International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

An Overview of Libcamera

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Abstract: ***Cameras have become very common in most consumer electronics and industrial products like mobile phones, augmented/virtual reality headsets, tablets, robotics, drones, automobiles, door cameras. To capture frames from the camera sensors these products use different camera APIs based on the industry segment, requirements and the underlying operating system of the product. In this paper we will provide an overview of the libcamera.***

Keywords: Cameras, HAL3, UVC, libcamera

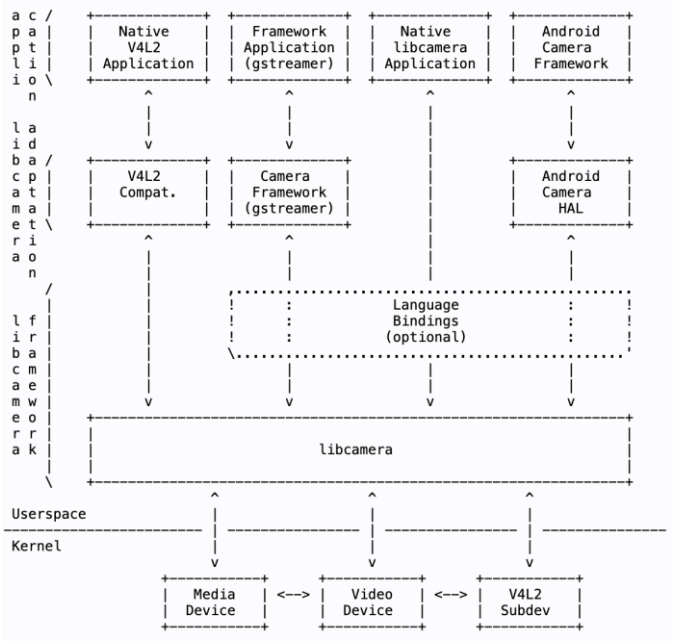
1. Introduction

Libcamera is the open source complex camera support library written for Linux, Android and ChromeOS. This library interfaces with Linux kernel device drivers and provides simple APIs to the developers for capturing the images from cameras on Linux based systems. The camera hardware pipeline typically consists of a camera sensor that captures raw frames, from monochrome or Bayer sensor, and transmits them on a bus (typically MIPI on mobile phones), a receiver that decodes the bus signals, and an ISP (image signal processor) that processes the raw image frames to produce high quality visually appealing images. The Linux kernel handles these multimedia devices through the Linux media subsystem and provides a set of APIs known as the V4L2 (Video for Linux 2) and the Media Controller APIs. The media controller APIs provide an interface to interact and control media devices. libcamera provides a complete camera stack for Linux based systems that abstracts the hardware configuration and algorithms for image quality enhancement to obtain visually appealing images from the camera.

2. Camera Stack

The camera stack comprises four software layers.

- The kernel drivers control the camera hardware (camera sensor, ISP HW blocks, actuators, EEPROM) and expose a low level interface to userspace through the V4L2 APIs. V4L2 APIs are Media Controller API, V4L2 video device API and V4L2 subdev API.
- The libcamera framework handles all control of the camera devices and exposes a native C++ API to upper layers.
- The libcamera adaptation layer provides interfaces for other frameworks to interact with libcamera.
- The applications and upper layer frameworks are based on the libcamera framework or libcamera adaptation. Applications can make use of the libcamera C++ API directly or use Gstreamer element (gstlibcamerasrc) through gstreamer pipelines or through a generic Android camera HAL3 on top of libcamera or like a UVC camera via the V4L2 APIs.



3. Architecture

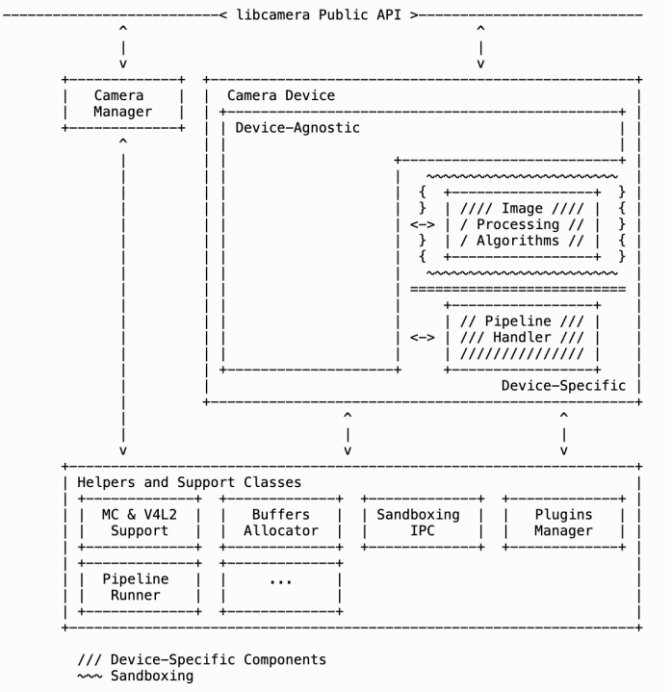
libcamera offers a unified API for the upper layers via a single library. It exposes multiple hardware components through its API. There are multiple helper functions and classes defined internally to expose these components.

Camera Manager - It enumerates cameras and instantiates Pipeline handlers. It also supports hotplug detection and notification events. There will always be one instance of a camera manager running per application.

Camera Device - The camera class represents each camera hardware that produces one or multiple image streams and provides the API to interact with the underlying device. If there are multiple instances of the camera hardware then each has its own instance of the camera class.

Pipeline Handler - The pipeline handler access and control hardware through the V4L2 and the media controller APIs and control the ISP and capture devices directly.

Image Processing Algorithms (IPA) - The image processing algorithms implement 3A (AE - Auto Exposure, AF - Auto Focus and AWB - Auto White Balance) and other algorithms. IPA modules can be part of the libcamera code base or provided externally by camera vendors in either open source or closed source form. They can interact with the libcamera through the API provided by the Pipeline Handler. They can only access the image and metadata which are mediated by the DMABUF instances passed by the Pipeline Handler.



As of writing this paper, libcamera supports the following hardware platforms.

- ARM Mali-C55
- Intel IPU3
- NXP iMX8MP
- RaspberryPi3, 4 and 0
- Rockchip RK3399

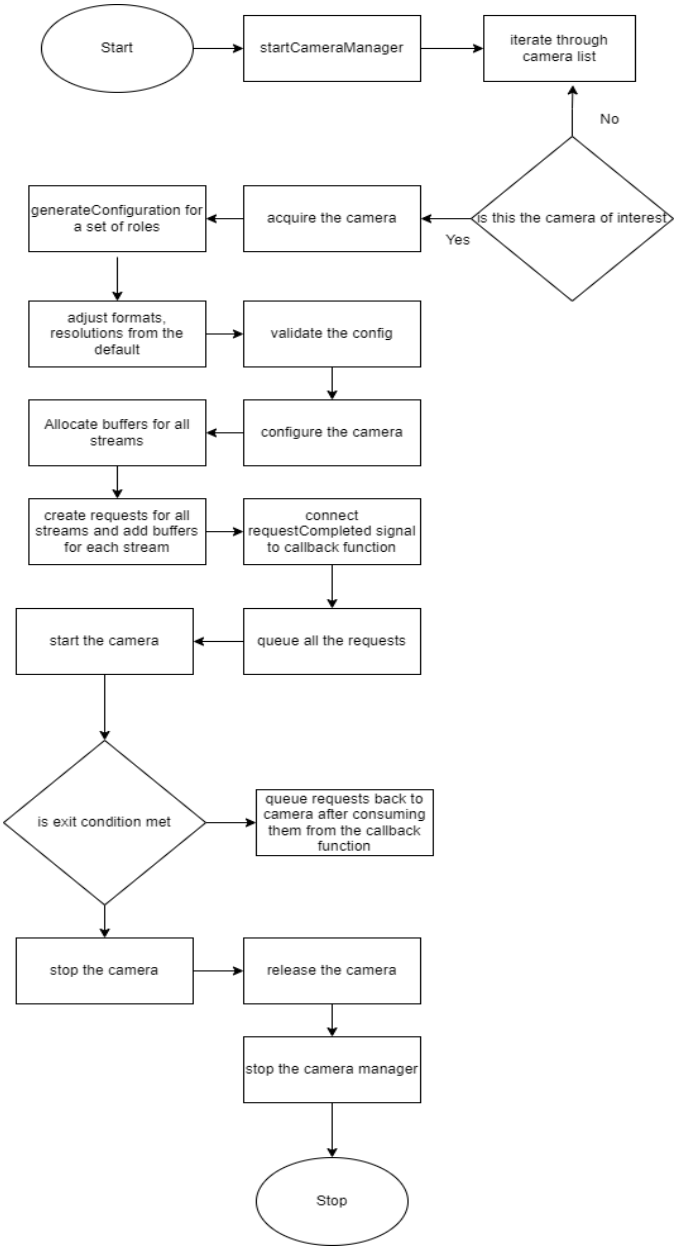
All the above devices provide dedicated pipeline handlers.

4. Libcamera Application

Libcamera application programming API closely resembles the HAL3 request model and hence the libcamera project also supports HAL3 emulation on top of libcamera API. The libcamera API flow is described in the flow diagram below.

5. Conclusion

This paper provided the high level overview of the most popular camera APIs used in the industry. This paper doesn't recommend any particular camera API to use as it is completely dependent on various factors like the market segment, underlying operating system, semiconductor vendor offerings etc., For more details of the particular API please refer to the corresponding API specification.



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