Rockchip Linux Memory Allocator开发文档

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瑞芯微电子股份有限公司

Rockchip Electronics Co., Ltd.

地址： 福建省福州市铜盘路软件园A区18号

网址： www.rock-chips.com

客户服务电话： +86-4007-700-590

客户服务传真： +86-591-83951833

客户服务邮箱： fae@rock-chips.com

前言

概述

本文介绍Rockchip Linux 5.10平台内存分配器相关技术。

Linux 5.10新增DMA-HEAP内存分配器，代码位于`drivers/dma-buf/heaps/`目录，专用于分配DMABUF类型的内存；对用户空间通过ioctl返回dmabuf的索引(fd)。

产品版本

芯片名称	内核版本
RK3588, RV1106	Linux-5.10

读者对象

本文档（本指南）主要适用于以下工程师：

技术支持工程师

软件开发工程师

修订记录

版本号	作者	修改日期	修改说明
V1.0.0	许剑群	2022-06-25	初始版本

目录

1. 分配器一：DMA-HEAP

分配器驱动代码位于`drivers/dma-buf/heaps/`目录。

```
drivers/dma-buf/heaps/
├── cma_heap.c  物理地址连续内存分配器驱动
├── deferred-free-helper.c  内存延迟释放驱动
├── deferred-free-helper.h
├── Kconfig
├── Makefile
├── page_pool.c  内存页缓存驱动
├── page_pool.h
└── system_heap.c  物理地址不连续虚拟地址连续内存分配器驱动
```

一个heap driver表示一种内存类型的分配器，支持模块化编译。Linux提供两种典型的内存分配器驱动：system-heap、cma-heap。

1.1 system-heap

system-heap默认支持cpu cache，cpu访问该分配器分配的内存是有cache的，访问速度快，但是device和cpu之间要通过软件行为保持数据一致性。该驱动延伸出不支持cpu cahce的分配器，system-uncached-heap。

system-heap默认支持defer-free，即延迟释放内存，在内存页缓存非空时，内存分配速度快。内存页缓存依赖于mm shrinker进行适当地回收。

system-heap通过add_dma_heap()向dma-heap增加分配器，获取唯一的索引，并在`/dev/dma_heap/`下创建分配器的设备，如`/dev/dma_heap/system-heap`和`/dev/dma_heap/system-uncached-heap`。

1.2 cma-heap

cma-heap默认支持cpu cache，cpu访问该分配器分配的内存是有cache的，访问速度快，但是device和cpu之间要通过软件行为保持数据一致性。

cma-heap是从cma_alloc分配内存页，而cma的内存区域是由cma的驱动确定，详细参看`Rockchip_Developer_Guide_Linux_CMA_CN`文档。该分配器分配到的是物理地址连续内存，适用于没有iommu的外设直接访问。

2. 分配器二：DRM-GEM

分配器驱动代码位于`drivers/gpu/drm/rockchip/`目录。

3. 分配器三：VB2-MEMOPS

分配器驱动代码位于`drivers/media/common/videobuf2/`目录。

4. RV1106专用分配器：RK-DMA-HEAP

RK-DMA-HEAP是RV1106专用的DMABUF内存分配器，基于DMA-HEAP。

RK-DMA-HEAP与DMA-HEAP的主要差异：

	Linux API	**RETURN**
Linux分配DMABUF	rk_dma_heap_buffer_alloc	struct dma_buf *
Linux分配PAGE数组	rk_dma_heap_alloc_contig_pages	struct page *
支持debug list		

> DMA-HEAP是DMABUF的分配器，但是RK-DMA-HEAP支持分配DMABUF，也支持分配普通的页数组。

4.1 rk-dma-heap-info

RK-DMA-HEAP的调试节点是`/proc/rk_dma_heap/rk-dma-heap-info`，读取节点会打印较多内容如下

```
# cat /proc/rk_dma_heap/rk-dma-heap-info
dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5656
    Alloc by (vmpi                ) [0x03e1b000-0x03e33fff] 0x00019000 (100 KiB)
        Attached Devices:
Total 0 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5655
    Alloc by (vmpi                ) [0x03e02000-0x03e1afff] 0x00019000 (100 KiB)
        Attached Devices:
        ffa50000.rkvenc
```

```
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5654
    Alloc by (vmpi                ) [0x03d96000-0x03e01fff] 0x0006c000 (432 KiB)
        Attached Devices:
Total 0 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5653
    Alloc by (vmpi                ) [0x03d86000-0x03d95fff] 0x00010000 (64 KiB)
        Attached Devices:
Total 0 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5652
    Alloc by (vmpi                ) [0x03d76000-0x03d85fff] 0x00010000 (64 KiB)
        Attached Devices:
        ffa50000.rkvenc
        ffa50000.rkvenc
Total 2 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5637
    Alloc by (vmpi                ) [0x03c76000-0x03d75fff] 0x00100000 (1024 KiB)
        Attached Devices:
        ffa50000.rkvenc
        ffa50000.rkvenc
Total 2 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5636
    Alloc by (vmpi                ) [0x03c74000-0x03c75fff] 0x00002000 (8 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5635
    Alloc by (vmpi                ) [0x03c72000-0x03c73fff] 0x00002000 (8 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5626
    Alloc by (vmpi                ) [0x03c40000-0x03c71fff] 0x00032000 (200 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5625
    Alloc by (vmpi                ) [0x03c3f000-0x03c3ffff] 0x00001000 (4 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5624
    Alloc by (vmpi                ) [0x03c37000-0x03c3efff] 0x00008000 (32 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached
```

```
dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5623
    Alloc by (vmpi                ) [0x03c36000-0x03c36fff] 0x00001000 (4 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5622
    Alloc by (vmpi                ) [0x03c2e000-0x03c35fff] 0x00008000 (32 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5621
    Alloc by (vmpi                ) [0x03b64000-0x03c2dfff] 0x000ca000 (808 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5610
    Alloc by (vmpi                ) [0x03acf000-0x03b63fff] 0x00095000 (596 KiB)
        Attached Devices:
        ffa00000.rkisp
        ffa50000.rkvenc
        ffa00000.rkisp
        ffa00000.rkisp
        ffa00000.rkisp
Total 5 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5609
    Alloc by (vmpi                ) [0x03ac0000-0x03acefff] 0x0000f000 (60 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5608
    Alloc by (vmpi                ) [0x03ab1000-0x03abffff] 0x0000f000 (60 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5607
    Alloc by (vmpi                ) [0x038ef000-0x03ab0fff] 0x001c2000 (1800 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5606
    Alloc by (vmpi                ) [0x038ed000-0x038eefff] 0x00002000 (8 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5605
    Alloc by (vmpi                ) [0x038b3000-0x038ecfff] 0x0003a000 (232 KiB)
        Attached Devices:
        ffa50000.rkvenc
```

```
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5604
    Alloc by (vmpi                ) [0x038b1000-0x038b2fff] 0x00002000 (8 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5603
    Alloc by (vmpi                ) [0x03877000-0x038b0fff] 0x0003a000 (232 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5602
    Alloc by (vmpi                ) [0x0324e000-0x03876fff] 0x00629000 (6308 KiB)
        Attached Devices:
        ffa50000.rkvenc
Total 1 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5586
    Alloc by (ff660000.npu        ) [0x0308c000-0x030f7fff] 0x0006c000 (432 KiB)
        Attached Devices:
Total 0 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5585
    Alloc by (ff660000.npu        ) [0x03087000-0x0308bfff] 0x00005000 (20 KiB)
        Attached Devices:
Total 0 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5584
    Alloc by (ff660000.npu        ) [0x03082000-0x03086fff] 0x00005000 (20 KiB)
        Attached Devices:
Total 0 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5583
    Alloc by (ff660000.npu        ) [0x0307d000-0x03081fff] 0x00005000 (20 KiB)
        Attached Devices:
Total 0 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5582
    Alloc by (ff660000.npu        ) [0x0306b000-0x0307cfff] 0x00012000 (72 KiB)
        Attached Devices:
Total 0 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5581
    Alloc by (ff660000.npu        ) [0x03059000-0x0306afff] 0x00012000 (72 KiB)
        Attached Devices:
Total 0 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5580
    Alloc by (ff660000.npu        ) [0x03047000-0x03058fff] 0x00012000 (72 KiB)
        Attached Devices:
Total 0 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5579
```

```
    Alloc by (ff660000.npu        ) [0x02e5f000-0x03046fff] 0x001e8000 (1952 KiB)
        Attached Devices:
Total 0 devices attached

dma-heap:<rk-dma-heap-cma> -dmabuf  i_ino = 5328
    Alloc by (vmpi                ) [0x02800000-0x02802fff] 0x00003000 (12 KiB)
        Attached Devices:
Total 0 devices attached

dma-heap:<rk-dma-heap-cma> -non dmabuf
    Alloc by (ffa00000.rkisp      ) [0x02803000-0x02813fff] 0x00011000 (68 KiB)
dma-heap:<rk-dma-heap-cma> -non dmabuf
    Alloc by (ffa00000.rkisp      ) [0x02814000-0x02824fff] 0x00011000 (68 KiB)
dma-heap:<rk-dma-heap-cma> -non dmabuf
    Alloc by (ffa00000.rkisp      ) [0x02825000-0x02825fff] 0x00001000 (4 KiB)
dma-heap:<rk-dma-heap-cma> -non dmabuf
    Alloc by (ffa00000.rkisp      ) [0x02826000-0x02826fff] 0x00001000 (4 KiB)
dma-heap:<rk-dma-heap-cma> -non dmabuf
    Alloc by (ffa00000.rkisp      ) [0x02827000-0x02dddfff] 0x005b7000 (5852 KiB)
dma-heap:<rk-dma-heap-cma> -non dmabuf
    Alloc by (ffa00000.rkisp      ) [0x02dde000-0x02e4efff] 0x00071000 (452 KiB)
dma-heap:<rk-dma-heap-cma> -non dmabuf
    Alloc by (rkisp-vir0          ) [0x02e4f000-0x02e52fff] 0x00004000 (16 KiB)
dma-heap:<rk-dma-heap-cma> -non dmabuf
    Alloc by (rkisp-vir0          ) [0x02e53000-0x02e56fff] 0x00004000 (16 KiB)
dma-heap:<rk-dma-heap-cma> -non dmabuf
    Alloc by (rkisp-vir0          ) [0x02e57000-0x02e5afff] 0x00004000 (16 KiB)
dma-heap:<rk-dma-heap-cma> -non dmabuf
    Alloc by (rkisp-vir0          ) [0x02e5b000-0x02e5efff] 0x00004000 (16 KiB)
dma-heap:<rk-dma-heap-cma> -non dmabuf
    Alloc by (ffa00000.rkisp      ) [0x030f8000-0x03249fff] 0x00152000 (1352 KiB)
dma-heap:<rk-dma-heap-cma> -non dmabuf
    Alloc by (ffa00000.rkisp      ) [0x0324a000-0x0324dfff] 0x00004000 (16 KiB)

Total : 0x1634000 (22736 KiB)
```

一般可以用 'Alloc'过滤出分配信息

```
# cat /proc/rk_dma_heap/rk-dma-heap-info |grep Alloc
        Alloc by (vmpi                ) [0x03e1b000-0x03e33fff] 0x00019000 (100
KiB)
        Alloc by (vmpi                ) [0x03e02000-0x03e1afff] 0x00019000 (100
KiB)
        Alloc by (vmpi                ) [0x03d96000-0x03e01fff] 0x0006c000 (432
KiB)
        Alloc by (vmpi                ) [0x03d86000-0x03d95fff] 0x00010000 (64
KiB)
        Alloc by (vmpi                ) [0x03d76000-0x03d85fff] 0x00010000 (64
KiB)
        Alloc by (vmpi                ) [0x03c76000-0x03d75fff] 0x00100000 (1024
KiB)
        Alloc by (vmpi                ) [0x03c74000-0x03c75fff] 0x00002000 (8
KiB)
        Alloc by (vmpi                ) [0x03c72000-0x03c73fff] 0x00002000 (8
KiB)
```

```
        Alloc by (vmpi                ) [0x03c40000-0x03c71fff] 0x00032000 (200
KiB)
        Alloc by (vmpi                ) [0x03c3f000-0x03c3ffff] 0x00001000 (4
KiB)
        Alloc by (vmpi                ) [0x03c37000-0x03c3efff] 0x00008000 (32
KiB)
        Alloc by (vmpi                ) [0x03c36000-0x03c36fff] 0x00001000 (4
KiB)
        Alloc by (vmpi                ) [0x03c2e000-0x03c35fff] 0x00008000 (32
KiB)
        Alloc by (vmpi                ) [0x03b64000-0x03c2dfff] 0x000ca000 (808
KiB)
        Alloc by (vmpi                ) [0x03acf000-0x03b63fff] 0x00095000 (596
KiB)
        Alloc by (vmpi                ) [0x03ac0000-0x03acefff] 0x0000f000 (60
KiB)
        Alloc by (vmpi                ) [0x03ab1000-0x03abffff] 0x0000f000 (60
KiB)
        Alloc by (vmpi                ) [0x038ef000-0x03ab0fff] 0x001c2000 (1800
KiB)
        Alloc by (vmpi                ) [0x038ed000-0x038eefff] 0x00002000 (8
KiB)
        Alloc by (vmpi                ) [0x038b3000-0x038ecfff] 0x0003a000 (232
KiB)
        Alloc by (vmpi                ) [0x038b1000-0x038b2fff] 0x00002000 (8
KiB)
        Alloc by (vmpi                ) [0x03877000-0x038b0fff] 0x0003a000 (232
KiB)
        Alloc by (vmpi                ) [0x0324e000-0x03876fff] 0x00629000 (6308
KiB)
        Alloc by (ff660000.npu        ) [0x0308c000-0x030f7fff] 0x0006c000 (432
KiB)
        Alloc by (ff660000.npu        ) [0x03087000-0x0308bfff] 0x00005000 (20
KiB)
        Alloc by (ff660000.npu        ) [0x03082000-0x03086fff] 0x00005000 (20
KiB)
        Alloc by (ff660000.npu        ) [0x0307d000-0x03081fff] 0x00005000 (20
KiB)
        Alloc by (ff660000.npu        ) [0x0306b000-0x0307cfff] 0x00012000 (72
KiB)
        Alloc by (ff660000.npu        ) [0x03059000-0x0306afff] 0x00012000 (72
KiB)
        Alloc by (ff660000.npu        ) [0x03047000-0x03058fff] 0x00012000 (72
KiB)
        Alloc by (ff660000.npu        ) [0x02e5f000-0x03046fff] 0x001e8000 (1952
KiB)
        Alloc by (vmpi                ) [0x02800000-0x02802fff] 0x00003000 (12
KiB)
        Alloc by (ffa00000.rkisp      ) [0x02803000-0x02813fff] 0x00011000 (68
KiB)
        Alloc by (ffa00000.rkisp      ) [0x02814000-0x02824fff] 0x00011000 (68
KiB)
        Alloc by (ffa00000.rkisp      ) [0x02825000-0x02825fff] 0x00001000 (4
KiB)
        Alloc by (ffa00000.rkisp      ) [0x02826000-0x02826fff] 0x00001000 (4
KiB)
```

```
        Alloc by (ffa00000.rkisp      ) [0x02827000-0x02dddfff] 0x005b7000 (5852
KiB)
        Alloc by (ffa00000.rkisp      ) [0x02dde000-0x02e4efff] 0x00071000 (452
KiB)
        Alloc by (rkisp-vir0          ) [0x02e4f000-0x02e52fff] 0x00004000 (16
KiB)
        Alloc by (rkisp-vir0          ) [0x02e53000-0x02e56fff] 0x00004000 (16
KiB)
        Alloc by (rkisp-vir0          ) [0x02e57000-0x02e5afff] 0x00004000 (16
KiB)
        Alloc by (rkisp-vir0          ) [0x02e5b000-0x02e5efff] 0x00004000 (16
KiB)
        Alloc by (ffa00000.rkisp      ) [0x030f8000-0x03249fff] 0x00152000 (1352
KiB)
        Alloc by (ffa00000.rkisp      ) [0x0324a000-0x0324dfff] 0x00004000 (16
KiB)
```

格式：Alloc by ([dmabuf name]) [0xaaaaaaaa-0xbbbbbbbb] 0xzzzzzzzz (dd KiB)

1. [dmabuf name]：在驱动中分配内存的线程名默认被设置为dmabuf name，各模块如果有指定字符串会覆盖默认值。如vmpi是rockit中调用rk-dma-heap的线程名。
2. [0xaaaaaaaa-0xbbbbbbbb]：0xaaaaaaaa是该内存区域的起始地址（物理地址），0xbbbbbbbb是结束地址（物理地址）。
3. 0xzzzzzzzz：是内存区间大小的十六进制值。
4. dd KiB：dd是内存区间大小的十进制值并转为KiB。