Unikraft

The second revolution of Unikernels

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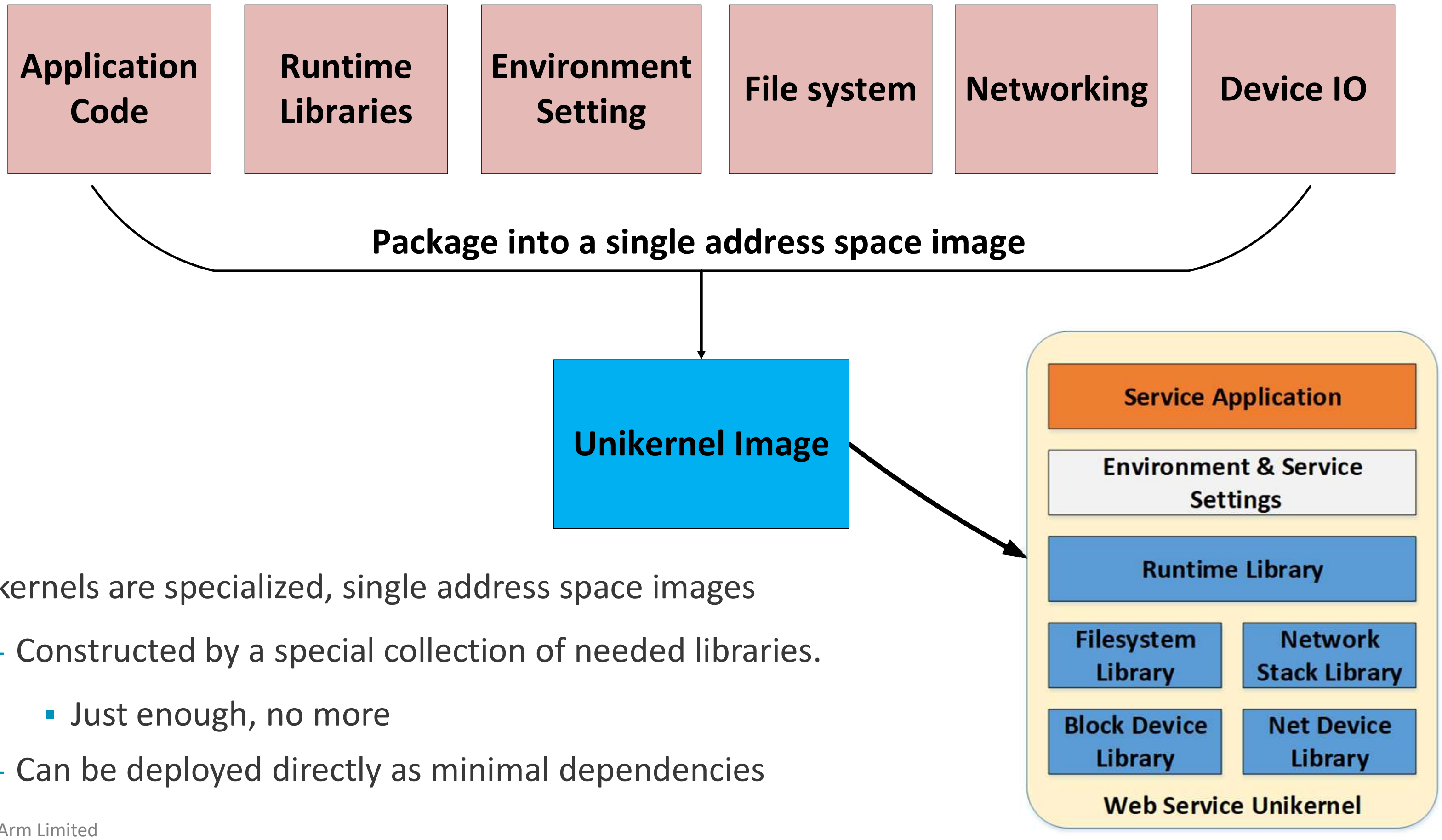
Agenda

- Unikernel concept and benefits
- What obstructs wide adoption of Unikernels
- The first revolution
- Unikraft brings the second revolution
- Features supported on Arm
- The gaps on Arm
- Summary

Unikernel basic concept



- Unikernels are specialized, single address space images
  - Constructed by a special collection of needed libraries.
    - Just enough, no more
  - Can be deployed directly as minimal dependencies

Unikernel benefits and use cases

Benefits

- No Operating System
  - Shorten the distance between hardware and software
  - Function call instead of system call
  - High deterministic performance
- Contains only needed libraries
  - Tiny footprint
  - Small attack surface
  - boots fast

Use cases

- Cloud application
  - Employed as a special kind of Container
- Host services
  - MirageOS has been used in Hyperkit, VPNkit and Datakit as Container host services like DHCP.
- IoT devices
  - Camera, Vehicle and other IoT things
- HPC
  - Scalable and predictable runtime behavior - HermitCore

What obstructs wide adoption of Unikernel?

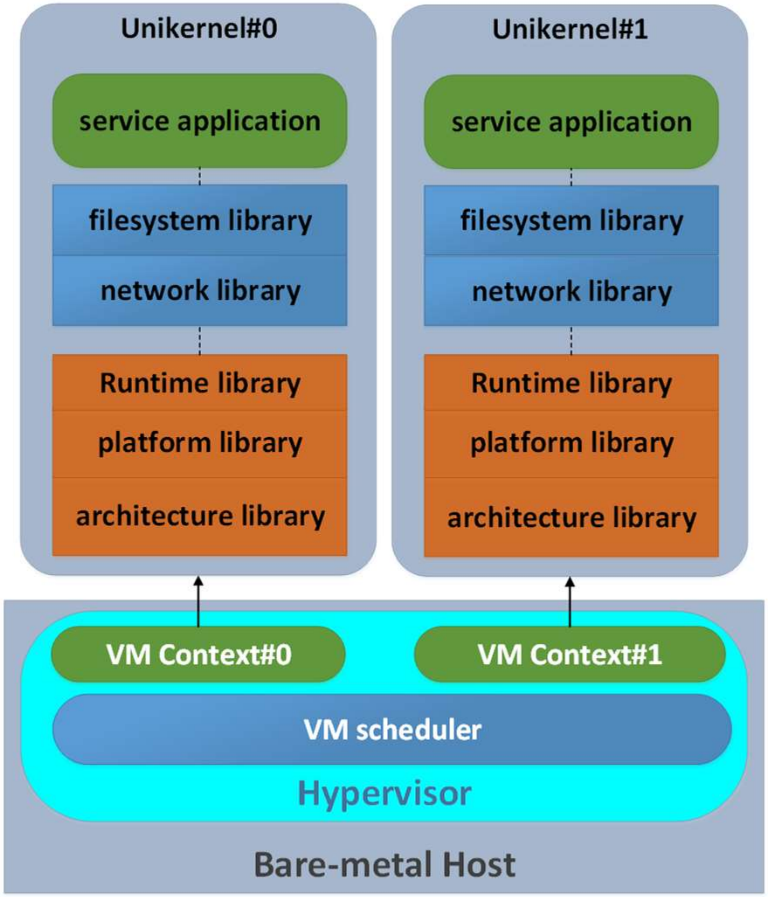
Removing Operating System brings several drawbacks:

- Resource isolations for multiple Unikernels
  - No process to protect jobs’ contexts
  - No scheduler to arrange jobs

- Rewriting massive libraries for rapidly changing hardware
  - Unable to re-use existing device drivers in OS

- Start from scratch to create an Unikernel application
  - No as many libraries as OS can provide
  - Can’t re-use previous research and development easily

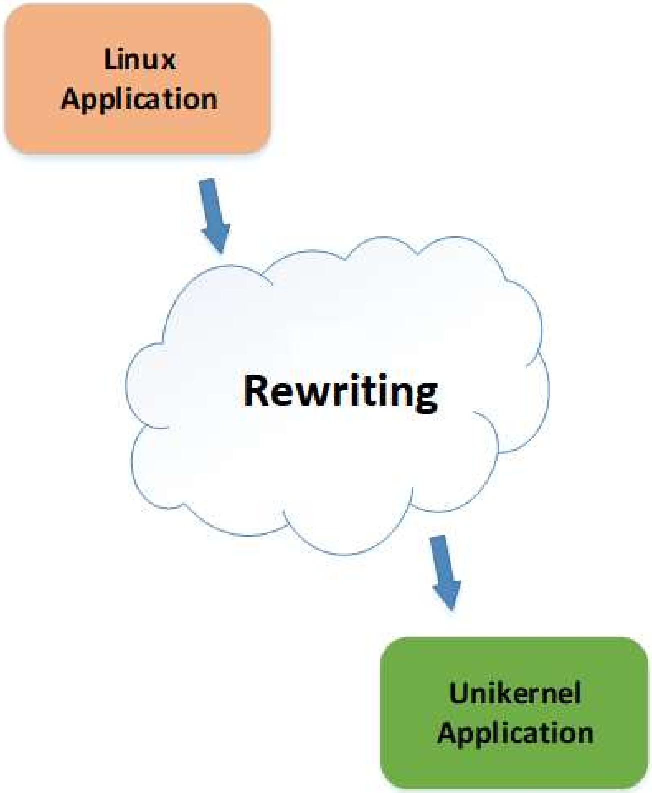
1st Revo: Deploying Unikernels in a Virtual Machine



Fortunately, modern hypervisors provide virtual machines with:

- Strong context isolation
  - Hardware isolation for resources
- Schedulers
  - Arrange jobs as scheduling Virtual Machine
- Consistent set of virtual devices
  - Consistent set of libraries for virtual devices

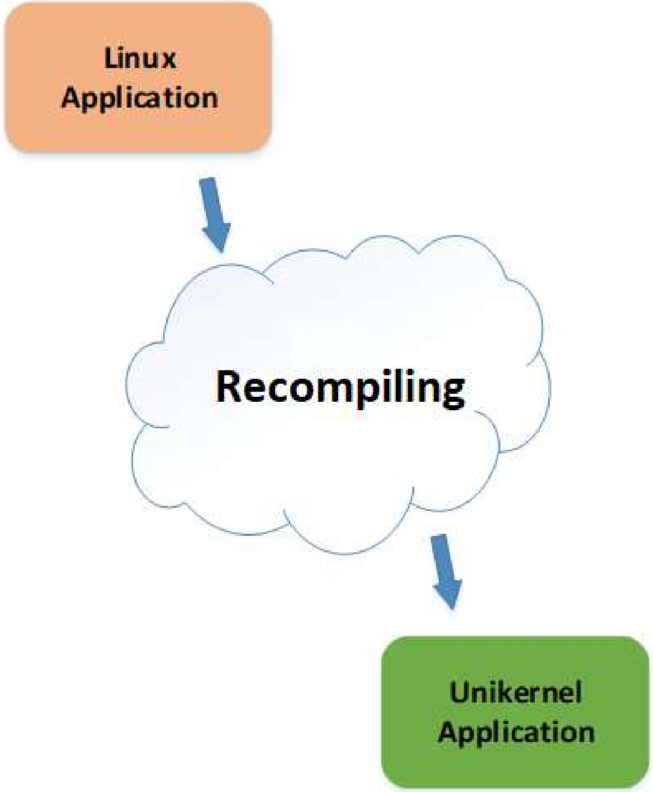
It’s still not easy to create Unikernels



However, in most cases, we still need to re-write almost all the existing applications for Unikernels:

- Porting manually
- Consuming lots of time
- Introducing mistakes easily
- Hard to re-use existing researches and developments

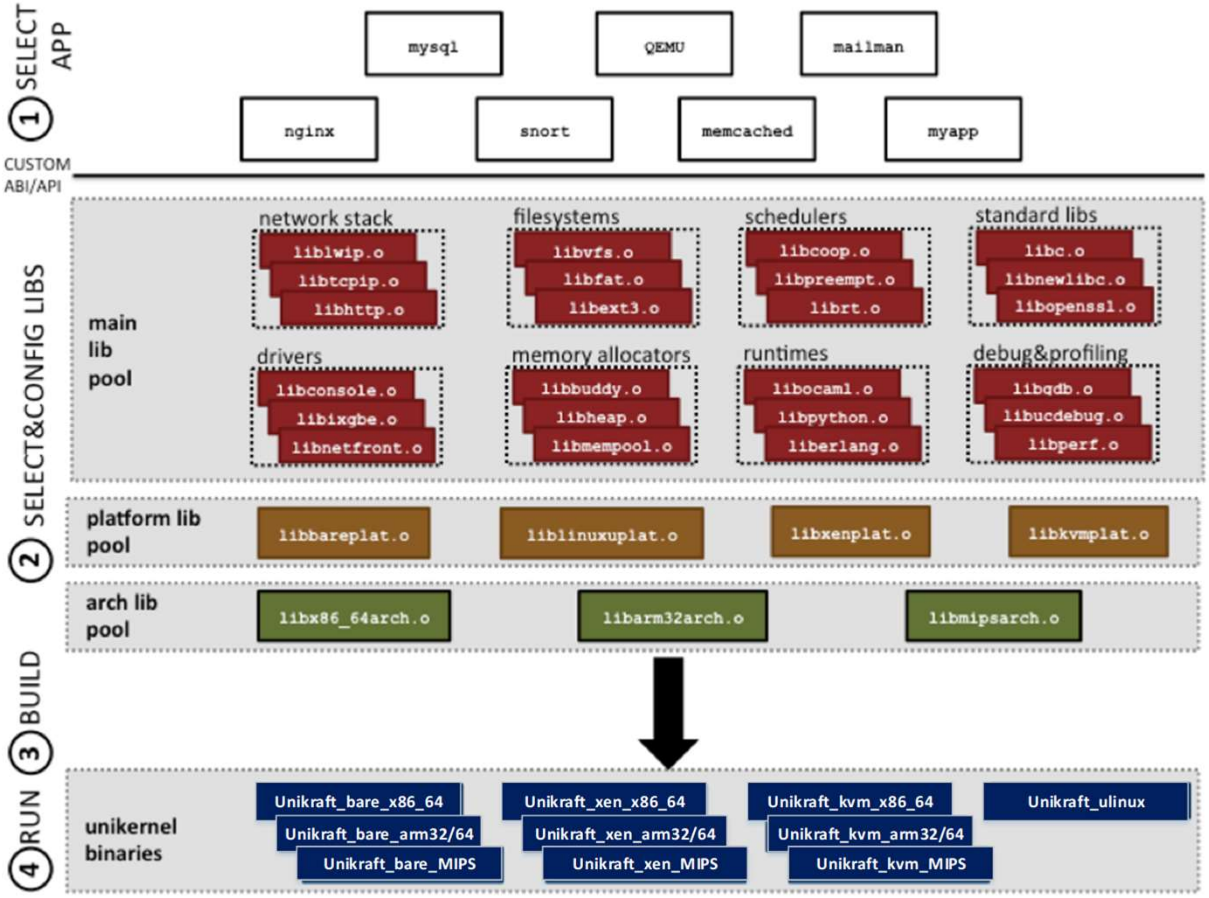
Unikraft - 2nd Revolution of Unikernels



Unikraft, introduced by NEC Laboratories Europe, is a development model – it's an SDK to:

- Reduce the effort of converting existing applications to Unikernels by
  - Reusing existing research and development
  - Configuring easily
  - Porting effort requires no rewriting
    - Recompiling application code in the best case
    - Small changes to the actual application code in the worst

Two important components of Unikraft

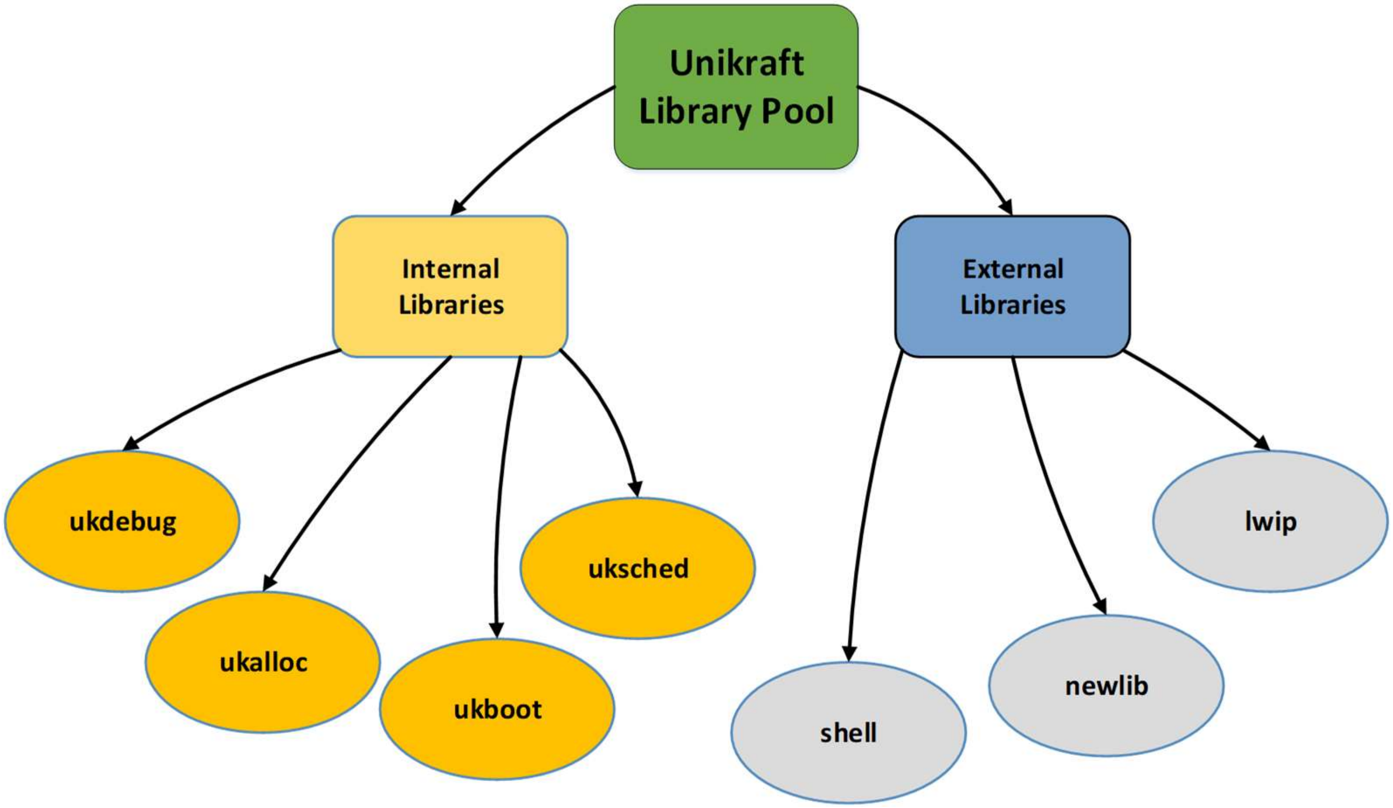


- Library pool
  - Architecture libraries
  - Platform libraries
  - OS functional libraries
  - Standard and runtime libraries
- Build toolchain
  - Provides a Linux style kconfig menu
  - Provides scripts to integrate/reuse existed library
  - Generates binaries for multiple platforms automatically

Figure modified from https://www.xenproject.org/developers/teams/unikraft.html

Internal libraries and external libraries

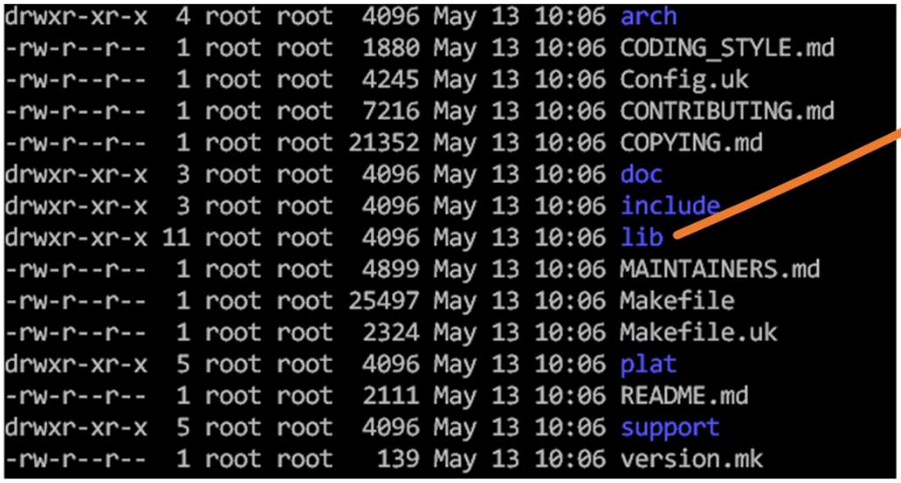
- Internal libraries
  - Memory allocators,
  - Schedulers,
  - Debug and boot
- External libraries
  - Lwip,
  - Newlib,
  - Shell.



Internal libraries VS External libraries

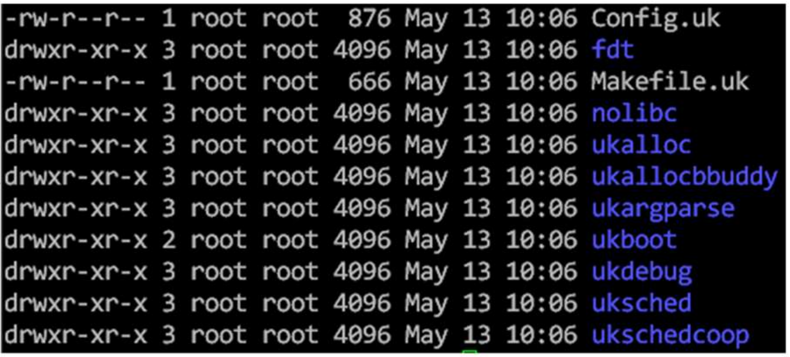
Internal libraries are no different than external ones, except for the fact that:

- They are part of the main Unikraft repository,



```
drwxr-xr-x  4 root root  4096 May 13 10:06 arch
-rw-r--r--  1 root root  1880 May 13 10:06 CODING_STYLE.md
-rw-r--r--  1 root root  4245 May 13 10:06 Config.uk
-rw-r--r--  1 root root  7216 May 13 10:06 CONTRIBUTING.md
-rw-r--r--  1 root root 21352 May 13 10:06 COPYING.md
drwxr-xr-x  3 root root  4096 May 13 10:06 doc
drwxr-xr-x  3 root root  4096 May 13 10:06 include
drwxr-xr-x 11 root root  4096 May 13 10:06 lib
-rw-r--r--  1 root root  4899 May 13 10:06 MAINTAINERS.md
-rw-r--r--  1 root root 25497 May 13 10:06 Makefile
-rw-r--r--  1 root root  2324 May 13 10:06 Makefile.uk
drwxr-xr-x  5 root root  4096 May 13 10:06 plat
-rw-r--r--  1 root root  2111 May 13 10:06 README.md
drwxr-xr-x  5 root root  4096 May 13 10:06 support
-rw-r--r--  1 root root   139 May 13 10:06 version.mk
```

Main Unikraft Repo



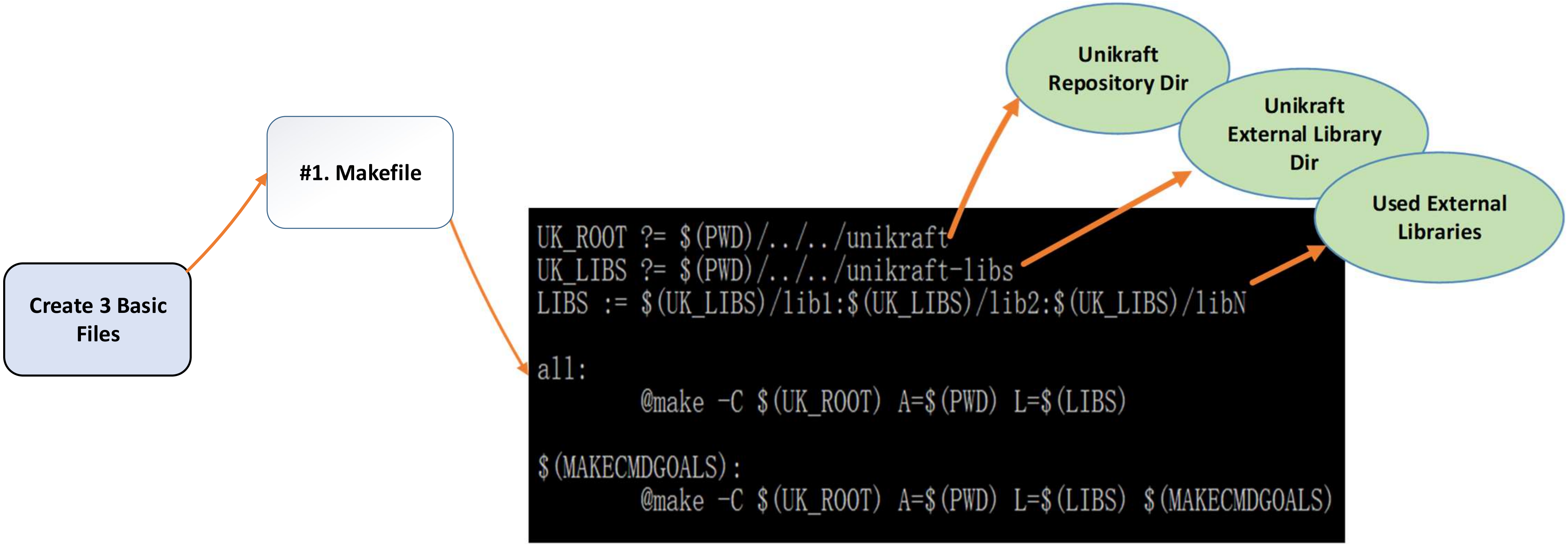
```
-rw-r--r-- 1 root root  876 May 13 10:06 Config.uk
drwxr-xr-x 3 root root 4096 May 13 10:06 fdt
-rw-r--r-- 1 root root  666 May 13 10:06 Makefile.uk
drwxr-xr-x 3 root root 4096 May 13 10:06 nolibc
drwxr-xr-x 3 root root 4096 May 13 10:06 ukalloc
drwxr-xr-x 3 root root 4096 May 13 10:06 ukallocbbuddy
drwxr-xr-x 3 root root 4096 May 13 10:06 ukargparse
drwxr-xr-x 2 root root 4096 May 13 10:06 ukboot
drwxr-xr-x 3 root root 4096 May 13 10:06 ukdebug
drwxr-xr-x 3 root root 4096 May 13 10:06 uksched
drwxr-xr-x 3 root root 4096 May 13 10:06 ukschedcoop
```

Internal Libraries

- They do not use any external source files,
- They must not have dependencies on external libraries.

Creating Unikernels with toolchain

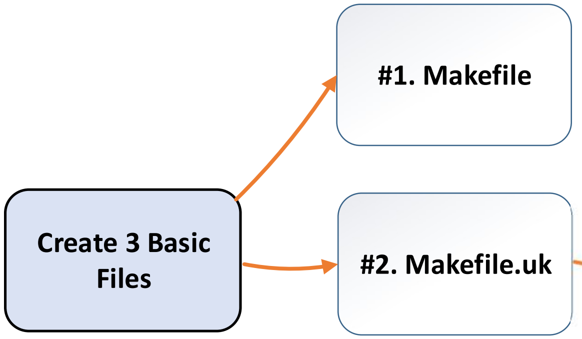
Using toolchain to port or develop an application to Unikraft:

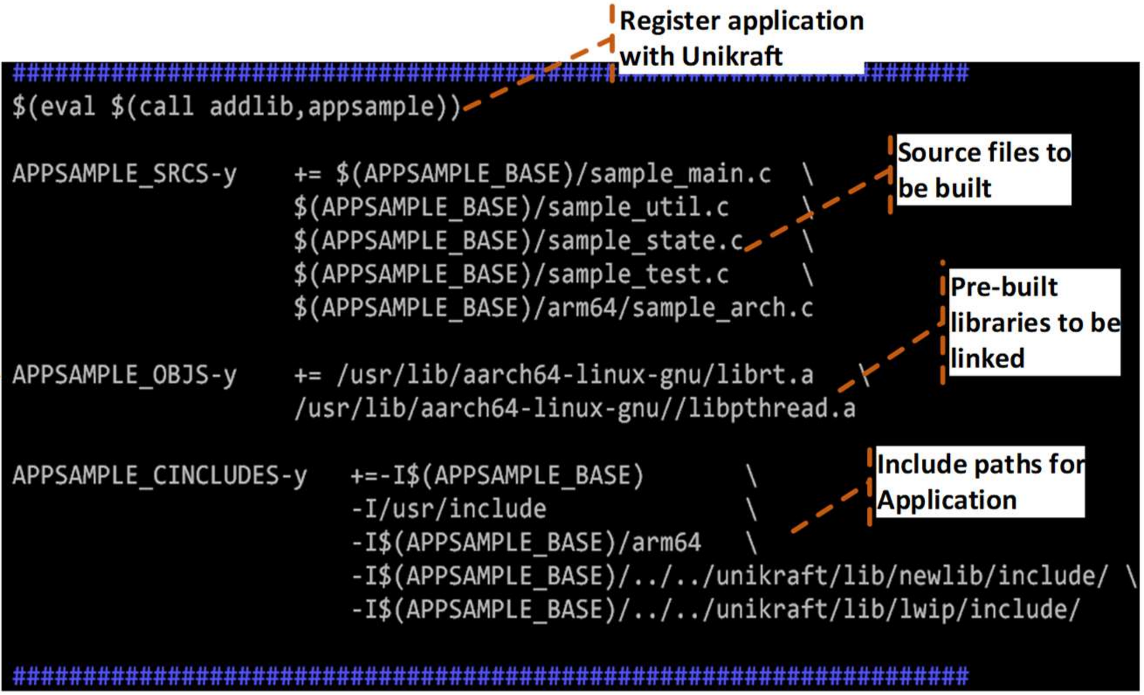


```
UK_ROOT ?= $(PWD)/../../unikraft
UK_LIBS ?= $(PWD)/../../unikraft-libs
LIBS := $(UK_LIBS)/lib1:$(UK_LIBS)/lib2:$(UK_LIBS)/libN

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

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

Creating Unikernels with toolchain

Using toolchain to port or develop an application to Unikraft:

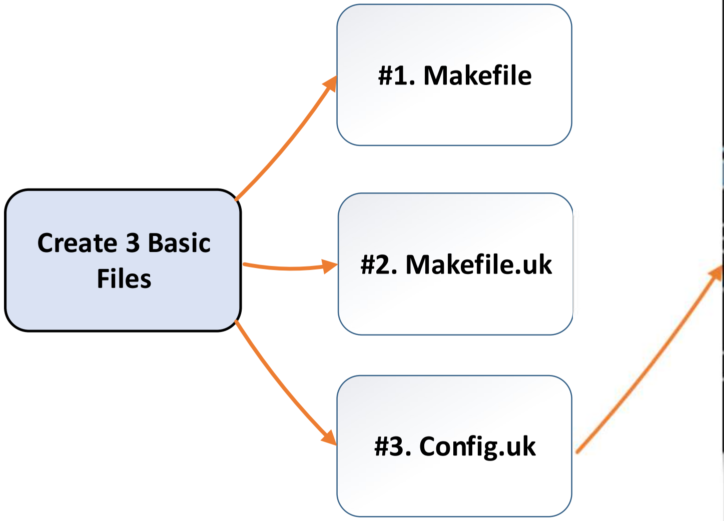


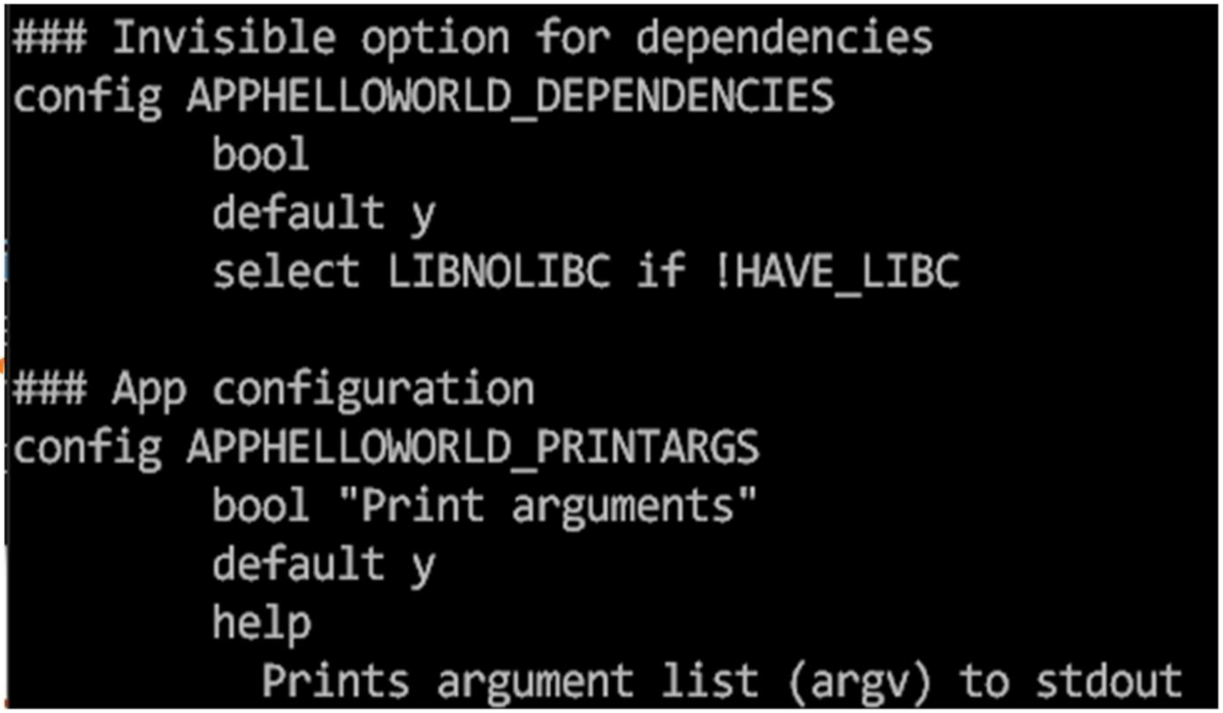

Register application with Unikraft
Source files to be built
Pre-built libraries to be linked
Include paths for Application

```
####################################################################
$(eval $(call addlib,appsample))

APPSAMPLE_SRCS-y     += $(APPSAMPLE_BASE)/sample_main.c  \
                     $(APPSAMPLE_BASE)/sample_util.c     \
                     $(APPSAMPLE_BASE)/sample_state.c    \
                     $(APPSAMPLE_BASE)/sample_test.c     \
                     $(APPSAMPLE_BASE)/arm64/sample_arch.c

APPSAMPLE_OBJS-y     += /usr/lib/aarch64-linux-gnu/librt.a   \
                     /usr/lib/aarch64-linux-gnu//libpthread.a

APPSAMPLE_CINCLUDES-y    +=-I$(APPSAMPLE_BASE)        \
                         -I/usr/include               \
                         -I$(APPSAMPLE_BASE)/arm64    \
                         -I$(APPSAMPLE_BASE)/../../unikraft/lib/newlib/include/ \
                         -I$(APPSAMPLE_BASE)/../../unikraft/lib/lwip/include/

####################################################################
```

Creating Unikernels with toolchain

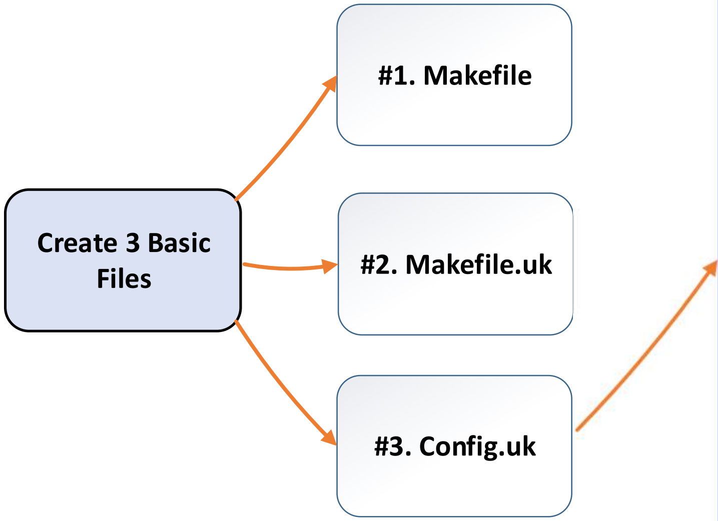
Using toolchain to port or develop an application to Unikraft:

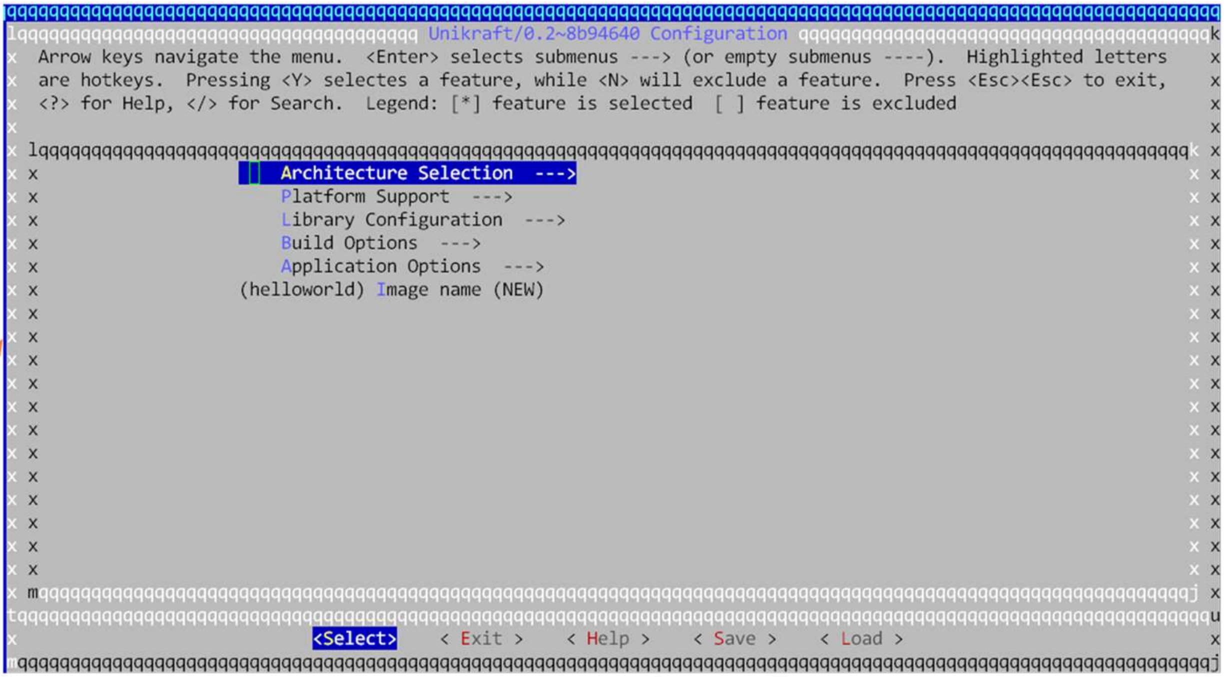



```
### Invisible option for dependencies
config APPHELLOWORLD_DEPENDENCIES
        bool
        default y
        select LIBNOLIBC if !HAVE_LIBC

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

Creating Unikernels with toolchain

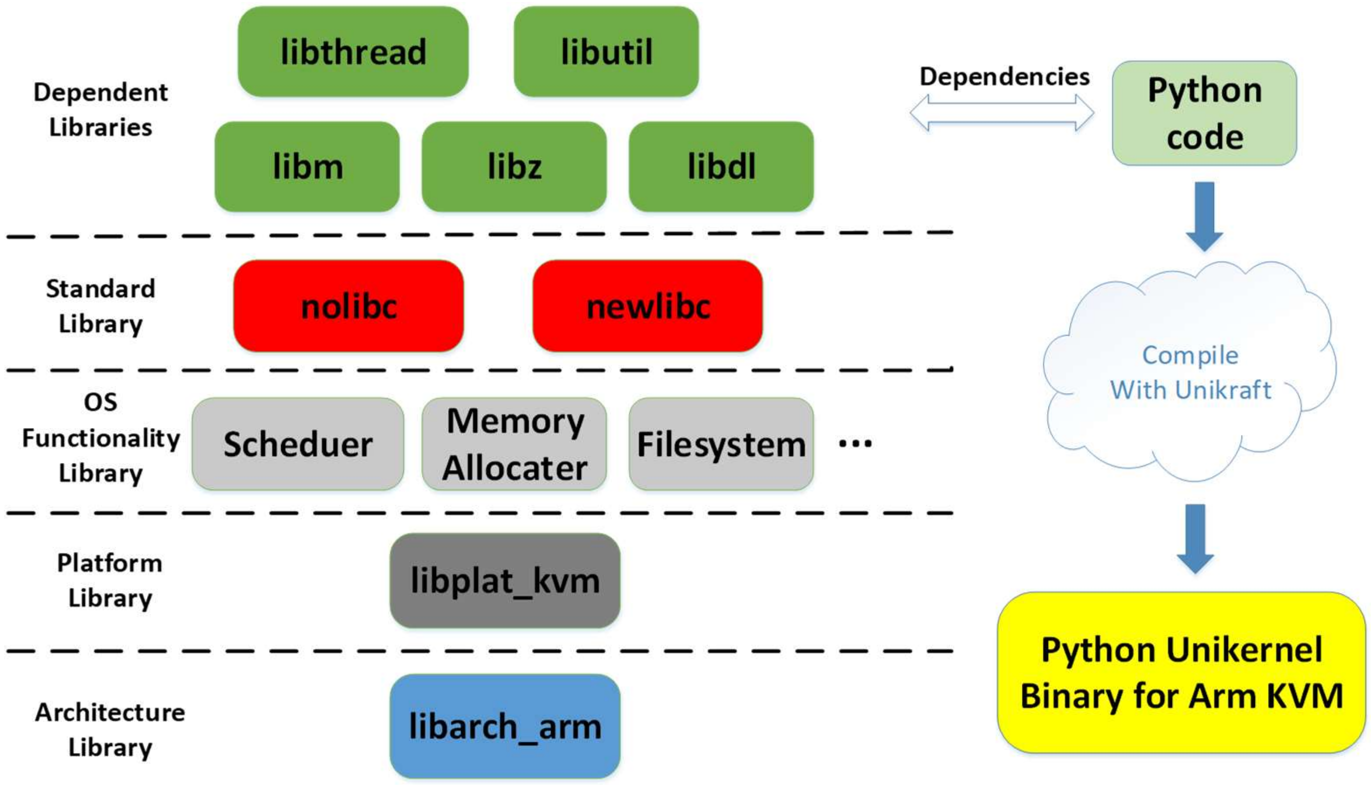
Using toolchain to port or develop an application to Unikraft:





```
Unikraft/0.2~8b94640 Configuration
 Arrow keys navigate the menu.  <Enter> selects submenus ---> (or empty submenus ----).  Highlighted letters
 are hotkeys.  Pressing <Y> selectes a feature, while <N> will exclude a feature.  Press <Esc><Esc> to exit,
 <?> for Help, </> for Search.  Legend: [*] feature is selected  [ ] feature is excluded

                          Architecture Selection  --->
                          Platform Support  --->
                          Library Configuration  --->
                          Build Options  --->
                          Application Options  --->
                      (helloworld) Image name (NEW)

                    <Select>    < Exit >    < Help >    < Save >    < Load >
```

Decomposing python for example

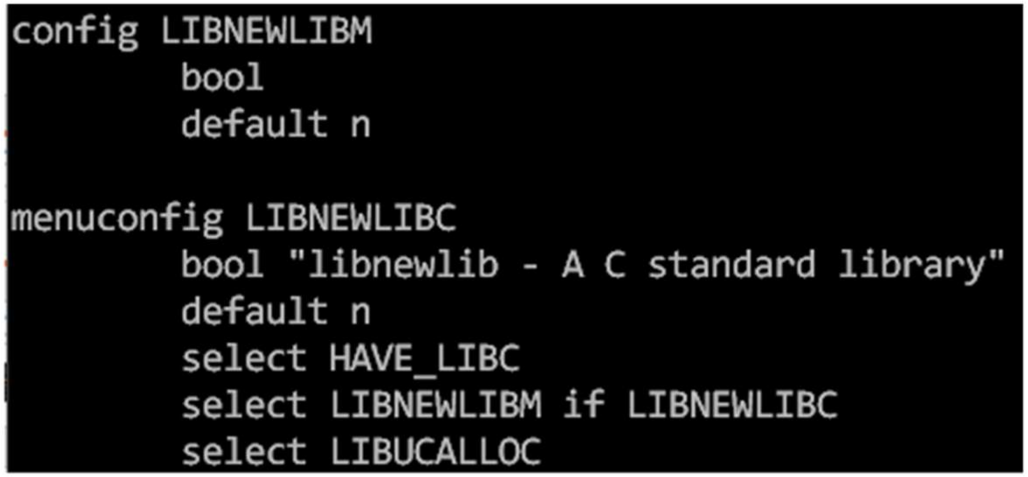


- Creating Makefile and Makefile.uk to tell Unikraft how to build python source files,
- Using Config.uk to populate the kconfig menu and select libraries from it,
- Build and Run.

Developing an external library

Developing or porting an external library isn't too different from porting an application

- No Makefile is needed for external libraries
- Makefile.uk follows the same format of application
- One difference relates to Config.uk
  - You surround your settings with ``menuconfig`` that enables selecting and deselecting the library.

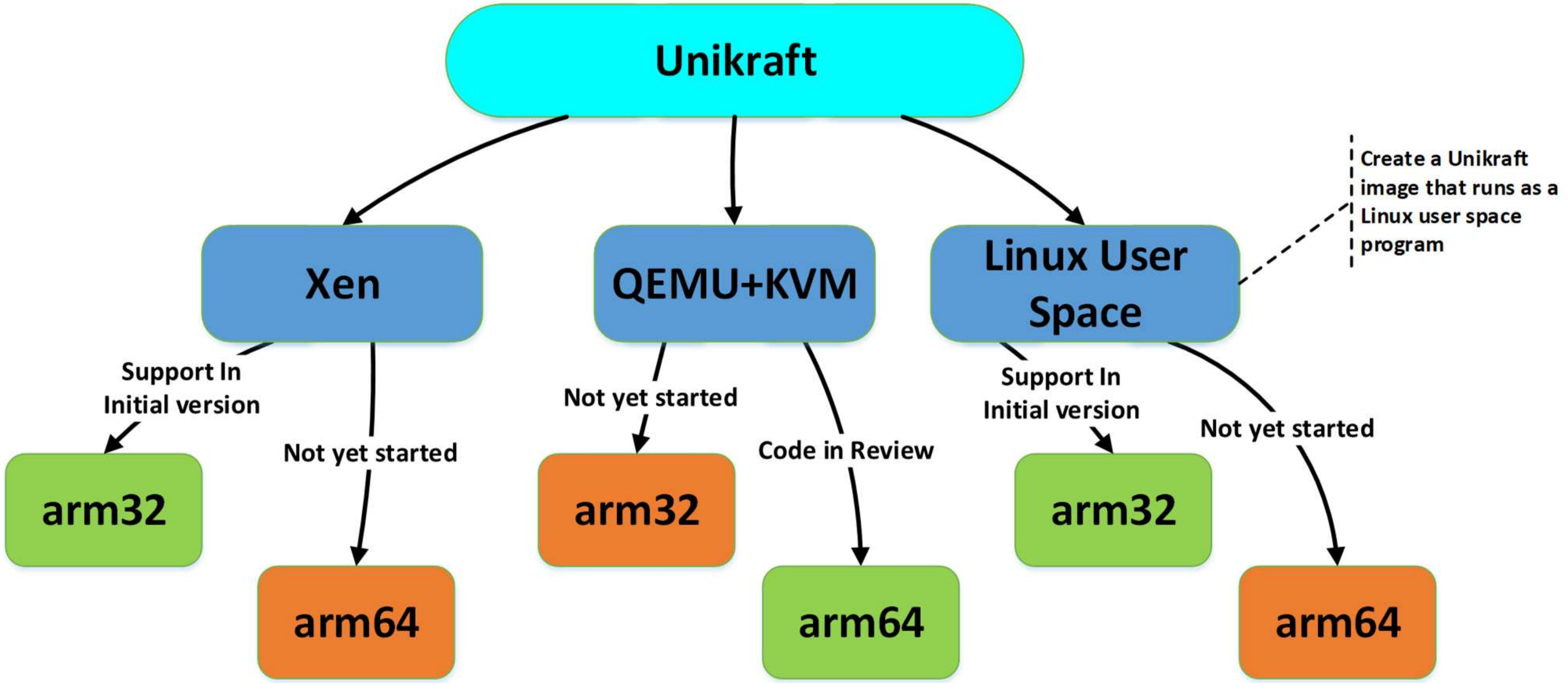


```
config LIBNEWLIBM
        bool
        default n

menuconfig LIBNEWLIBC
        bool "libnewlib - A C standard library"
        default n
        select HAVE_LIBC
        select LIBNEWLIBM if LIBNEWLIBC
        select LIBUCALLOC
```

Config.uk of newlibc

Arm support status

The initial version of Unikraft came with Arm32 supports:



What we have done on Arm

Now we are working on the Arm64 Linux-KVM / QEMU, we have (not yet merged:)

- Improved multi-arch and multi-plat support,
  - By modifying the build scripts and restructuring the folders
- Added boot code for Arm64 QEMU-KVM,
- Support for single CPU for the first version,
- Enabled MMU
- Setup a 1:1 mapping for physical memory and virtual memory,
- Added an exception table,
  - That handles SYNC, IRQ and other exceptions
- Device tree support,
- PL011 UART for console,
  - Early debug console and STDIO
- Virtual timer for ticks.

Support multiple thread on Arm

Like most Unikernel projects, Unikraft supports single process but multiple threads. Current support status:

- Unikraft scheduler library is in reviewing (by Constin Lupu)

- Need to implement GIC interrupt controller libraries for timer interrupt.
  - GICv2 for low cost Arm SoC, Like IoT devices
  - GICv3 and GICv4 for high performance Arm SoC, like Arm Servers
  - GICv2m and GICv3-ITS for MSI/MSI-X will not be supported initially

- Need to implement ARMv8 virtual timer library
  - Current timer library only provides ticks for timestamp
  - Need to sync timer APIs for scheduler with Costin

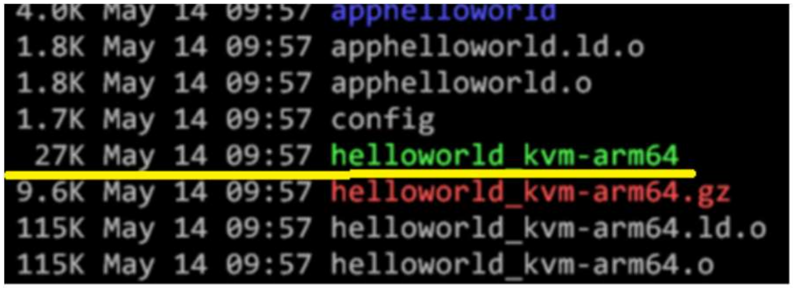
Foreseeable libraries on Arm

- Bare essential device libraries
  - GICv2, GICv3, GICv4 and ARMv8 virtual timer
- Bus libraries
  - virtio-mmio for Kvm
  - xenbus for Xen
  - Generic ECAM PCI host controller (optional, required by PCI pass-through)
- Virtual device libraries
  - netfront and blkfront for Xen
  - virtio-net and virtio-blk for Kvm
  - tapdev on Linux-user
- PSCI driver
  - implement a PSCI interface to shutdown virtual machine.

Footprint and boot time

Footprint:

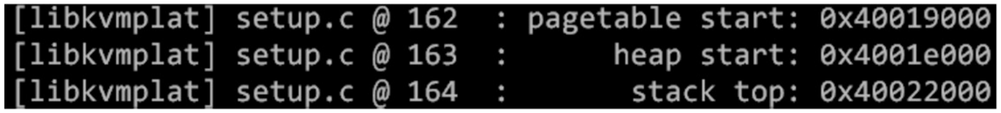
- helloworld_kvm-arm64, 27 Kbytes



```
4.0K May 14 09:57 apphelloworld
1.8K May 14 09:57 apphelloworld.ld.o
1.8K May 14 09:57 apphelloworld.o
1.7K May 14 09:57 config
 27K May 14 09:57 helloworld_kvm-arm64
9.6K May 14 09:57 helloworld_kvm-arm64.gz
115K May 14 09:57 helloworld_kvm-arm64.ld.o
115K May 14 09:57 helloworld_kvm-arm64.o
```

Minimal memory usage, 132 Kbytes

- 64KiB for DTB
  - Can be optimized, if you don’t need device tree
- 28KiB for image (text, data, and bss)
  - 4KiB alignment
- 20KiB for page table (not bss, a reserved memory area)
  - Can be optimized, if you don’t need page table
- Left 20KiB for stack and heap



```
[libkvmplat] setup.c @ 162  : pagetable start: 0x40019000
[libkvmplat] setup.c @ 163  :      heap start: 0x4001e000
[libkvmplat] setup.c @ 164  :       stack top: 0x40022000
```

Boot time:

- ~50ms on Arm64 Cortex-A53 with QEMU

Summary

Unikraft reduces the barrier of converting an application to Unikernel greatly.

- It would be conducive to expand the Unikernel ecosystem.

But, Unikraft is new, it still has the following gaps:

- Need to implement more OS functionality libraries
- Need to improve the compatibility of standard LibC
- Need to implement more external libraries
- Add High-level language support (ocaml, ruby, node.js and lua)
- Support more platforms and hypervisors (kvmtool, ukvm and etc)
- Support enhanced profiling and tracing

References

Unikraft project wiki:

https://wiki.xenproject.org/wiki/Category:Unikraft

Unikraft project repositories:

http://xenbits.xen.org/gitweb/

Unikraft mailing list:

minios-devel@lists.xen.org (Shared with mini-os)

Unikraft Arm64 QEMU-KVM supports patches:

https://github.com/Weichen81/unikraft/tree/staging

Thank You!

Danke!

Merci!

谢谢!

ありがとう!

Gracias!

Kiitos!

arm