

# Embedded Operating System for *Raspberry $\pi$* with *Yocto*

Kaloyan Krastev\*

Tuesday 21<sup>st</sup> November, 2023 <sup>†</sup>

---

\*Triple Helix Consulting

<sup>†</sup>revision 2893

# table of contents

<b>1</b>	<b>introduction</b>	<b>3</b>
<b>2</b>	<b>metadata</b>	<b>5</b>
2.1	application . . . . .	5
2.2	layers . . . . .	6
<b>3</b>	<b>build</b>	<b>8</b>
3.1	configuration . . . . .	8
3.2	image . . . . .	8
<b>4</b>	<b>connection</b>	<b>9</b>
<b>5</b>	<b>outlook</b>	<b>10</b>

# 1 introduction

This article[7] reports the progress in the configuration and build of a Linux-based operating system for *Raspberry  $\pi$* [9] with *Yocto*[2]. Please refer [8] for technical details.

The *central processing unit* (CPU) is *ARM Cortex-A72*. It is a high performance CPU with low power consumption. With dimensions of 9 x 7 x 2 cm, the machine has 4 GB of RAM. As there are no fixed storage devices, *images* are installed on *SD* cards.

Embedded devices[11] are compact systems with specific purpose. Embedded operating systems provide a limited number of services defined by this purpose and device *hardware* (HW). There are important reasons why Linux is a preferred *operating system* (OS) kernel for embedded devices. Since such devices usually have limited HW resources, they rely on optimized *software* (SW) implementations. Smaller and faster than their original, such programs have limited, but usually sufficient functionality. For example, *BusyBox* combines tiny versions of many common *unix* utilities into a single executable[1]. Another example is *Dropbear SSH* - an optimized *secure shell* (SSH) server implementation[6]. *Dropbear* is significantly smaller in size compared to *OpenSSH*. Unlike *GNU is not UNIX* (GNU)/Linux desktop distributions[10], embedded Linux has neither a *graphical user interface* (GUI) for system configuration nor a centralized service manager like *systemd*.

*Yocto* Project[2] provides a popular framework for configuration and build of Linux-based operating systems. First of all, *Yocto* supports HW via a SW layer called *board support package* (BSP). In addition, there are custom distribution configuration and a tool called *Bitbake* to create SW packages and to build OS *images*. These *images* are configurable and operational. There is a bootloader, a

kernel release and the user-space part of the [OS](#), including custom user applications. This approach is indispensable when it comes to embedded devices. *Yocto* images are collections of [SW](#) packages. Packages are created via [SW](#) recipes. Although a recipe may have all sorts of instructions, a typical one contains the source code location and the [SW](#) build configuration. These are architecture independent. However, binaries are cross-compiled in case of different target machine processor architecture. This applies to the entire [OS](#).

## 2 metadata

As they differ, it could be extremely useful to isolate the [SW](#) development from the [OS](#) build. This way developers may work and test a [SW](#) application on their own. As far as I could fetch the source code, in example, from a *git* repository, in theory, it should not be too complicated to build an [OS](#) able to run this application. What is more, I can build it for a computing device of my choice. I just need the corresponding [BSP](#) and a *bitbake* recipe to fetch the source code, configure, cross-compile, install binaries and create a package.

A complete list of *github* [SW](#) repositories used in this project includes *Yocto*, the [BSP](#), a [SW](#) layer with custom recipes, the configuration and the source code of the application and the dependencies. Note that for a relatively simple application I must fetch six [SW](#) repositories. Follow links for details.

- *Yocto* reference distribution [yoctoproject.org/poky.git](http://yoctoproject.org/poky.git)
- [BSP](#) layer for *Raspberry*  $\pi$  boards [agherzan/meta-raspberrypi.git](https://github.com/agherzan/meta-raspberrypi)
- *Yocto* configuration [TripleHelixConsulting/rpiconf.git](https://github.com/TripleHelixConsulting/rpiconf)
- [SW](#) layer [kaloyanski/meta-thc.git](https://github.com/kaloyanski/meta-thc)
- immediate mode [GUI](#) [kaloyanski/imgui\\_aarch64\\_glfw\\_opengl2\\_exper](https://github.com/kaloyanski/imgui_aarch64_glfw_opengl2_experimental)
- graphics library framework [glfw/glfw.git](https://github.com/glfw/glfw)

### 2.1 application

*Dear ImGui*[3] is a bloat-free [GUI](#) library for C++. It outputs optimized vertex buffers that you can render anytime in your 3D-pipeline-enabled application. It is fast, portable, renderer agnostic,

and self-contained (no external dependencies). *Dear ImGui* is designed to enable fast iterations and to empower programmers to create content creation tools and visualization/debug tools (as opposed to UI for the average end-user). It favors simplicity and productivity toward this goal and lacks certain features commonly found in more high-level libraries. *Dear ImGui* is particularly suited to integration in game engines (for tooling), real-time 3D applications, full-screen applications, embedded applications, or any applications on console platforms where operating system features are non-standard.

*Dear ImGui* depends on *GLFW*[\[4\]](#), an open-source, multi-platform library for *OpenGL*, *OpenGL ES* and *Vulkan* development on the desktop. It provides a simple API for creating windows, contexts and surfaces, receiving input and events. *GLFW* is written in *C* and supports *Windows*, *macOS*, *X11* and *Wayland*.

*Dear ImGui* is licensed under the *MIT* License. *GLFW* is licensed under the *zlib/libpng* license.

## 2.2 layers

Here is a list of *Yocto metadata* layers. The project reference distribution is *poky*.

- *meta*  
user-space
- *meta – poky*  
*Yocto* reference distribution
- *meta – raspberrypi*  
This[\[5\]](#) is the general [HW](#) specific [BSP](#) overlay for the *RaspberryPi* device. The core [BSP](#) part of *meta – raspberrypi* works with different *OpenEmbedded/ Yocto* distributions and layer stacks.

In short, the recipes to build the kernel and kernel modules are in this layer. For details see the package *linux-raspberrypi*. In addition, here is the [HW](#) specific firmware. The build configuration corresponds the specific [HW](#), in this case *Raspberry  $\pi$* .

- *meta – thc*

I have introduced a new *Yocto* [SW](#) layer to control the build of *Dear ImGui* and *GLFW*. As long as the source codes have a standard build configuration, the *bitbake* recipes are straightforward. Both instructions inherit *cmake bitbake* class.

## 3 build

### 3.1 configuration

*Yocto* provides a list of image types. I have chosen *core – image – x11*<sup>[2]</sup> - a very basic X11 image with a terminal. In the main build configuration, apart from *Dear ImGui* and *GLFW*, I have added the following packages;

- *os – release*  
OS identification
- *Dropbear*  
Compact SSH server<sup>[6]</sup>
- *thcp*  
OS post-configuration scripts

### 3.2 image

The used space on the `/root` partition of the OS is 220 MB. The free space is configurable. The kernel *ARM*, 64 bit boot executable *image* of 23 MB is a *Raspberry π* configuration of Linux 5.15. This kernel release has a *long – term support* (LTS). The total size of kernel modules is 21 MB.

*Yocto* provides multiple SW package and OS *image* formats. Further, different ways exist to install *images*. Finally, formats do not matter, as long as the result is a complete OS on an *SD* card. I recommend the classic command-line tool *dd* to copy data. It works fine with different *image* formats like *rpi – sdimg*, *hddimg* and *wic*.



## 4 connection

Connected embedded systems can communicate to one another and to cloud-based *platform-as-a-service* (PaaS) solutions. In addition, a remote control may be required. An SSH server is a standard solution for both problems.

Wireless connection is established via classic command-line tools like *ip*, *iw*, *udhcpc*, and *wpa\_supplicant*. Custom shell scripts are installed in `/usr/bin`, as well as a running GUI example to demonstrate the usage of the *Dear ImGui* library. Once an *internet protocol* (IP) address is assigned, the SSH server by *Dropbear* allows for a secured remote login, remote control and file transfer.

## 5 outlook

This reports the progress in the development of a custom Linux-based OS for *Raspberry*  $\pi$  [9]. The kernel version of this embedded OS is Linux release 5.15. An example GUI application using the *Dear ImGui* library is built as a part of the OS. In addition, an SSH server provides remote connection, data transfer and device control. As the OS is now functional, performance and real-time tests are ongoing.

## acronyms

BSP	<i>board support package</i>
CPU	<i>central processing unit</i>
GNU	<i>GNU is not UNIX</i>
GUI	<i>graphical user interface</i>
HW	<i>hardware</i>
IP	<i>internet protocol</i>
LTS	<i>long – term support</i>
OS	<i>operating system</i>
PaaS	<i>platform-as-a-service</i>
SSH	<i>secure shell</i>
SW	<i>software</i>

# bibliography

- [1] Erik Andersen. *BusyBox*. 2023.  
URL: <https://busybox.net> (visited on 2023).
- [2] Yocto Project community. *Yocto Project*. 2023.  
URL: <https://www.yoctoproject.org> (visited on 2023).
- [3] Omar Cornut. *Dear ImGui*. 2023.  
URL: <https://github.com/ocornut/imgui> (visited on 2023).
- [4] Marcus Geelnard and Camilla Löwy. *OpenGL*. 2023.  
URL: <https://www.glfw.org> (visited on 2023).
- [5] Andrei Gherzan. *meta-raspberrypi*. 2023.  
URL: <https://github.com/agherzan/meta-raspberrypi>  
(visited on 2023).
- [6] Matt Johnston. *Dropbear SSH*. 2023.  
URL: <https://matt.ucc.asn.au/dropbear/dropbear.html>  
(visited on 2023).
- [7] Kaloyan Krastev.  
*Embedded Operating System for Raspberry  $\pi$  with Yocto*. 2023. URL:  
<https://kaloyanski.github.io/meta-thc/thcport.html>  
(visited on 2023).
- [8] Kaloyan Krastev. *Building Embedded Operating System with  
IMGUI Demo for Raspberry  $\pi$  with Yocto*. 2023. URL:  
<https://kaloyanski.github.io/meta-thc/thchowto.html>  
(visited on 2023).
- [9] Raspberry  $\pi$  Ltd. *Rasperi  $\pi$* . 2023.  
URL: <https://www.raspberrypi.com> (visited on 2023).

- [10] Atanas Georgiev Rusev. *Manjaro Linux User Guide*. Packt Publishing Limited, 2023.
- [11] Frank Vasquez and Chris Simmonds. *Mastering Embedded Linux Programming*. Packt Publishing Limited, 2021.