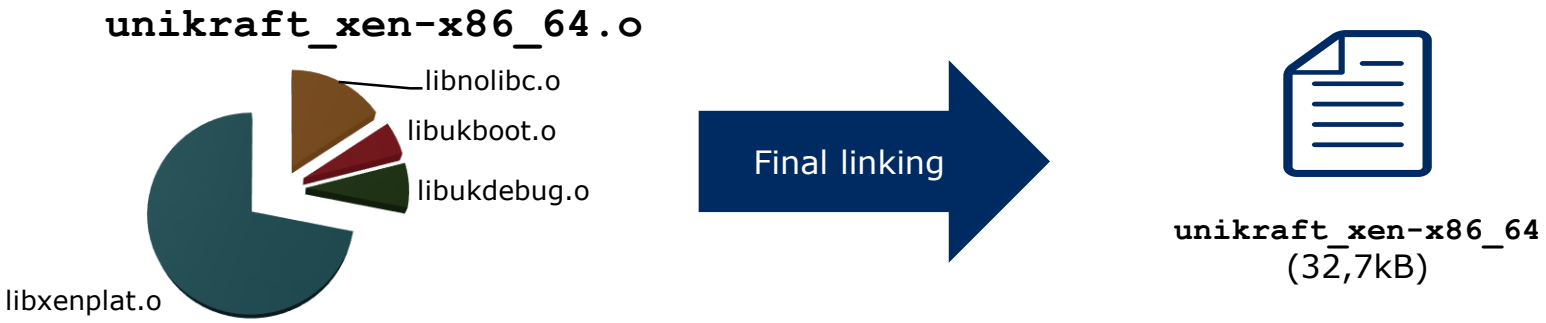
- libarmctx
  - Scheduling/context switch support for Arm

Platform Libraries

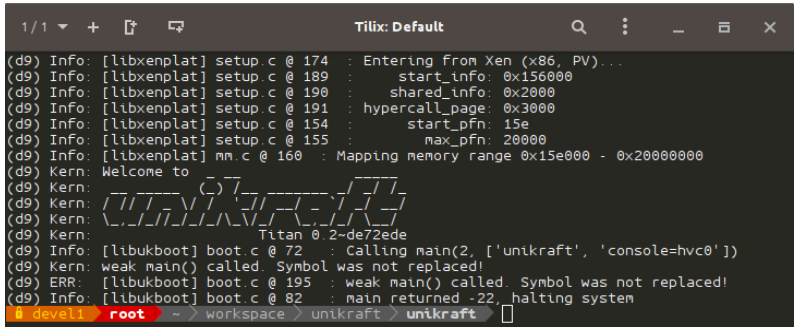
- libxenplat
  - Arm64 support
  - netfront support
- liblinuxuplat
  - tap device based networking support

A Baseline Example…

- *Xen PV x86_64 binary*



- Boots and prints messages to debug console (with min. 208kB RAM)



- More functional example: VNF Unikernel Click: 4.5 MB (8 MB RAM)

Unikraft

It is Open Source!

Join us!

- Unikraft is OpenSource since Dec 2017 and under the umbrella of

- Community is growing! External contributors from
  - Romania (networking, scheduling; from University Politehnica Bucharest)
  - Israel (bare-metal support, VGA driver)
  - China (Arm64 support; from Arm)

There is still a lot to do! Get in touch with us!

Drop us a mail
minios-devel@lists.xen.org
Join our IRC channel
#unikraft on Freenode

Resources

- Wiki
  - https://wiki.xenproject.org/ (Search for Unikraft)
- Dokumentation
  - http://www.unikraft.org
- Sources (GIT)
  - http://xenbits.xen.org/gitweb/ (Namespace: Unikraft)
- Mailing list (shared with Mini-OS)
  - minios-devel@lists.xen.org
- IRC Channel on Freenode
  - #unikraft
- NEC-Team
  - http://sysml.neclab.eu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Example

"Hello World" with Unikraft

Repo Structure

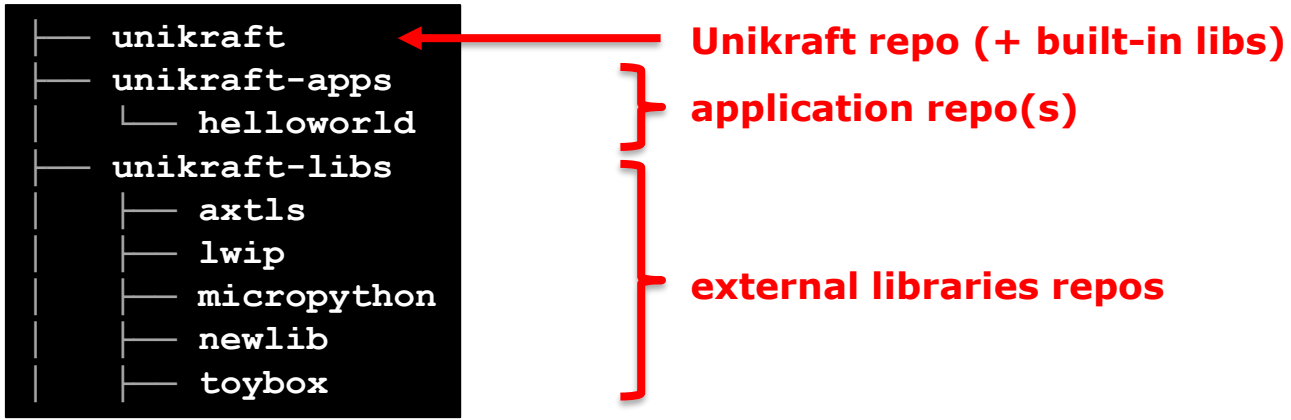
- Clone the main Unikraft repo

```
git clone git://xenbits.xen.org/unikraft/unikraft.git
```

- Clone any external library repos

```
git clone git://xenbits.xen.org/unikraft/libs/newlib.git
```

- Create repo for the actual application



“Hello World” Application

Four files to integrate to Unikraft

- `Makefile` – Entry point for make
- `Makefile.uk` – Describe build for Unikraft
- `Config.uk` – Dependencies and configuration options
- `main.c` – Source code of application

Hello World – Four Required Files (I)

Makefile: specify where the main Unikraft repo is,
as well as repos for external libraries

```
UK_ROOT ?= $(PWD)/../../unikraft
UK_LIBS ?= $(PWD)/../../unikraft-libs
LIBS := $(UK_LIBS)/newlib

all:
	@make -C $(UK_ROOT) A=$(PWD) L=$(LIBS)

$(MAKECMDGOALS):
	@make -C $(UK_ROOT) A=$(PWD) L=$(LIBS) $(MAKECMDGOALS)
```

← path to Unikraft repo

← path to external libs

← external libs needed (colon separated)

Hello World – Four Required Files (II)

Makefile.uk: specifies the sources to build for the application

```
$(eval $(call addlib,apphelloworld))

APPHELLOWORLD_SRCS-y += $(APPHELLOWORLD_BASE)/main.c
```

register app with unikraft build system

Add main.c to build

Hello World – Four Required Files (III)

Config.uk: to populate Unikraft's menu with application-specific option

```
### Invisible option for dependencies
config APPHELLOWORLD_DEPENDENCIES
        bool
        default y
        select LIBNOLIBC if !HAVE_LIBC

### App configuration
config APPHELLOWORLD_PRINTARGS
        bool "Print arguments"
        default y
        help
          Prints argument list (argv) to stdout
```

Hello World – Four Required Files (IV)

main.c: application source file that provides a `main()` function

```c
#include <stdio.h>
/* Import user configuration: */
#include <uk/config.h>

int main(int argc, char *argv[])
{
	printf("Hello world!\n");
#if CONFIG_APPHELLOWORLD_PRINTARGS
	int i;
	printf("Arguments:");
	for (i=0; i<argc; ++i)
		printf(" \"%s\"", argv[i]);
	printf("\n");
#endif
}
```

Libc functionality is provided by a libc or nolibc (dependency in Config.uk)

Unikernel entry point after boot

defined by Config.uk