## Linux Application Summit – LAS 2020

# Libcamera: Making Complex cameras Easy!

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```
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a e  |  |                 |
m n  |  |-----------------|
e s  |  |      ov5640     |
r o  |  |-----------------|
a r  |  |        0        |
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A    /  +-----------------+
P    |  |     capture     |
I    |  |   /dev/video0   |
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```
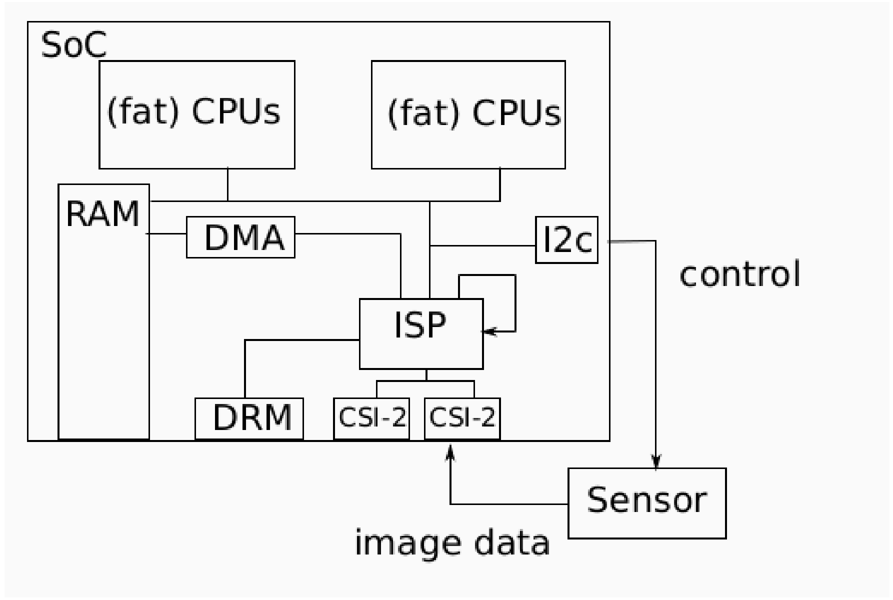

## Complexity increases - Image signal processors

- System peripherals that operate on digital images
- DMA, resizing, scaling, cropping, pixel format conversions
- Kernel exposed new API named ‘MediaController’



```
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                     |      vm6558     |  |   CCP2 input    |  |  jt8ev1 2-0037  |  | as3645a 2-0030  |
                     |/dev/v4l-subdev11|  |   /dev/video0   |  |/dev/v4l-subdev8 |  |/dev/v4l-subdev8 |
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                                          |      CCP2       |  |      CSI2a      |
                                          |/dev/v4l-subdev0 |  |/dev/v4l-subdev1 |
                                          |-----------------|  |-----------------|
                                          |        1        |  |        1        |
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                                                   |   /---------------/|
                                                   v   v                v
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                                          |        0        |  |   CSI2a output  |
+-----------------+                       |-----------------|  |   /dev/video1   |
|  resizer input  |                       |      CCDC       |  +-----------------+
|   /dev/video5   |                       |/dev/v4l-subdev2 |  +-----------------+
+-----------------+                       |-----------------|  |  preview input  |
         |                                |    1   |   2    |  |   /dev/video3   |
         |                                +-----------------+  +-----------------+
         |   /----------------/----------------/   /--/  \----------\   |
         v   v                |                    v                v   v
+-----------------+           |           +-----------------+  +-----------------+            +---+ Sensors & flash
|        0        |<.         v           |        0        |  |        0        |            +---+ OMAP3 ISP
|-----------------| | +-----------------+ |-----------------|  |-----------------|            +---+ API
|     resizer     | | |  CCDC output    | |      AEWB       |  |     preview     |
|/dev/v4l-subdev4 | | |  /dev/video2    | |/dev/v4l-subdev4 |  |/dev/v4l-subdev3 |
|-----------------| | +-----------------+ |-----------------|  |-----------------|
|        1        | |                     |                 |  |        1        |
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```

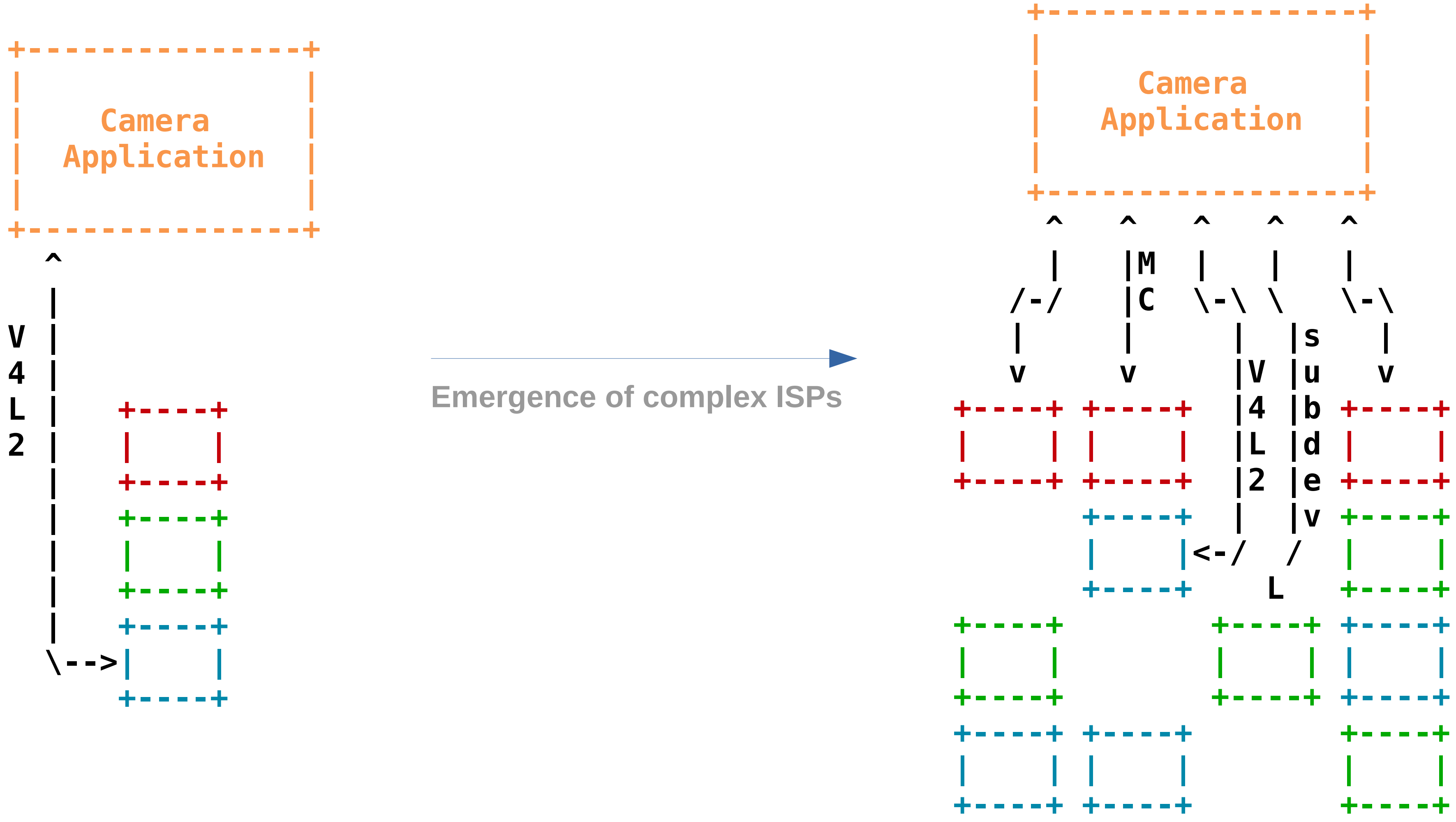
Camera Application
V4L2
Emergence of complex ISPs
Camera Application
MC
V4L2
subdev
L

- Problem statement:
  - Applications are requested to know a lot of details on the underlying hardware.
  - Triggering capture operations requires precise configuration and setup of the whole pipeline(ISP).
  - Recent modern laptops are shipping with powerful ISPs like Intel IPU3.

- *Subject*: Re: Webcams not recognized on a Dell Latitude 5285 laptop
- *From*: Nicolas Dufresne <nicolas@xxxxxxxxxxxx>
- *Date*: Sun, 01 Apr 2018 15:45:16 -0400
- *In-reply-to*: <f69b1c0c-fce3-c1c5-4eeb-7941028991de@univ-grenoble-alpes.fr>

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```
This laptop embeds one of these new "complex" cameras from Intel. They
requires IPU3 driver. Though, unlike traditional webcam, you need
special userspace to use it (there is no embedded firmware to manage
focus, whitebalance, etc, userspace code need to read the stats and
manage that). As of now, there is no good plan on how to support this
in userspace.
```

```
   _
+-/ \-+
| (o) | libcamera
+-----+
```

## libcamera is a complete user space camera stack

- Abstract away from application all interfacing with V4L2 and Media-Controller
- Aims to be compatible with Linux V4L2-based applications, Android and ChromeOS
- Decent on documentation, application developer and pipeline handler guides, sample applications…

## ...

- mail based development: mailing list + patchwork
- we use Meson and Ninja, and they’re great.
- Newcomers and contributors’ friendly(believe me!)

- git://linuxtv.org/libcamera.git
- www.libcamera.org
- IRC: irc://chat.freenode.net/#libcamera
- Mailing list: libcamera-devel@lists.libcamera.org

## Complex cameras debate

- Why Embedded Cameras are Difficult, and How to Make Them Easy
  **Laurent Pinchart**, Ideas on Board

- Complex Cameras on Linux
  **Mauro Carvalho Chehab**, Samsung

- Image Signal Processing (ISP) Drivers & how to merge one upstream
  **Helen Koike**, Collabora

```
 a c /    +-------------+  +-------------+  +-------------+  +-------------+
 p a |    |   Native    |  |  Framework  |  |   Native    |  |   Android   |
 p t |    |    V4L2     |  | Application |  |  libcamera  |  |   Camera    |
 l i |    | Application |  | (gstreamer) |  | Application |  |  Framework  |
 i o \    +-------------+  +-------------+  +-------------+  +-------------+
   n             ^                ^                ^                ^
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 l a             |                |                |                |
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 c p |    |    V4L2     |  |   Camera    |         |         |   Android   |
 a t |    |   Compat.   |  |  Framework  |         |         |   Camera    |
 m a |    |             |  | (gstreamer) |         |         |     HAL     |
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     /           |         .................................................
     |           |         !      :            Language             :      !
 l f |           |         !      :            Bindings             :      !
 i r |           |         !      :           (optional)            :      !
 b a |           |         `...............................................'
 c m |           |                |                |                |
 a e |           |                |                |                |
 m w |           v                v                v                v
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 r r |    |                                                                |
 a k |    |                           libcamera                            |
     |    |                                                                |
     \    +----------------------------------------------------------------+
                           ^                ^                ^
 Userspace                 |                |                |
---------------------------|----------------|----------------|----------------
 Kernel                    |                |                |
                           v                v                v
                     +-----------+    +-----------+    +-----------+
                     |   Media   |<-->|   Video   |<-->|   V4L2    |
                     |  Device   |    |  Device   |    |  Subdev   |
                     +-----------+    +-----------+    +-----------+
```
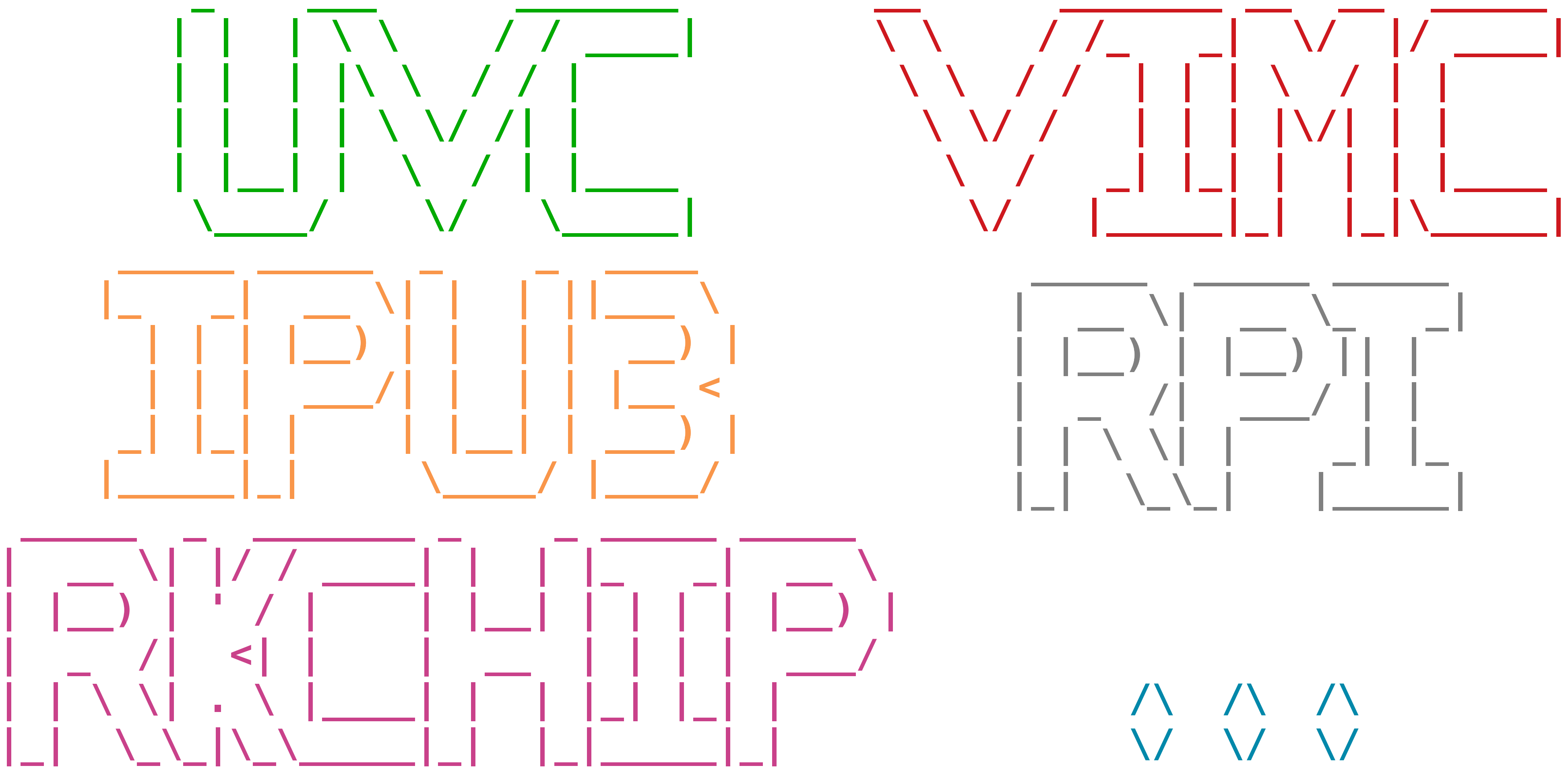

Camera Stack

```
-------------------< libcamera Public API >----------------------------
         ^                                      ^
         |                                      |
         v                                      v
  +-------------+  +--------------------------------------------------+
  |   Camera    |  |  Camera Device                                   |
  |   Devices   |  | +----------------------------------------------+ |
  |   Manager   |  | | Device-Agnostic                              | |
  +-------------+  | |                                              | |
         ^         | |  +-----------------+  +----------------------+ |
         |         | |  |      State      |  |   ~~~~~~~~~~~~~~~~~~~  |
         |         | |  |     Machine     |  |  {  +-------------+  } |
         |         | |  +-----------------+  |  }  |////Image////|  { |
         |         | |                       | <-> |/Processing//|  } |
         |         | |  +-----------------+  |  }  |/Algorithms//|  { |
         |         | |  |     Streams     |  |  {  +-------------+  } |
         |         | |  +-----------------+  |   ~~~~~~~~~~~~~~~~~~~  |
         |         | |                       | ====================== |
         |         | |  +-----------------+  |     +-------------+    |
         |         | |  |     Access      |  |     |//Pipeline///|    |
         |         | |  |     Control     |  | <-> |///Handler///|    |
         |         | |  +-----------------+  |     |/////////////|    |
         |         | +-----------------------+     +-------------+    |
         |         |                                  Device-Specific |
         |         +--------------------------------------------------+
         |                     ^                         ^
         |                     |                         |
         v                     v                         v
+---------------------------------------------------------------------+
| Helpers and Support Classes                                         |
| +-------------+  +-------------+  +-------------+  +-------------+  |
| |  MC & V4L2  |  |   Buffers   |  | Sandboxing  |  |   Plugins   |  |
| |   Support   |  |  Allocator  |  |     IPC     |  |   Manager   |  |
| +-------------+  +-------------+  +-------------+  +-------------+  |
| +-------------+  +-------------+  +-------------+  +-------------+  |
| |  Pipeline   |  |   Debug +   |  |    Multi    |  |     ...     |  |
| |   Runner    |  |   Logging   |  |  Threading  |  |             |  |    /// Device-Specific Components
| +-------------+  +-------------+  +-------------+  +-------------+  |    ~~~ Sandboxing
+---------------------------------------------------------------------+
```

## Libcamera Architecture



Platforms supported by libcamera

## libcamera API

- CameraManager : camera enumeration
- Camera Configuration
- Config validation(negotiation with application’s request)
- FrameBuffer allocation
- Frame Capture

## CameraManager : camera enumeration

```
CameraManager *cm = new CameraManager();
cm→start();


for (auto const &camera : cm→cameras())
      std::cout << camera->id() << std::endl;
```

## Camera Configuration

```
std::string cameraId = cm→cameras()[0]→id();
camera = cm→get(cameraId);


camera→acquire(); // exclusive lock



std::unique_ptr<CameraConfiguration> config =
    camera→generateConfiguration({ StreamRole::StillCapture });
```

## Validation

- Generated CameraConfiguration has a StreamConfiguration instance for each StreamRole.

```
StreamConfiguration &streamConfig = config→at(0);

std::cout << "Default StillCapture configuration is: " << streamConfig.toString();
// Default StillCapture configuration is: 1280x720-MJPEG


//custom application’s request
streamConfig.size.width = 640;
streamConfig.size.height = 480;

config->validate();
```

## Framebuffer allocator

```
FrameBufferAllocator *allocator = new FrameBufferAllocator(camera);


for (StreamConfiguration &cfg : *config) {

    int ret = allocator->allocate(cfg.stream());


    unsigned int allocated = allocator->buffers(cfg.stream()).size();

    std::cout << "Allocated " << allocated << " buffers for stream";

}
```

## Frame Capture

- Happens through object called `Request`
- `Request` associate atleast one stream with FrameBuffer where stream data can be written.
- Request is queued to Camera with camera::queueRequest() after starting the camera via camera::start()
- Camera will emit Camera::requestCompleted signal; thereafter Frame data can be accessed.

## libcamera sample applications

- Cam - swiss knife commandline tool
- Qcam - Qt GUI based application
- Simple-cam - Minimal reference code depicting libcamera usage.

- Don’t forget there is already decent documentation and app developers guide in:

  src/libcamera/Documentation/guides

Please join! libcamera is a young project.

Read the doc: http://libcamera.org/docs.html

Read patches: git://linuxtv.org/libcamera.git

Have a chat: #libcamera on freenode

We welcome inputs from anyone working with cameras!

**Thank you!**

**Questions?**