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(25)
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(22)
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(5)
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(17)
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(18)
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(22)
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(43)
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(93)
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更多

当不需要在用户态访问时，是不需要与struct file关联的，内核结构ion_handle/ion_buffer唯一的表征了该buffer，所以与struct file关联的工作是在ioctl(ion, ION_IOC_SHARE/ION_IOC_MAP, &share)中完成并输出的，用于后续的mmap调用；或者该进程不需要mmap而是仅仅向别的进程binder transfer，这就实现了用户态进行buffer流转控制，而内核态完成buffer数据流转。

转自http://blog.csdn.net/kris_fei/article/details/8588661 & http://blog.csdn.net/kris_fei/article/details/8618587

考察平台：

chipset: MSM8X25Q
codebase: Android 4.1

ION概念：

ION是Google的下一代内存管理器，用来支持不同的内存分配机制，如CARVOUT(PMEM)，物理连续内存(kmalloc)，虚拟地址连续但物理不连续内存(vmalloc)， IOMMU等。

用户空间和内核空间都可以使用ION，用户空间是通过/dev/ion来创建client的。

说到client, 顺便看下ION相关比较重要的几个概念。

Heap: 用来表示内存分配的相关信息，包括id, type, name等。用struct ion_heap表示。

Client: Ion的使用者，用户空间和内核控件要使用ION的buffer,必须先创建一个client, 一个client可以有多个buffer，用struct ion_buffer表示。

Handle: 将buffer该抽象出来，可以认为ION用handle来管理buffer，一般用户直接拿到的是handle,而不是buffer。用struct ion_handle表示。

heap类型：

由于ION可以使用多种memory分配机制，例如物理连续和不连续的，所以ION使用enum ion_heap_type表示。

```
[cpp]
01. /**
02.  * enum ion_heap_types - list of all possible types of heaps
03.  * @ION_HEAP_TYPE_SYSTEM:    memory allocated via vmalloc
04.  * @ION_HEAP_TYPE_SYSTEM_CONTIG: memory allocated via kmalloc
05.  * @ION_HEAP_TYPE_CARVEOUT:  memory allocated from a prereserved
```

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OS_Install_Tips (12)
C++ (60)
HR (9)
health (1)
tv&&music&&fun (9)
compile (9)
并发处理相关 (8)
const&mutable (2)
callback_func (1)
ipc (1)
camera_framework (9)
sp&wp (3)
selinux (1)
initrc (3)
cmd (2)
virtual_func (2)
stl (1)
log (2)
mediaplayer (1)
parcel (1)
property (2)
debug (1)
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```
06.  *           carveout heap, allocations are physically
07.  *           contiguous
08.  * @ION_HEAP_TYPE_IOMMU: IOMMU memory
09.  * @ION_HEAP_TYPE_CP:   memory allocated from a prereserved
10.  *           carveout heap, allocations are physically
11.  *           contiguous. Used for content protection.
12.  * @ION_HEAP_TYPE_DMA:   memory allocated via DMA API
13.  * @ION_HEAP_END:        helper for iterating over heaps
14.  */
15.  enum ion_heap_type {
16.      ION_HEAP_TYPE_SYSTEM,
17.      ION_HEAP_TYPE_SYSTEM_CONTIG,
18.      ION_HEAP_TYPE_CARVEOUT,
19.      ION_HEAP_TYPE_IOMMU,
20.      ION_HEAP_TYPE_CP,
21.      ION_HEAP_TYPE_DMA,
22.      ION_HEAP_TYPE_CUSTOM, /* must be last so device specific heaps always
23.                             are at the end of this enum */
24.      ION_NUM_HEAPS,
25.  };
```

[cpp]

```
01.  <span xmlns="http://www.w3.org/1999/xhtml" style="">/**
02.  * enum ion_heap_types - list of all possible types of heaps
03.  * @ION_HEAP_TYPE_SYSTEM:   memory allocated via vmalloc
04.  * @ION_HEAP_TYPE_SYSTEM_CONTIG: memory allocated via kmalloc
05.  * @ION_HEAP_TYPE_CARVEOUT: memory allocated from a prereserved
06.  *           carveout heap, allocations are physically
07.  *           contiguous
08.  * @ION_HEAP_TYPE_IOMMU: IOMMU memory
09.  * @ION_HEAP_TYPE_CP:   memory allocated from a prereserved
10.  *           carveout heap, allocations are physically
11.  *           contiguous. Used for content protection.
12.  * @ION_HEAP_TYPE_DMA:   memory allocated via DMA API
13.  * @ION_HEAP_END:        helper for iterating over heaps
14.  */
15.  enum ion_heap_type {
16.      ION_HEAP_TYPE_SYSTEM,
17.      ION_HEAP_TYPE_SYSTEM_CONTIG,
18.      ION_HEAP_TYPE_CARVEOUT,
19.      ION_HEAP_TYPE_IOMMU,
20.      ION_HEAP_TYPE_CP,
21.      ION_HEAP_TYPE_DMA,
22.      ION_HEAP_TYPE_CUSTOM, /* must be last so device specific heaps always
23.                             are at the end of this enum */
24.      ION_NUM_HEAPS,
25.  };</span>
```

代码中的注释很明确地说明了哪种type对应的是分配哪种memory。不同type的heap需要不同的method去分配，不过都是用struct ion_heap_ops来表示的。如以下例子：

[cpp]

```
01.  static struct ion_heap_ops carveout_heap_ops = {
02.      .allocate = ion_carveout_heap_allocate,
03.      .free = ion_carveout_heap_free,
04.      .phys = ion_carveout_heap_phys,
05.      .map_user = ion_carveout_heap_map_user,
06.      .map_kernel = ion_carveout_heap_map_kernel,
07.      .unmap_user = ion_carveout_heap_unmap_user,
08.      .unmap_kernel = ion_carveout_heap_unmap_kernel,
09.      .map_dma = ion_carveout_heap_map_dma,
10.      .unmap_dma = ion_carveout_heap_unmap_dma,
11.      .cache_op = ion_carveout_cache_ops,
12.      .print_debug = ion_carveout_print_debug,
13.      .map_iommu = ion_carveout_heap_map_iommu,
14.      .unmap_iommu = ion_carveout_heap_unmap_iommu,
15.  };
16.
17.  static struct ion_heap_ops kmalloc_ops = {
18.      .allocate = ion_system_contig_heap_allocate,
19.      .free = ion_system_contig_heap_free,
20.      .phys = ion_system_contig_heap_phys,
21.      .map_dma = ion_system_contig_heap_map_dma,
22.      .unmap_dma = ion_system_heap_unmap_dma,
23.      .map_kernel = ion_system_heap_map_kernel,
```

关闭

* 四大线程池详解

```
24.     .unmap_kernel = ion_system_heap_unmap_kernel,
25.     .map_user = ion_system_contig_heap_map_user,
26.     .cache_op = ion_system_contig_heap_cache_ops,
27.     .print_debug = ion_system_contig_print_debug,
28.     .map_iommu = ion_system_contig_heap_map_iommu,
29.     .unmap_iommu = ion_system_heap_unmap_iommu,
30. };
```

[cpp]

```
01. <span xmlns="http://www.w3.org
/1999/xhtml" style="">static struct ion_heap_ops carveout_heap_ops = {
02.     .allocate = ion_carveout_heap_allocate,
03.     .free = ion_carveout_heap_free,
04.     .phys = ion_carveout_heap_phys,
05.     .map_user = ion_carveout_heap_map_user,
06.     .map_kernel = ion_carveout_heap_map_kernel,
07.     .unmap_user = ion_carveout_heap_unmap_user,
08.     .unmap_kernel = ion_carveout_heap_unmap_kernel,
09.     .map_dma = ion_carveout_heap_map_dma,
10.     .unmap_dma = ion_carveout_heap_unmap_dma,
11.     .cache_op = ion_carveout_cache_ops,
12.     .print_debug = ion_carveout_print_debug,
13.     .map_iommu = ion_carveout_heap_map_iommu,
14.     .unmap_iommu = ion_carveout_heap_unmap_iommu,
15. };
16.
17. static struct ion_heap_ops kmalloc_ops = {
18.     .allocate = ion_system_contig_heap_allocate,
19.     .free = ion_system_contig_heap_free,
20.     .phys = ion_system_contig_heap_phys,
21.     .map_dma = ion_system_contig_heap_map_dma,
22.     .unmap_dma = ion_system_heap_unmap_dma,
23.     .map_kernel = ion_system_heap_map_kernel,
24.     .unmap_kernel = ion_system_heap_unmap_kernel,
25.     .map_user = ion_system_contig_heap_map_user,
26.     .cache_op = ion_system_contig_heap_cache_ops,
27.     .print_debug = ion_system_contig_print_debug,
28.     .map_iommu = ion_system_contig_heap_map_iommu,
29.     .unmap_iommu = ion_system_heap_unmap_iommu,
30. };</span>
```

Heap ID :

同一种type的heap上当然可以分为若该若干个chunk供用户使用，所以ION又使用ID来区分了。例如在type为ION_HEAP_TYPE_CARVEOUT的heap上，audio和display部分都需要使用，ION就用ID来区分。

Heap id用enumion_heap_ids表示。

[cpp]

```
01. /**
02.  * These are the only ids that should be used for Ion heap ids.
03.  * The ids listed are the order in which allocation will be attempted
04.  * if specified. Don't swap the order of heap ids unless you know what
05.  * you are doing!
06.  * Id's are spaced by purpose to allow new Id's to be inserted in-between (for
07.  * possible fallbacks)
08.  */
09.
10. enum ion_heap_ids {
11.     INVALID_HEAP_ID = -1,
12.     ION_CP_MM_HEAP_ID = 8,
13.     ION_CP_MFC_HEAP_ID = 12,
14.     ION_CP_WB_HEAP_ID = 16, /* 8660 only */
15.     ION_CAMERA_HEAP_ID = 20, /* 8660 only */
16.     ION_SF_HEAP_ID = 24,
17.     ION_IOMMU_HEAP_ID = 25,
18.     ION_QSECOM_HEAP_ID = 26,
19.     ION_AUDIO_HEAP_BL_ID = 27,
20.     ION_AUDIO_HEAP_ID = 28,
21.
22.     ION_MM_FIRMWARE_HEAP_ID = 29,
23.     ION_SYSTEM_HEAP_ID = 30,
24.
25.     ION_HEAP_ID_RESERVED = 31 /** Bit reserved for ION_SECURE flag */
26. };
```

关闭

```
[cpp]
01. <span xmlns="http://www.w3.org/1999/xhtml" style="">/**
02.  * These are the only ids that should be used for Ion heap ids.
03.  * The ids listed are the order in which allocation will be attempted
04.  * if specified. Don't swap the order of heap ids unless you know what
05.  * you are doing!
06.  * Id's are spaced by purpose to allow new Id's to be inserted in-between (for
07.  * possible fallbacks)
08.  */
09.
10. enum ion_heap_ids {
11.     INVALID_HEAP_ID = -1,
12.     ION_CP_MM_HEAP_ID = 8,
13.     ION_CP_MFC_HEAP_ID = 12,
14.     ION_CP_WB_HEAP_ID = 16, /* 8660 only */
15.     ION_CAMERA_HEAP_ID = 20, /* 8660 only */
16.     ION_SF_HEAP_ID = 24,
17.     ION_IOMMU_HEAP_ID = 25,
18.     ION_QSECOM_HEAP_ID = 26,
19.     ION_AUDIO_HEAP_BL_ID = 27,
20.     ION_AUDIO_HEAP_ID = 28,
21.
22.     ION_MM_FIRMWARE_HEAP_ID = 29,
23.     ION_SYSTEM_HEAP_ID = 30,
24.
25.     ION_HEAP_ID_RESERVED = 31 /** Bit reserved for ION_SECURE flag */
26. };</span>
```

Heap 定义：

了解了heap type和id，看看如何被用到了，本平台使用的文件为board-qrd7627a.c，有如下定义：

```
[cpp]
01. /**
02.  * These heaps are listed in the order they will be allocated.
03.  * Don't swap the order unless you know what you are doing!
04.  */
05. struct ion_platform_heap msm7627a_heaps[] = {
06.     {
07.         .id = ION_SYSTEM_HEAP_ID,
08.         .type = ION_HEAP_TYPE_SYSTEM,
09.         .name = ION_VMALLOC_HEAP_NAME,
10.     },
11. #ifdef CONFIG_MSM_MULTIMEDIA_USE_ION
12.     /* PMEM_ADSP = CAMERA */
13.     {
14.         .id = ION_CAMERA_HEAP_ID,
15.         .type = CAMERA_HEAP_TYPE,
16.         .name = ION_CAMERA_HEAP_NAME,
17.         .memory_type = ION_EBI_TYPE,
18.         .extra_data = (void *)&co_mm_ion_pdata,
19.         .priv = (void *)&ion_cma_device.dev,
20.     },
21.     /* AUDIO HEAP 1 */
22.     {
23.         .id = ION_AUDIO_HEAP_ID,
24.         .type = ION_HEAP_TYPE_CARVEOUT,
25.         .name = ION_AUDIO_HEAP_NAME,
26.         .memory_type = ION_EBI_TYPE,
27.         .extra_data = (void *)&co_ion_pdata,
28.     },
29.     /* PMEM_MDP = SF */
30.     {
31.         .id = ION_SF_HEAP_ID,
32.         .type = ION_HEAP_TYPE_CARVEOUT,
33.         .name = ION_SF_HEAP_NAME,
34.         .memory_type = ION_EBI_TYPE,
35.         .extra_data = (void *)&co_ion_pdata,
36.     },
37.     /* AUDIO HEAP 2 */
38.     {
39.         .id = ION_AUDIO_HEAP_BL_ID,
40.         .type = ION_HEAP_TYPE_CARVEOUT,
41.         .name = ION_AUDIO_HEAP_NAME,
42.         .memory_type = ION_EBI_TYPE,
43.         .extra_data = (void *)&co_ion_pdata,
```

[关闭](#)

```
44.         .base = BOOTLOADER_BASE_ADDR,
45.     },
46.
47. #endif
48. };

[cpp]

01. <span xmlns="http://www.w3.org/1999/xhtml" style="">/**
02.  * These heaps are listed in the order they will be allocated.
03.  * Don't swap the order unless you know what you are doing!
04.  */
05. struct ion_platform_heap msm7627a_heaps[] = {
06.     {
07.         .id = ION_SYSTEM_HEAP_ID,
08.         .type = ION_HEAP_TYPE_SYSTEM,
09.         .name = ION_VMALLOC_HEAP_NAME,
10.     },
11. #ifdef CONFIG_MSM_MULTIMEDIA_USE_ION
12.     /* PMEM_ADSP = CAMERA */
13.     {
14.         .id = ION_CAMERA_HEAP_ID,
15.         .type = CAMERA_HEAP_TYPE,
16.         .name = ION_CAMERA_HEAP_NAME,
17.         .memory_type = ION_EBI_TYPE,
18.         .extra_data = (void *)&co_mm_ion_pdata,
19.         .priv = (void *)&ion_cma_device.dev,
20.     },
21.     /* AUDIO_HEAP 1 */
22.     {
23.         .id = ION_AUDIO_HEAP_ID,
24.         .type = ION_HEAP_TYPE_CARVEOUT,
25.         .name = ION_AUDIO_HEAP_NAME,
26.         .memory_type = ION_EBI_TYPE,
27.         .extra_data = (void *)&co_ion_pdata,
28.     },
29.     /* PMEM_MDP = SF */
30.     {
31.         .id = ION_SF_HEAP_ID,
32.         .type = ION_HEAP_TYPE_CARVEOUT,
33.         .name = ION_SF_HEAP_NAME,
34.         .memory_type = ION_EBI_TYPE,
35.         .extra_data = (void *)&co_ion_pdata,
36.     },
37.     /* AUDIO_HEAP 2 */
38.     {
39.         .id = ION_AUDIO_HEAP_BL_ID,
40.         .type = ION_HEAP_TYPE_CARVEOUT,
41.         .name = ION_AUDIO_BL_HEAP_NAME,
42.         .memory_type = ION_EBI_TYPE,
43.         .extra_data = (void *)&co_ion_pdata,
44.         .base = BOOTLOADER_BASE_ADDR,
45.     },
46.
47. #endif
48. };</span>
```

ION Handle :

当Ion client分配buffer时，相应的一个唯一的handle也会被指定，当然client可以多次申请ion buffer。申请好buffer之后，返回的是一个ion handle，不过要知道Ion buffer才和实际的内存相关，包括size, address等信息。

Struct ion_handle和struct ion_buffer如下：

```
[cpp]  C  ?

01. /**
02.  * ion_handle - a client local reference to a buffer
03.  * @ref:      reference count
04.  * @client:   back pointer to the client the buffer resides in
05.  * @buffer:   pointer to the buffer
06.  * @node:     node in the client's handle rbtree
07.  * @kmap_cnt: count of times this client has mapped to kernel
08.  * @dmap_cnt: count of times this client has mapped for dma
09.  *
10.  * Modifications to node, map_cnt or mapping should be protected by the
11.  * lock in the client. Other fields are never changed after initialization.
12.  */
13. struct ion_handle {
```

关闭

```

14.     struct kref ref;
15.     struct ion_client *client;
16.     struct ion_buffer *buffer;
17.     struct rb_node node;
18.     unsigned int kmap_cnt;
19.     unsigned int iommu_map_cnt;
20. };
21.
22. /**
23.  * struct ion_buffer - metadata for a particular buffer
24.  * @ref:         reference count
25.  * @node:        node in the ion_device buffers tree
26.  * @dev:         back pointer to the ion_device
27.  * @heap:        back pointer to the heap the buffer came from
28.  * @flags:       buffer specific flags
29.  * @size:        size of the buffer
30.  * @priv_virt:   private data to the buffer representable as
31.  *               a void *
32.  * @priv_phys:   private data to the buffer representable as
33.  *               an ion_phys_addr_t (and someday a phys_addr_t)
34.  * @lock:        protects the buffers cnt fields
35.  * @kmap_cnt:    number of times the buffer is mapped to the kernel
36.  * @vaddr:       the kernel mapping if kmap_cnt is not zero
37.  * @dmap_cnt:    number of times the buffer is mapped for dma
38.  * @sg_table:    the sg table for the buffer if dmap_cnt is not zero
39.  */
40. struct ion_buffer {
41.     struct kref ref;
42.     struct rb_node node;
43.     struct ion_device *dev;
44.     struct ion_heap *heap;
45.     unsigned long flags;
46.     size_t size;
47.     union {
48.         void *priv_virt;
49.         ion_phys_addr_t priv_phys;
50.     };
51.     struct mutex lock;
52.     int kmap_cnt;
53.     void *vaddr;
54.     int dmap_cnt;
55.     struct sg_table *sg_table;
56.     int umap_cnt;
57.     unsigned int iommu_map_cnt;
58.     struct rb_root iommu_maps;
59.     int marked;
60. };

```

[cpp]

```

01. <span xmlns="http://www.w3.org/1999/xhtml" style="">/**
02.  * ion_handle - a client local reference to a buffer
03.  * @ref:         reference count
04.  * @client:      back pointer to the client the buffer resides in
05.  * @buffer:      pointer to the buffer
06.  * @node:        node in the client's handle rbtree
07.  * @kmap_cnt:    count of times this client has mapped to kernel
08.  * @dmap_cnt:    count of times this client has mapped for dma
09.  *
10.  * Modifications to node, map_cnt or mapping should be protected by the
11.  * lock in the client. Other fields are never changed after initialization.
12.  */
13. struct ion_handle {
14.     struct kref ref;
15.     struct ion_client *client;
16.     struct ion_buffer *buffer;
17.     struct rb_node node;
18.     unsigned int kmap_cnt;
19.     unsigned int iommu_map_cnt;
20. };
21.
22. /**
23.  * struct ion_buffer - metadata for a particular buffer
24.  * @ref:         reference count
25.  * @node:        node in the ion_device buffers tree
26.  * @dev:         back pointer to the ion_device
27.  * @heap:        back pointer to the heap the buffer came from
28.  * @flags:       buffer specific flags
29.  * @size:        size of the buffer
30.  * @priv_virt:   private data to the buffer representable as

```

关闭

```

31.      *          a void *
32.      * @priv_phys:   private data to the buffer representable as
33.      *          an ion_phys_addr_t (and someday a phys_addr_t)
34.      * @lock:       protects the buffers cnt fields
35.      * @kmap_cnt:   number of times the buffer is mapped to the kernel
36.      * @vaddr:      the kernel mapping if kmap_cnt is not zero
37.      * @dmap_cnt:   number of times the buffer is mapped for dma
38.      * @sg_table:   the sg table for the buffer if dmap_cnt is not zero
39.      */
40.  struct ion_buffer {
41.      struct kref ref;
42.      struct rb_node node;
43.      struct ion_device *dev;
44.      struct ion_heap *heap;
45.      unsigned long flags;
46.      size_t size;
47.      union {
48.          void *priv_virt;
49.          ion_phys_addr_t priv_phys;
50.      };
51.      struct mutex lock;
52.      int kmap_cnt;
53.      void *vaddr;
54.      int dmap_cnt;
55.      struct sg_table *sg_table;
56.      int umap_cnt;
57.      unsigned int iommu_map_cnt;
58.      struct rb_root iommu_maps;
59.      int marked;
60.  };</span>

```

ION Client :

用户空间和内核空间都可以成为client，不过创建的方法稍稍有点区别，先了解下基本的操作流程吧。

内核空间:

先创建client:

```

[cpp]      C  {}
01.  struct ion_client *ion_client_create(struct ion_device *dev,
02.                                     unsigned int heap_mask,
03.                                     const char *name)

[cpp]
01.  <span xmlns="http://www.w3.org
/1999/xhtml" style="">struct ion_client *ion_client_create(struct ion_device *dev,
02.                                     unsigned int heap_mask,
03.                                     const char *name)</span>

```

heap_mask: 可以分配的heap type，如carveout,system heap, iommu等。

高通使用msm_ion_client_create函数封装了下。

有了client之后就可以分配内存：

```

[cpp]      C  {}
01.  struct ion_handle *ion_alloc(struct ion_client *client, size_t len,
02.                              size_t align, unsigned int flags)

[cpp]
01.  <span xmlns="http://www.w3.org
/1999/xhtml" style="">struct ion_handle *ion_alloc(st
02.                              size_t align, unsigned int flags)</span>

```

flags: 分配的heap id.

有了handle也就是buffer之后就准备使用了，不过还是物理地址，需要map：

```

[cpp]      C  {}
01.  void *ion_map_kernel(struct ion_client *client, struct ion_handle *handle,
02.                      unsigned long flags)

[cpp]
01.  <span xmlns="http://www.w3.org

```

关闭



```
02. /1999/xhtml1" style="">void *ion_map_kernel(struct ion_client *client, struct ion_handle  
    unsigned long flags)</span>
```

用户空间:



用户空间如果想使用ION, 也必须先要创建client, 不过它是打开/dev/ion, 实际上它最终也会调用ion_client_create。

不过和内核空间创建client的一点区别是, 用户空间不能选择heap type (使用预订的heap id隐含heap type), 但是内核空间却可以。

另外, 用户空间是通过IOCTL来分配内存的, cmd为ION_IOC_ALLOC。

```
[cpp]    
01. ion_fd = open("/dev/ion", O_RDONLY | O_SYNC);  
02. ioctl(ion_fd, ION_IOC_ALLOC, alloc);  
  
[cpp]  
01. <span xmlns="http://www.w3.org/1999/xhtml1" style="">ion_fd = open("  
    /dev/ion", O_RDONLY | O_SYNC);  
02. ioctl(ion_fd, ION_IOC_ALLOC, alloc); </span>
```

alloc为struct ion_allocation_data, len是申请buffer的长度, flags是heap id。



```
[cpp]    
01. /**  
02.  * struct ion_allocation_data - metadata passed from userspace for allocations  
03.  * @len:      size of the allocation  
04.  * @align:    required alignment of the allocation  
05.  * @flags:    flags passed to heap  
06.  * @handle:   pointer that will be populated with a cookie to use to refer  
07.  *           to this allocation  
08.  *  
09.  * Provided by userspace as an argument to the ioctl  
10.  */  
11. struct ion_allocation_data {  
12.     size_t len;  
13.     size_t align;  
14.     unsigned int flags;  
15.     struct ion_handle *handle;  
16. };  
  
[cpp]  
01. <span xmlns="http://www.w3.org/1999/xhtml1" style="">/**  
02.  * struct ion_allocation_data - metadata passed from userspace for allocations  
03.  * @len:      size of the allocation  
04.  * @align:    required alignment of the allocation  
05.  * @flags:    flags passed to heap  
06.  * @handle:   pointer that will be populated with a cookie to use to refer  
07.  *           to this allocation  
08.  *  
09.  * Provided by userspace as an argument to the ioctl  
10.  */  
11. struct ion_allocation_data {  
12.     size_t len;  
13.     size_t align;  
14.     unsigned int flags;  
15.     struct ion_handle *handle;  
16. };</span>
```

分配好了buffer之后, 如果用户空间想使用buffer, 先需要mmap. ION是

通过调用ION_IOC_MAP来得到可以mmap的fd, 然后再执行mmap得到buffer address。

然后, 你也可以将此fd传给另一个进程, 如通过binder传递。在另一个进程中通过ION_IOC_IMPORT这个IOCTL来得到这块共享buffer了。

来看一个例子:

```
[cpp]    
01. 进程A:  
02. int ionfd = open("/dev/ion", O_RDONLY | O_DSYNC);  
03. alloc_data.len = 0x1000;  
04. alloc_data.align = 0x1000;
```

关闭


```
05.   alloc_data.flags = ION_HEAP(ION_CP_MM_HEAP_ID);
06.   rc = ioctl(ionfd, ION_IOC_ALLOC, &alloc_data);
07.   fd_data.handle = alloc_data.handle;
08.   rc = ioctl(ionfd, ION_IOC_SHARE, &fd_data);
09.   shared_fd = fd_data.fd;
10.
11.   进程B:
12.   fd_data.fd = shared_fd;
13.   rc = ioctl(ionfd, ION_IOC_IMPORT, &fd_data);

[cpp]

01.   <span xmlns="http://www.w3.org/1999/xhtml" style="">进程A:
02.   int ionfd = open("/dev/ion", O_RDONLY | O_DSYNC);
03.   alloc_data.len = 0x1000;
04.   alloc_data.align = 0x1000;
05.   alloc_data.flags = ION_HEAP(ION_CP_MM_HEAP_ID);
06.   rc = ioctl(ionfd, ION_IOC_ALLOC, &alloc_data);
07.   fd_data.handle = alloc_data.handle;
08.   rc = ioctl(ionfd, ION_IOC_SHARE, &fd_data);
09.   shared_fd = fd_data.fd;
10.
11.   进程B:
12.   fd_data.fd = shared_fd;
13.   rc = ioctl(ionfd, ION_IOC_IMPORT, &fd_data); </span>
```

从上一篇ION基本概念中，我们了解了heap type, heap id, client, handle以及如何使用，本篇再从原理上分析下ION的运作流程。

MSM8x25Q平台使用的是board-qrd7627.c，ION相关定义如下：

```
[cpp]

01.  /**
02.   * These heaps are listed in the order they will be allocated.
03.   * Don't swap the order unless you know what you are doing!
04.   */
05.  struct ion_platform_heap msm7627a_heaps[] = {
06.      {
07.          .id = ION_SYSTEM_HEAP_ID,
08.          .type = ION_HEAP_TYPE_SYSTEM,
09.          .name = ION_VMALLOC_HEAP_NAME,
10.      },
11.  #ifdef CONFIG_MSM_MULTIMEDIA_USE_ION
12.      /* PMEM_ADSP = CAMERA */
13.      {
14.          .id = ION_CAMERA_HEAP_ID,
15.          .type = CAMERA_HEAP_TYPE,
16.          .name = ION_CAMERA_HEAP_NAME,
17.          .memory_type = ION_EBI_TYPE,
18.          .extra_data = (void *)&co_mm_ion_pdata,
19.          .priv = (void *)&ion_cma_device.dev,
20.      },
21.      /* AUDIO HEAP 1 */
22.      {
23.          .id = ION_AUDIO_HEAP_ID,
24.          .type = ION_HEAP_TYPE_CARVEOUT,
25.          .name = ION_AUDIO_HEAP_NAME,
26.          .memory_type = ION_EBI_TYPE,
27.          .extra_data = (void *)&co_ion_pdata,
28.      },
29.      /* PMEM_MDP = SF */
30.      {
31.          .id = ION_SF_HEAP_ID,
32.          .type = ION_HEAP_TYPE_CARVEOUT,
33.          .name = ION_SF_HEAP_NAME,
34.          .memory_type = ION_EBI_TYPE,
35.          .extra_data = (void *)&co_ion_pdata,
36.      },
37.      /* AUDIO HEAP 2 */
38.      {
39.          .id = ION_AUDIO_HEAP_BL_ID,
40.          .type = ION_HEAP_TYPE_CARVEOUT,
41.          .name = ION_AUDIO_BL_HEAP_NAME,
42.          .memory_type = ION_EBI_TYPE,
43.          .extra_data = (void *)&co_ion_pdata,
44.          .base = BOOTLOADER_BASE_ADDR,
```

[关闭](#)

```
45.     },
46.
47. #endif
48. };
49.
50. static struct ion_co_heap_pdata co_ion_pdata = {
51.     .adjacent_mem_id = INVALID_HEAP_ID,
52.     .align = PAGE_SIZE,
53. };
54.
55. static struct ion_co_heap_pdata co_mm_ion_pdata = {
56.     .adjacent_mem_id = INVALID_HEAP_ID,
57.     .align = PAGE_SIZE,
58. };
59.
60. static u64 msm_dmask = DMA_BIT_MASK(32);
61.
62. static struct platform_device ion_cma_device = {
63.     .name = "ion-cma-device",
64.     .id = -1,
65.     .dev = {
66.         .dma_mask = &msm_dmask,
67.         .coherent_dma_mask = DMA_BIT_MASK(32),
68.     }
69. };
```

[cpp]

```
01. <span xmlns="http://www.w3.org/1999/xhtml" style="">/**
02.  * These heaps are listed in the order they will be allocated.
03.  * Don't swap the order unless you know what you are doing!
04.  */
05. struct ion_platform_heap msm7627a_heaps[] = {
06.     {
07.         .id = ION_SYSTEM_HEAP_ID,
08.         .type = ION_HEAP_TYPE_SYSTEM,
09.         .name = ION_VMALLOC_HEAP_NAME,
10.     },
11. #ifdef CONFIG_MSM_MULTIMEDIA_USE_ION
12.     /* PMEM_ADSP = CAMERA */
13.     {
14.         .id = ION_CAMERA_HEAP_ID,
15.         .type = CAMERA_HEAP_TYPE,
16.         .name = ION_CAMERA_HEAP_NAME,
17.         .memory_type = ION_EBI_TYPE,
18.         .extra_data = (void *)&co_mm_ion_pdata,
19.         .priv = (void *)&ion_cma_device.dev,
20.     },
21.     /* AUDIO HEAP 1 */
22.     {
23.         .id = ION_AUDIO_HEAP_ID,
24.         .type = ION_HEAP_TYPE_CARVEOUT,
25.         .name = ION_AUDIO_HEAP_NAME,
26.         .memory_type = ION_EBI_TYPE,
27.         .extra_data = (void *)&co_ion_pdata,
28.     },
29.     /* PMEM_MDP = SF */
30.     {
31.         .id = ION_SF_HEAP_ID,
32.         .type = ION_HEAP_TYPE_CARVEOUT,
33.         .name = ION_SF_HEAP_NAME,
34.         .memory_type = ION_EBI_TYPE,
35.         .extra_data = (void *)&co_ion_pdata,
36.     },
37.     /* AUDIO HEAP 2 */
38.     {
39.         .id = ION_AUDIO_HEAP_BL_ID,
40.         .type = ION_HEAP_TYPE_CARVEOUT,
41.         .name = ION_AUDIO_BL_HEAP_NAME,
42.         .memory_type = ION_EBI_TYPE,
43.         .extra_data = (void *)&co_ion_pdata,
44.         .base = BOOTLOADER_BASE_ADDR,
45.     },
46.
47. #endif
48. };
49.
50. static struct ion_co_heap_pdata co_ion_pdata = {
51.     .adjacent_mem_id = INVALID_HEAP_ID,
52.     .align = PAGE_SIZE,
```

关闭

```
53. };
54.
55. static struct ion_co_heap_pdata co_mm_ion_pdata = {
56.     .adjacent_mem_id = INVALID_HEAP_ID,
57.     .align = PAGE_SIZE,
58. };
59.
60. static u64 msm_dmamask = DMA_BIT_MASK(32);
61.
62. static struct platform_device ion_cma_device = {
63.     .name = "ion-cma-device",
64.     .id = -1,
65.     .dev = {
66.         .dma_mask = &msm_dmamask,
67.         .coherent_dma_mask = DMA_BIT_MASK(32),
68.     }
69. };</span>
```

Qualcomm提示了不要轻易调换顺序，因为后面代码处理是将顺序定死了的，一旦你调换了，代码就无法正常运行了。

另外，本系统中只使用了ION_HEAP_TYPE_CARVEOUT和ION_HEAP_TYPE_SYSTEM这两种h

对于ION_HEAP_TYPE_CARVEOUT的内存分配，后面将会发现，其实就是之前讲述过的使用mem pool来分配的。

Platform device如下,在msm_ion.c中用到。

```
[cpp] C ⌘
01. static struct ion_platform_data ion_pdata = {
02.     .nr = MSM_ION_HEAP_NUM,
03.     .has_outer_cache = 1,
04.     .heaps = msm7627a_heaps,
05. };
06.
07. static struct platform_device ion_dev = {
08.     .name = "ion-msm",
09.     .id = 1,
10.     .dev = { .platform_data = &ion_pdata },
11. };

[cpp]
01. <span xmlns="http://www.w3.org
/1999/xhtml" style="">static struct ion_platform_data ion_pdata = {
02.     .nr = MSM_ION_HEAP_NUM,
03.     .has_outer_cache = 1,
04.     .heaps = msm7627a_heaps,
05. };
06.
07. static struct platform_device ion_dev = {
08.     .name = "ion-msm",
09.     .id = 1,
10.     .dev = { .platform_data = &ion_pdata },
11. };</span>
```

ION初始化

转到msm_ion.c，ion.c的某些函数也被重新封装了下.万事都从设备匹配开始：

```
[cpp] C ⌘
01. static struct platform_driver msm_ion_driver = {
02.     .probe = msm_ion_probe,
03.     .remove = msm_ion_remove,
04.     .driver = { .name = "ion-msm" }
05. };
06. static int __init msm_ion_init(void)
07. {
08.     /*调用msm_ion_probe */
09.     return platform_driver_register(&msm_ion_driver);
10. }
11.
12. static int msm_ion_probe(struct platform_device *pdev)
13. {
14.     /*即board-qrd7627a.c中的ion_pdata */
15.     struct ion_platform_data *pdata = pdev->dev.platform_data;
16.     int err;
```

关闭

```

17.     int i;
18.
19.     /*heap数量*/
20.     num_heaps = pdata->nr;
21.     /*分配struct ion_heap */
22.     heaps = kcalloc(pdata->nr, sizeof(struct ion_heap *), GFP_KERNEL);
23.
24.     if (!heaps) {
25.         err = -ENOMEM;
26.         goto out;
27.     }
28.     /*创建节点, 最终是/dev/ion, 供用户空间操作。*/
29.     idev = ion_device_create(NULL);
30.     if (IS_ERR_OR_NULL(idev)) {
31.         err = PTR_ERR(idev);
32.         goto freeheaps;
33.     }
34.     /*最终是根据adjacent_mem_id 是否定义了来分配相邻内存,
35. 我们没用到, 忽略此函数。*/
36.     msm_ion_heap_fixup(pdata->heaps, num_heaps);
37.
38.     /* create the heaps as specified in the board file */
39.     for (i = 0; i < num_heaps; i++) {
40.         struct ion_platform_heap *heap_data = &pdata->heaps[i];
41.         /*分配ion*/
42.         msm_ion_allocate(heap_data);
43.
44.         heap_data->has_outer_cache = pdata->has_outer_cache;
45.         /*创建ion heap。*/
46.         heaps[i] = ion_heap_create(heap_data);
47.         if (IS_ERR_OR_NULL(heaps[i])) {
48.             heaps[i] = 0;
49.             continue;
50.         } else {
51.             if (heap_data->size)
52.                 pr_info("ION heap %s created at %lx "
53.                     "with size %x\n", heap_data->name,
54.                     heap_data->base,
55.                     heap_data->size);
56.             else
57.                 pr_info("ION heap %s created\n",
58.                     heap_data->name);
59.         }
60.         /*创建的heap添加到idev中, 以便后续使用。*/
61.         ion_device_add_heap(idev, heaps[i]);
62.     }
63.     /*检查heap之间是否有重叠部分*/
64.     check_for_heap_overlap(pdata->heaps, num_heaps);
65.     platform_set_drvdata(pdev, idev);
66.     return 0;
67.
68. freeheaps:
69.     kfree(heaps);
70. out:
71.     return err;
72. }
73.
74. 通过ion_device_create创建/dev/ion节点:
75. struct ion_device *ion_device_create(long (*custom_ioctl)
76.                                     (struct ion_client *client,
77.                                     unsigned int cmd,
78.                                     unsigned long arg))
79. {
80.     struct ion_device *idev;
81.     int ret;
82.
83.     idev = kzalloc(sizeof(struct ion_device), GFP_KERNEL);
84.     if (!idev)
85.         return ERR_PTR(-ENOMEM);
86.     /*是个misc设备*/
87.     idev->dev.minor = MISC_DYNAMIC_MINOR;
88.     /*节点名字为ion*/
89.     idev->dev.name = "ion";
90.     /*fops为ion_fops, 所以对应ion的操作都会调用ion_fops的函数指针。*/
91.     idev->dev.fops = &ion_fops;
92.     idev->dev.parent = NULL;
93.     ret = misc_register(&idev->dev);
94.     if (ret) {
95.         pr_err("ion: failed to register misc device.\n");
96.         return ERR_PTR(ret);

```

关闭

```
97.     }
98.     /*创建debugfs目录, 路径为/sys/kernel/debug/ion/**/
99.     idev->debug_root = debugfs_create_dir("ion", NULL);
100.    if (IS_ERR_OR_NULL(idev->debug_root))
101.        pr_err("ion: failed to create debug files.\n");
102.
103.    idev->custom_ioctl = custom_ioctl;
104.    idev->buffers = RB_ROOT;
105.    mutex_init(&idev->lock);
106.    idev->heaps = RB_ROOT;
107.    idev->clients = RB_ROOT;
108.    /*在ion目录下创建一个check_leaked_fds文件, 用来检查Ion的使用是否有内存泄漏。如果申请了ion之后
不需要使用却没有释放, 就会导致memory leak.*/
109.    debugfs_create_file("check_leaked_fds", 0664, idev->debug_root, idev,
110.        &debug_leak_fops);
111.    return idev;
112. }
113.
114. msm_ion_allocate:
115. static void msm_ion_allocate(struct ion_platform_heap *heap)
116. {
117.
118.     if (!heap->base && heap->extra_data) {
119.         unsigned int align = 0;
120.         switch (heap->type) {
121.             /*获取align参数*/
122.             case ION_HEAP_TYPE_CARVEOUT:
123.                 align =
124.                     ((struct ion_co_heap_pdata *) heap->extra_data)->align;
125.                 break;
126.             /*此type我们没用到.*/
127.             case ION_HEAP_TYPE_CP:
128.                 {
129.                     struct ion_cp_heap_pdata *data =
130.                         (struct ion_cp_heap_pdata *)
131.                         heap->extra_data;
132.                     if (data->reusable) {
133.                         const struct fmem_data *fmem_info =
134.                             fmem_get_info();
135.                         heap->base = fmem_info->phys;
136.                         data->virt_addr = fmem_info->virt;
137.                         pr_info("ION heap %s using FMEM\n", heap->name);
138.                     } else if (data->mem_is_fmem) {
139.                         const struct fmem_data *fmem_info =
140.                             fmem_get_info();
141.                         heap->base = fmem_info->phys + fmem_info->size;
142.                     }
143.                     align = data->align;
144.                     break;
145.                 }
146.             default:
147.                 break;
148.         }
149.         if (align && !heap->base) {
150.             /*获取heap的base address.*/
151.             heap->base = msm_ion_get_base(heap->size,
152.                 heap->memory_type,
153.                 align);
154.             if (!heap->base)
155.                 pr_err("%s: could not get memory for heap %s "
156.                     "(id %x)\n", __func__, heap->name, heap->id);
157.         }
158.     }
159. }
160.
161. static unsigned long msm_ion_get_base(unsigned long :
162.     unsigned int align)
163. {
164.     switch (memory_type) {
165.         /*我们定义的是ebi type, 看见没, 此函数在mem pool中分析过了。
166.         原理就是使用Mempool 来管理分配内存.*/
167.         case ION_EBI_TYPE:
168.             return allocate_contiguous_ebi_nomap(size, align);
169.             break;
170.         case ION_SMI_TYPE:
171.             return allocate_contiguous_memory_nomap(size, MEMTYPE_SMI,
172.                 align);
173.             break;
174.         default:
175.             pr_err("%s: Unknown memory type %d\n", __func__, memory_type);
```

关闭

```
176.         return 0;
177.     }
178. }
179. ion_heap_create:
180. struct ion_heap *ion_heap_create(struct ion_platform_heap *heap_data)
181. {
182.     struct ion_heap *heap = NULL;
183.     /*根据Heap type调用相应的创建函数。*/
184.     switch (heap_data->type) {
185.     case ION_HEAP_TYPE_SYSTEM_CONTIG:
186.         heap = ion_system_contig_heap_create(heap_data);
187.         break;
188.     case ION_HEAP_TYPE_SYSTEM:
189.         heap = ion_system_heap_create(heap_data);
190.         break;
191.     case ION_HEAP_TYPE_CARVEOUT:
192.         heap = ion_carveout_heap_create(heap_data);
193.         break;
194.     case ION_HEAP_TYPE_IOMMU:
195.         heap = ion_iommu_heap_create(heap_data);
196.         break;
197.     case ION_HEAP_TYPE_CP:
198.         heap = ion_cp_heap_create(heap_data);
199.         break;
200. #ifdef CONFIG_CMA
201.     case ION_HEAP_TYPE_DMA:
202.         heap = ion_cma_heap_create(heap_data);
203.         break;
204. #endif
205.     default:
206.         pr_err("%s: Invalid heap type %d\n", __func__,
207.             heap_data->type);
208.         return ERR_PTR(-EINVAL);
209.     }
210.
211.     if (IS_ERR_OR_NULL(heap)) {
212.         pr_err("%s: error creating heap %s type %d base %lu size %u\n",
213.             __func__, heap_data->name, heap_data->type,
214.             heap_data->base, heap_data->size);
215.         return ERR_PTR(-EINVAL);
216.     }
217.     /*保存Heap的name,id和私有数据。*/
218.     heap->name = heap_data->name;
219.     heap->id = heap_data->id;
220.     heap->priv = heap_data->priv;
221.     return heap;
222. }
```

[cpp]

```
01. <span xmlns="http://www.w3.org
02. /1999/xhtml" style="">static struct platform_driver msm_ion_driver = {
03.     .probe = msm_ion_probe,
04.     .remove = msm_ion_remove,
05.     .driver = { .name = "ion-msm" }
06. };
07. static int __init msm_ion_init(void)
08. {
09.     /*调用msm_ion_probe */
10.     return platform_driver_register(&msm_ion_driver);
11. }
12. static int msm_ion_probe(struct platform_device *pdev)
13. {
14.     /*即board-qrd7627a.c中的ion_pdata */
15.     struct ion_platform_data *pdata = pdev->dev.platf
16.     int err;
17.     int i;
18.
19.     /*heap数量*/
20.     num_heaps = pdata->nr;
21.     /*分配struct ion_heap */
22.     heaps = kcalloc(pdata->nr, sizeof(struct ion_heap *), GFP_KERNEL);
23.
24.     if (!heaps) {
25.         err = -ENOMEM;
26.         goto out;
27.     }
28.     /*创建节点,最终是/dev/ion,供用户空间操作。*/
29.     idev = ion_device_create(NULL);
```

关闭

```
30.     if (IS_ERR_OR_NULL(idev)) {
31.         err = PTR_ERR(idev);
32.         goto freeheaps;
33.     }
34.     /*最终是根据adjacent_mem_id 是否定义了来分配相邻内存，
35. 我们没用到，忽略此函数。*/
36.     msm_ion_heap_fixup(pdata->heaps, num_heaps);
37.
38.     /* create the heaps as specified in the board file */
39.     for (i = 0; i < num_heaps; i++) {
40.         struct ion_platform_heap *heap_data = &pdata->heaps[i];
41.         /*分配ion*/
42.         msm_ion_allocate(heap_data);
43.
44.         heap_data->has_outer_cache = pdata->has_outer_cache;
45.         /*创建ion heap. */
46.         heaps[i] = ion_heap_create(heap_data);
47.         if (IS_ERR_OR_NULL(heaps[i])) {
48.             heaps[i] = 0;
49.             continue;
50.         } else {
51.             if (heap_data->size)
52.                 pr_info("ION heap %s created at %lx "
53.                     "with size %x\n", heap_data->name,
54.                     heap_data->base,
55.                     heap_data->size);
56.             else
57.                 pr_info("ION heap %s created\n",
58.                     heap_data->name);
59.         }
60.         /*创建的heap添加到idev中，以便后续使用。*/
61.         ion_device_add_heap(idev, heaps[i]);
62.     }
63.     /*检查heap之间是否有重叠部分*/
64.     check_for_heap_overlap(pdata->heaps, num_heaps);
65.     platform_set_drvdata(pdev, idev);
66.     return 0;
67.
68. freeheaps:
69.     kfree(heaps);
70. out:
71.     return err;
72. }
73.
74. 通过ion_device_create创建/dev/ion节点：
75. struct ion_device *ion_device_create(long (*custom_ioctl)
76.     (struct ion_client *client,
77.     unsigned int cmd,
78.     unsigned long arg))
79. {
80.     struct ion_device *idev;
81.     int ret;
82.
83.     idev = kzalloc(sizeof(struct ion_device), GFP_KERNEL);
84.     if (!idev)
85.         return ERR_PTR(-ENOMEM);
86.     /*是个misc设备*/
87.     idev->dev.minor = MISC_DYNAMIC_MINOR;
88.     /*节点名字为ion*/
89.     idev->dev.name = "ion";
90.     /*fops为ion_fops，所以对应ion的操作都会调用ion_fops的函数指针。*/
91.     idev->dev.fops = &ion_fops;
92.     idev->dev.parent = NULL;
93.     ret = misc_register(&idev->dev);
94.     if (ret) {
95.         pr_err("ion: failed to register misc device.\n");
96.         return ERR_PTR(ret);
97.     }
98.     /*创建debugfs目录，路径为/sys/kernel/debug/ion*/
99.     idev->debug_root = debugfs_create_dir("ion", NULL);
100.    if (IS_ERR_OR_NULL(idev->debug_root))
101.        pr_err("ion: failed to create debug files.\n");
102.
103.    idev->custom_ioctl = custom_ioctl;
104.    idev->buffers = RB_ROOT;
105.    mutex_init(&idev->lock);
106.    idev->heaps = RB_ROOT;
107.    idev->clients = RB_ROOT;
108.    /*在ion目录下创建一个check_leaked_fds文件，用来检查Ion的使用是否有内存泄漏。如果申请了ion之后
    不需要使用却没有释放，就会导致memory leak.*/
```

关闭

```
109.     debugfs_create_file("check_leaked_fds", 0664, idev->debug_root, idev,
110.         &debug_leak_fops);
111.     return idev;
112. }
113.
114. msm_ion_allocate :
115. static void msm_ion_allocate(struct ion_platform_heap *heap)
116. {
117.
118.     if (!heap->base && heap->extra_data) {
119.         unsigned int align = 0;
120.         switch (heap->type) {
121.             /*获取align参数*/
122.             case ION_HEAP_TYPE_CARVEOUT:
123.                 align =
124.                     ((struct ion_co_heap_pdata *) heap->extra_data)->align;
125.                 break;
126.             /*此type我们没使用到。*/
127.             case ION_HEAP_TYPE_CP:
128.                 {
129.                     struct ion_cp_heap_pdata *data =
130.                         (struct ion_cp_heap_pdata *)
131.                         heap->extra_data;
132.                     if (data->reusable) {
133.                         const struct fmem_data *fmem_info =
134.                             fmem_get_info();
135.                         heap->base = fmem_info->phys;
136.                         data->virt_addr = fmem_info->virt;
137.                         pr_info("ION heap %s using FMEM\n", heap->name);
138.                     } else if (data->mem_is_fmem) {
139.                         const struct fmem_data *fmem_info =
140.                             fmem_get_info();
141.                         heap->base = fmem_info->phys + fmem_info->size;
142.                     }
143.                     align = data->align;
144.                     break;
145.                 }
146.             default:
147.                 break;
148.         }
149.         if (align && !heap->base) {
150.             /*获取heap的base address。*/
151.             heap->base = msm_ion_get_base(heap->size,
152.                 heap->memory_type,
153.                 align);
154.             if (!heap->base)
155.                 pr_err("%s: could not get memory for heap %s "
156.                     "(id %x)\n", __func__, heap->name, heap->id);
157.         }
158.     }
159. }
160.
161. static unsigned long msm_ion_get_base(unsigned long size, int memory_type,
162.     unsigned int align)
163. {
164.     switch (memory_type) {
165.         /*我们定义的是ebi type，看见没，此函数在mem pool中分析过了。
166.         原理就是使用Mempool 来管理分配内存。*/
167.         case ION_EBI_TYPE:
168.             return allocate_contiguous_ebi_nomap(size, align);
169.             break;
170.         case ION_SMI_TYPE:
171.             return allocate_contiguous_memory_nomap(size, MEMTYPE_SMI,
172.                 align);
173.             break;
174.         default:
175.             pr_err("%s: Unknown memory type %d\n", __func__, memory_type);
176.             return 0;
177.     }
178. }
179. ion_heap_create :
180. struct ion_heap *ion_heap_create(struct ion_platform_heap *heap_data)
181. {
182.     struct ion_heap *heap = NULL;
183.     /*根据Heap type调用相应的创建函数。*/
184.     switch (heap_data->type) {
185.         case ION_HEAP_TYPE_SYSTEM_CONTIG:
186.             heap = ion_system_contig_heap_create(heap_data);
187.             break;
188.         case ION_HEAP_TYPE_SYSTEM:
```

关闭


```
189.         heap = ion_system_heap_create(heap_data);
190.         break;
191.     case ION_HEAP_TYPE_CARVEOUT:
192.         heap = ion_carveout_heap_create(heap_data);
193.         break;
194.     case ION_HEAP_TYPE_IOMMU:
195.         heap = ion_iommu_heap_create(heap_data);
196.         break;
197.     case ION_HEAP_TYPE_CP:
198.         heap = ion_cp_heap_create(heap_data);
199.         break;
200. #ifdef CONFIG_CMA
201.     case ION_HEAP_TYPE_DMA:
202.         heap = ion_cma_heap_create(heap_data);
203.         break;
204. #endif
205.     default:
206.         pr_err("%s: Invalid heap type %d\n", __func__,
207.             heap_data->type);
208.         return ERR_PTR(-EINVAL);
209.     }
210.
211.     if (IS_ERR_OR_NULL(heap)) {
212.         pr_err("%s: error creating heap %s type %d base %lu size %u\n",
213.             __func__, heap_data->name, heap_data->type,
214.             heap_data->base, heap_data->size);
215.         return ERR_PTR(-EINVAL);
216.     }
217.     /*保存Heap的name,id和私有数据。*/
218.     heap->name = heap_data->name;
219.     heap->id = heap_data->id;
220.     heap->priv = heap_data->priv;
221.     return heap;
222. }
```

从下面的代码可以得知, ION_HEAP_TYPE_SYSTEM_CONTIG使用kmalloc创建

的, ION_HEAP_TYPE_SYSTEM使用的是vmalloc,而ion_carveout_heap_create就是系统预分配了一片内存区域供其使用。Ion在申请使用的时候,会根据当前的type来操作各自的heap->ops。分别看下三个函数:

```
[cpp]
01. struct ion_heap *ion_system_contig_heap_create(struct ion_platform_heap *pheap)
02. {
03.     struct ion_heap *heap;
04.
05.     heap = kzalloc(sizeof(struct ion_heap), GFP_KERNEL);
06.     if (!heap)
07.         return ERR_PTR(-ENOMEM);
08.     /*使用的是kmalloc_ops, 上篇有提到哦*/
09.     heap->ops = &kmalloc_ops;
10.     heap->type = ION_HEAP_TYPE_SYSTEM_CONTIG;
11.     system_heap_contig_has_outer_cache = pheap->has_outer_cache;
12.     return heap;
13. }
14. struct ion_heap *ion_system_heap_create(struct ion_platform_heap *pheap)
15. {
16.     struct ion_heap *heap;
17.
18.     heap = kzalloc(sizeof(struct ion_heap), GFP_KERNEL);
19.     if (!heap)
20.         return ERR_PTR(-ENOMEM);
21.     /*和上面函数的区别仅在于ops*/
22.     heap->ops = &vmalloc_ops;
23.     heap->type = ION_HEAP_TYPE_SYSTEM;
24.     system_heap_has_outer_cache = pheap->has_outer_cache;
25.     return heap;
26. }
27. struct ion_heap *ion_carveout_heap_create(struct ion_platform_heap *heap_data)
28. {
29.     struct ion_carveout_heap *carveout_heap;
30.     int ret;
31.
32.     carveout_heap = kzalloc(sizeof(struct ion_carveout_heap), GFP_KERNEL);
33.     if (!carveout_heap)
34.         return ERR_PTR(-ENOMEM);
35.     /* 重新创建一个新的pool, 这里有点想不通的是为什么不直接使用全局的mempools呢? */
36.     carveout_heap->pool = gen_pool_create(12, -1);
37.     if (!carveout_heap->pool) {
```

关闭

```

38.         kfree(carveout_heap);
39.         return ERR_PTR(-ENOMEM);
40.     }
41.     carveout_heap->base = heap_data->base;
42.     ret = gen_pool_add(carveout_heap->pool, carveout_heap->base,
43.         heap_data->size, -1);
44.     if (ret < 0) {
45.         gen_pool_destroy(carveout_heap->pool);
46.         kfree(carveout_heap);
47.         return ERR_PTR(-EINVAL);
48.     }
49.     carveout_heap->heap.ops = &carveout_heap_ops;
50.     carveout_heap->heap.type = ION_HEAP_TYPE_CARVEOUT;
51.     carveout_heap->allocated_bytes = 0;
52.     carveout_heap->total_size = heap_data->size;
53.     carveout_heap->has_outer_cache = heap_data->has_outer_cache;
54.
55.     if (heap_data->extra_data) {
56.         struct ion_co_heap_pdata *extra_data =
57.             heap_data->extra_data;
58.
59.         if (extra_data->setup_region)
60.             carveout_heap->bus_id = extra_data->setup_region();
61.         if (extra_data->request_region)
62.             carveout_heap->request_region =
63.                 extra_data->request_region;
64.         if (extra_data->release_region)
65.             carveout_heap->release_region =
66.                 extra_data->release_region;
67.     }
68.     return &carveout_heap->heap;
69. }
70.
71. Heap创建完成，然后保存到idev中：
72. void ion_device_add_heap(struct ion_device *dev, struct ion_heap *heap)
73. {
74.     struct rb_node **p = &dev->heaps.rb_node;
75.     struct rb_node *parent = NULL;
76.     struct ion_heap *entry;
77.
78.     if (!heap->ops->allocate || !heap->ops->free || !heap->ops->map_dma ||
79.         !heap->ops->unmap_dma)
80.         pr_err("%s: can not add heap with invalid ops struct.\n",
81.             __func__);
82.
83.     heap->dev = dev;
84.     mutex_lock(&dev->lock);
85.     while (*p) {
86.         parent = *p;
87.         entry = rb_entry(parent, struct ion_heap, node);
88.
89.         if (heap->id < entry->id) {
90.             p = &(*p)->rb_left;
91.         } else if (heap->id > entry->id) {
92.             p = &(*p)->rb_right;
93.         } else {
94.             pr_err("%s: can not insert multiple heaps with "
95.                 "id %d\n", __func__, heap->id);
96.             goto end;
97.         }
98.     }
99.     /*使用红黑树保存*/
100.    rb_link_node(&heap->node, parent, p);
101.    rb_insert_color(&heap->node, &dev->heaps);
102.    /*以heap name创建fs,位于ion目录下。如vamlloc, camera preview . audio 等*/
103.    debugfs_create_file(heap->name, 0664, dev->debug_
104.        &debug_heap_fops);
105.    end:
106.    mutex_unlock(&dev->lock);
107. }

```

[cpp]

```

01. <span xmlns="http://www.w3.org
02. /1999/xhtml" style="">struct ion_heap *ion_system_contig_heap_create(struct ion_platfor
03. {
04.     struct ion_heap *heap;
05.
06.     heap = kzalloc(sizeof(struct ion_heap), GFP_KERNEL);
07.     if (!heap)

```

关闭

```
07.         return ERR_PTR(-ENOMEM);
08.         /*使用的是kmalloc_ops, 上篇有提到哦*/
09.         heap->ops = &kmalloc_ops;
10.         heap->type = ION_HEAP_TYPE_SYSTEM_CONTIG;
11.         system_heap_contig_has_outer_cache = pheap->has_outer_cache;
12.         return heap;
13.     }
14.     struct ion_heap *ion_system_heap_create(struct ion_platform_heap *pheap)
15.     {
16.         struct ion_heap *heap;
17.
18.         heap = kzalloc(sizeof(struct ion_heap), GFP_KERNEL);
19.         if (!heap)
20.             return ERR_PTR(-ENOMEM);
21.         /*和上面函数的区别仅在于ops*/
22.         heap->ops = &vmalloc_ops;
23.         heap->type = ION_HEAP_TYPE_SYSTEM;
24.         system_heap_has_outer_cache = pheap->has_outer_cache;
25.         return heap;
26.     }
27.     struct ion_heap *ion_carveout_heap_create(struct ion_platform_heap *heap_data)
28.     {
29.         struct ion_carveout_heap *carveout_heap;
30.         int ret;
31.
32.         carveout_heap = kzalloc(sizeof(struct ion_carveout_heap), GFP_KERNEL);
33.         if (!carveout_heap)
34.             return ERR_PTR(-ENOMEM);
35.         /* 重新创建一个新的pool, 这里有点想不通的是为什么不直接使用全局的mempools呢? */
36.         carveout_heap->pool = gen_pool_create(12, -1);
37.         if (!carveout_heap->pool) {
38.             kfree(carveout_heap);
39.             return ERR_PTR(-ENOMEM);
40.         }
41.         carveout_heap->base = heap_data->base;
42.         ret = gen_pool_add(carveout_heap->pool, carveout_heap->base,
43.             heap_data->size, -1);
44.         if (ret < 0) {
45.             gen_pool_destroy(carveout_heap->pool);
46.             kfree(carveout_heap);
47.             return ERR_PTR(-EINVAL);
48.         }
49.         carveout_heap->heap.ops = &carveout_heap_ops;
50.         carveout_heap->heap.type = ION_HEAP_TYPE_CARVEOUT;
51.         carveout_heap->allocated_bytes = 0;
52.         carveout_heap->total_size = heap_data->size;
53.         carveout_heap->has_outer_cache = heap_data->has_outer_cache;
54.
55.         if (heap_data->extra_data) {
56.             struct ion_co_heap_pdata *extra_data =
57.                 heap_data->extra_data;
58.
59.             if (extra_data->setup_region)
60.                 carveout_heap->bus_id = extra_data->setup_region();
61.             if (extra_data->request_region)
62.                 carveout_heap->request_region =
63.                     extra_data->request_region;
64.             if (extra_data->release_region)
65.                 carveout_heap->release_region =
66.                     extra_data->release_region;
67.         }
68.         return &carveout_heap->heap;
69.     }
70.
71.     Heap创建完成, 然后保存到idev中:
72.     void ion_device_add_heap(struct ion_device *dev, struct
73.     {
74.         struct rb_node **p = &dev->heaps.rb_node;
75.         struct rb_node *parent = NULL;
76.         struct ion_heap *entry;
77.
78.         if (!heap->ops->allocate || !heap->ops->free || !heap->ops->map_dma ||
79.             !heap->ops->unmap_dma)
80.             pr_err("%s: can not add heap with invalid ops struct.\n",
81.                 __func__);
82.
83.         heap->dev = dev;
84.         mutex_lock(&dev->lock);
85.         while (*p) {
86.             parent = *p;
```

关闭

```
87.         entry = rb_entry(parent, struct ion_heap, node);
88.
89.         if (heap->id < entry->id) {
90.             p = &(*p)->rb_left;
91.         } else if (heap->id > entry->id) {
92.             p = &(*p)->rb_right;
93.         } else {
94.             pr_err("%s: can not insert multiple heaps with "
95.                  "id %d\n", __func__, heap->id);
96.             goto end;
97.         }
98.     }
99.     /*使用红黑树保存*/
100.    rb_link_node(&heap->node, parent, p);
101.    rb_insert_color(&heap->node, &dev->heaps);
102.    /*以heap name创建fs,位于ion目录下。如vamlloc, camera_preview, audio 等*/
103.    debugfs_create_file(heap->name, 0664, dev->debug_root, heap,
104.                        &debug_heap_fops);
105. end:
106.     mutex_unlock(&dev->lock);
107. }
108. </span>
```

到此，ION初始化已经完成了。接下来该如何使用呢？嗯，通过前面创建的misc设备也就是idev了！
有个fops为ion_fops吗？先来看下用户空间如何使用ION，最后看内核空间如何使用。

ION用户空间使用

```
[cpp]
01. Ion_fops结构如下：
02. static const struct file_operations ion_fops = {
03.     .owner          = THIS_MODULE,
04.     .open            = ion_open,
05.     .release         = ion_release,
06.     .unlocked_ioctl = ion_ioctl,
07. };
08.
09. 用户空间都是通过ioctl来控制。先看ion_open.
10.
11. static int ion_open(struct inode *inode, struct file *file)
12. {
13.     struct miscdevice *miscdev = file->private_data;
14.     struct ion_device *dev = container_of(miscdev, struct ion_device, dev);
15.     struct ion_client *client;
16.     char debug_name[64];
17.
18.     pr_debug("%s: %d\n", __func__, __LINE__);
19.     snprintf(debug_name, 64, "%u", task_pid_nr(current->group_leader));
20.     /*根据idev和task pid为name创建ion client*/
21.     client = ion_client_create(dev, -1, debug_name);
22.     if (IS_ERR_OR_NULL(client))
23.         return PTR_ERR(client);
24.     file->private_data = client;
25.
26.     return 0;
27. }
```

```
[cpp]
01. <span xmlns="http://www.w3.org/1999/xhtml" style="">Ion_fops结构如下：
02. static const struct file_operations ion_fops = {
03.     .owner          = THIS_MODULE,
04.     .open            = ion_open,
05.     .release         = ion_release,
06.     .unlocked_ioctl = ion_ioctl,
07. };
08.
09. 用户空间都是通过ioctl来控制。先看ion_open.
10.
11. static int ion_open(struct inode *inode, struct file *file)
12. {
13.     struct miscdevice *miscdev = file->private_data;
14.     struct ion_device *dev = container_of(miscdev, struct ion_device, dev);
15.     struct ion_client *client;
16.     char debug_name[64];
17.
18.     pr_debug("%s: %d\n", __func__, __LINE__);
19.     snprintf(debug_name, 64, "%u", task_pid_nr(current->group_leader));
```

关闭

```
20.     /*根据idev和task pid为name创建ion_client*/
21.     client = ion_client_create(dev, -1, debug_name);
22.     if (IS_ERR_OR_NULL(client))
23.         return PTR_ERR(client);
24.     file->private_data = client;
25.
26.     return 0;
27. }
```

前一篇文章有说到，要使用ION，必须要先创建ion_client，因此用户空间在open ion的时候创建了client。

```
[cpp]
01. struct ion_client *ion_client_create(struct ion_device *dev,
02.                                     unsigned int heap_mask,
03.                                     const char *name)
04. {
05.     struct ion_client *client;
06.     struct task_struct *task;
07.     struct rb_node **p;
08.     struct rb_node *parent = NULL;
09.     struct ion_client *entry;
10.     pid_t pid;
11.     unsigned int name_len;
12.
13.     if (!name) {
14.         pr_err("%s: Name cannot be null\n", __func__);
15.         return ERR_PTR(-EINVAL);
16.     }
17.     name_len = strlen(name, 64);
18.
19.     get_task_struct(current->group_leader);
20.     task_lock(current->group_leader);
21.     pid = task_pid_nr(current->group_leader);
22.     /* don't bother to store task struct for kernel threads,
23.        they can't be killed anyway */
24.     if (current->group_leader->flags & PF_KTHREAD) {
25.         put_task_struct(current->group_leader);
26.         task = NULL;
27.     } else {
28.         task = current->group_leader;
29.     }
30.     task_unlock(current->group_leader);
31.     /*分配ion client struct.*/
32.     client = kzalloc(sizeof(struct ion_client), GFP_KERNEL);
33.     if (!client) {
34.         if (task)
35.             put_task_struct(current->group_leader);
36.         return ERR_PTR(-ENOMEM);
37.     }
38.     /*下面就是保存一系列参数了。*/
39.     client->dev = dev;
40.     client->handles = RB_ROOT;
41.     mutex_init(&client->lock);
42.
43.     client->name = kzalloc(name_len+1, GFP_KERNEL);
44.     if (!client->name) {
45.         put_task_struct(current->group_leader);
46.         kfree(client);
47.         return ERR_PTR(-ENOMEM);
48.     } else {
49.         strcpy(client->name, name, name_len+1);
50.     }
51.
52.     client->heap_mask = heap_mask;
53.     client->task = task;
54.     client->pid = pid;
55.
56.     mutex_lock(&dev->lock);
57.     p = &dev->clients.rb_node;
58.     while (*p) {
59.         parent = *p;
60.         entry = rb_entry(parent, struct ion_client, node);
61.
62.         if (client < entry)
63.             p = &(*p)->rb_left;
64.         else if (client > entry)
65.             p = &(*p)->rb_right;
66.     }
```

关闭

```
67.      /*当前client添加到idev的clients根树上去。*/
68.      rb_link_node(&client->node, parent, p);
69.      rb_insert_color(&client->node, &dev->clients);
70.
71.      /*在ION先创建的文件名字是以pid命名的。*/
72.      client->debug_root = debugfs_create_file(name, 0664,
73.          dev->debug_root, client,
74.          &debug_client_fops);
75.      mutex_unlock(&dev->lock);
76.
77.      return client;
78.  }
```

[cpp]

```
01.  <span xmlns="http://www.w3.org
02.  /1999/xhtml" style="">struct ion_client *ion_client_create(struct ion_devic
03.          unsigned int heap_mask,
04.          const char *name)
05.  {
06.      struct ion_client *client;
07.      struct task_struct *task;
08.      struct rb_node **p;
09.      struct rb_node *parent = NULL;
10.      struct ion_client *entry;
11.      pid_t pid;
12.      unsigned int name_len;
13.
14.      if (!name) {
15.          pr_err("%s: Name cannot be null\n", __func__);
16.          return ERR_PTR(-EINVAL);
17.      }
18.      name_len = strlen(name, 64);
19.
20.      get_task_struct(current->group_leader);
21.      task_lock(current->group_leader);
22.      pid = task_pid_nr(current->group_leader);
23.      /* don't bother to store task struct for kernel threads,
24.       they can't be killed anyway */
25.      if (current->group_leader->flags & PF_KTHREAD) {
26.          put_task_struct(current->group_leader);
27.          task = NULL;
28.      } else {
29.          task = current->group_leader;
30.      }
31.      task_unlock(current->group_leader);
32.      /*分配ion client struct.*/
33.      client = kzalloc(sizeof(struct ion_client), GFP_KERNEL);
34.      if (!client) {
35.          if (task)
36.              put_task_struct(current->group_leader);
37.          return ERR_PTR(-ENOMEM);
38.      }
39.      /*下面就是保存一系列参数了。*/
40.      client->dev = dev;
41.      client->handles = RB_ROOT;
42.      mutex_init(&client->lock);
43.
44.      client->name = kzalloc(name_len+1, GFP_KERNEL);
45.      if (!client->name) {
46.          put_task_struct(current->group_leader);
47.          kfree(client);
48.          return ERR_PTR(-ENOMEM);
49.      } else {
50.          strcpy(client->name, name, name_len+1);
51.      }
52.
53.      client->heap_mask = heap_mask;
54.      client->task = task;
55.      client->pid = pid;
56.
57.      mutex_lock(&dev->lock);
58.      p = &dev->clients.rb_node;
59.      while (*p) {
60.          parent = *p;
61.          entry = rb_entry(parent, struct ion_client, node);
62.
63.          if (client < entry)
64.              p = &(*p)->rb_left;
65.          else if (client > entry)
```

关闭

```
65.         p = &(*p)->rb_right;
66.     }
67.     /*当前client添加到idev的clients根树上去。*/
68.     rb_link_node(&client->node, parent, p);
69.     rb_insert_color(&client->node, &dev->clients);
70.
71.     /*在ION先创建的文件名字是以pid命名的。*/
72.     client->debug_root = debugfs_create_file(name, 0664,
73.         dev->debug_root, client,
74.         &debug_client_fops);
75.     mutex_unlock(&dev->lock);
76.
77.     return client;
78. }
```

有了client之后，用户程序就可以开始申请分配ION buffer了！通过ioctl命令实现。

ion_ioctl函数有若干个cmd，ION_IOC_ALLOC和ION_IOC_FREE相对应，表示申请和释放buffer。

使用前先要调用ION_IOC_MAP才能得到buffer address，而ION_IOC_IMPORT是为了将这块内存间另一个进程。

```
[cpp]
01. static long ion_ioctl(struct file *filp, unsigned int cmd, unsigned long arg)
02. {
03.     struct ion_client *client = filp->private_data;
04.
05.     switch (cmd) {
06.     case ION_IOC_ALLOC:
07.     {
08.         struct ion_allocation_data data;
09.
10.         if (copy_from_user(&data, (void __user *)arg, sizeof(data)))
11.             return -EFAULT;
12.         /*分配buffer.*/
13.         data.handle = ion_alloc(client, data.len, data.align,
14.             data.flags);
15.
16.         if (IS_ERR(data.handle))
17.             return PTR_ERR(data.handle);
18.
19.         if (copy_to_user((void __user *)arg, &data, sizeof(data))) {
20.             ion_free(client, data.handle);
21.             return -EFAULT;
22.         }
23.         break;
24.     }
25.     case ION_IOC_FREE:
26.     {
27.         struct ion_handle_data data;
28.         bool valid;
29.
30.         if (copy_from_user(&data, (void __user *)arg,
31.             sizeof(struct ion_handle_data)))
32.             return -EFAULT;
33.         mutex_lock(&client->lock);
34.         valid = ion_handle_validate(client, data.handle);
35.         mutex_unlock(&client->lock);
36.         if (!valid)
37.             return -EINVAL;
38.         ion_free(client, data.handle);
39.         break;
40.     }
41.     case ION_IOC_MAP:
42.     case ION_IOC_SHARE:
43.     {
44.         struct ion_fd_data data;
45.         int ret;
46.         if (copy_from_user(&data, (void __user *)arg, sizeof(data)))
47.             return -EFAULT;
48.         /*判断当前cmd是否被调用过了，调用过就返回，否则设置flags.*/
49.         ret = ion_share_set_flags(client, data.handle, filp->f_flags);
50.         if (ret)
51.             return ret;
52.
53.         data.fd = ion_share_dma_buf(client, data.handle);
54.         if (copy_to_user((void __user *)arg, &data, sizeof(data)))
55.             return -EFAULT;
56.         if (data.fd < 0)
```

[关闭](#)

```
57.         return data.fd;
58.     break;
59. }
60. case ION_IOC_IMPORT:
61. {
62.     struct ion_fd_data data;
63.     int ret = 0;
64.     if (copy_from_user(&data, (void __user *)arg,
65.         sizeof(struct ion_fd_data)))
66.         return -EFAULT;
67.     data.handle = ion_import_dma_buf(client, data.fd);
68.     if (IS_ERR(data.handle))
69.         data.handle = NULL;
70.     if (copy_to_user((void __user *)arg, &data,
71.         sizeof(struct ion_fd_data)))
72.         return -EFAULT;
73.     if (ret < 0)
74.         return ret;
75.     break;
76. }
77. case ION_IOC_CUSTOM:
78. --snip
79. case ION_IOC_CLEAN_CACHES:
80. case ION_IOC_INV_CACHES:
81. case ION_IOC_CLEAN_INV_CACHES:
82. --snip
83. case ION_IOC_GET_FLAGS:
84. --snip
85. default:
86.     return -ENOTTY;
87. }
88. return 0;
89. }
```

[cpp]

```
01. <span xmlns="http://www.w3.org
02. /1999/xhtml" style="">static long ion_ioctl(struct file *filp, unsigned int cmd, unsigned
03. {
04.     struct ion_client *client = filp->private_data;
05.
06.     switch (cmd) {
07.     case ION_IOC_ALLOC:
08.     {
09.         struct ion_allocation_data data;
10.
11.         if (copy_from_user(&data, (void __user *)arg, sizeof(data)))
12.             return -EFAULT;
13.         /*分配buffer.*/
14.         data.handle = ion_alloc(client, data.len, data.align,
15.             data.flags);
16.
17.         if (IS_ERR(data.handle))
18.             return PTR_ERR(data.handle);
19.
20.         if (copy_to_user((void __user *)arg, &data, sizeof(data))) {
21.             ion_free(client, data.handle);
22.             return -EFAULT;
23.         }
24.         break;
25.     }
26. case ION_IOC_FREE:
27. {
28.     struct ion_handle_data data;
29.     bool valid;
30.
31.     if (copy_from_user(&data, (void __user *)arg,
32.         sizeof(struct ion_handle_data)))
33.         return -EFAULT;
34.     mutex_lock(&client->lock);
35.     valid = ion_handle_validate(client, data.handle);
36.     mutex_unlock(&client->lock);
37.     if (!valid)
38.         return -EINVAL;
39.     ion_free(client, data.handle);
40.     break;
41. }
42. case ION_IOC_MAP:
43. case ION_IOC_SHARE:
44. {
```

关闭


```
44.     struct ion_fd_data data;
45.     int ret;
46.     if (copy_from_user(&data, (void __user *)arg, sizeof(data)))
47.         return -EFAULT;
48.     /*判断当前cmd是否被调用过了, 调用过就返回, 否则设置flags.*/
49.     ret = ion_share_set_flags(client, data.handle, filp->f_flags);
50.     if (ret)
51.         return ret;
52.
53.     data.fd = ion_share_dma_buf(client, data.handle);
54.     if (copy_to_user((void __user *)arg, &data, sizeof(data)))
55.         return -EFAULT;
56.     if (data.fd < 0)
57.         return data.fd;
58.     break;
59. }
60. case ION_IOC_IMPORT:
61. {
62.     struct ion_fd_data data;
63.     int ret = 0;
64.     if (copy_from_user(&data, (void __user *)arg,
65.         sizeof(struct ion_fd_data)))
66.         return -EFAULT;
67.     data.handle = ion_import_dma_buf(client, data.fd);
68.     if (IS_ERR(data.handle))
69.         data.handle = NULL;
70.     if (copy_to_user((void __user *)arg, &data,
71.         sizeof(struct ion_fd_data)))
72.         return -EFAULT;
73.     if (ret < 0)
74.         return ret;
75.     break;
76. }
77. case ION_IOC_CUSTOM:
78. --snip
79. case ION_IOC_CLEAN_CACHES:
80. case ION_IOC_INV_CACHES:
81. case ION_IOC_CLEAN_INV_CACHES:
82. --snip
83. case ION_IOC_GET_FLAGS:
84. --snip
85. default:
86.     return -ENOTTY;
87. }
88. return 0;
89. }</span>
```

下面分小节说明分配和共享的原理。

ION_IOC_ALLOC

```
[cpp] C {
01. struct ion_handle *ion_alloc(struct ion_client *client, size_t len,
02.     size_t align, unsigned int flags)
03. {
04. --snip
05.
06.     mutex_lock(&dev->lock);
07.     /*循环遍历当前Heap链表.*/
08.     for (n = rb_first(&dev->heaps); n != NULL; n = rb_next(n)) {
09.         struct ion_heap *heap = rb_entry(n, struct ion_heap, node);
10.         /*只有heap type和id都符合才去创建buffer.*/
11.         /* if the client doesn't support this heap type */
12.         if (!(1 <= heap->type & client->heap_mask))
13.             continue;
14.         /* if the caller didn't specify this heap type */
15.         if (!(1 <= heap->id & flags))
16.             continue;
17.         /* Do not allow un-secure heap if secure is specified */
18.         if (secure_allocation && (heap->type != ION_HEAP_TYPE_CP))
19.             continue;
20.         buffer = ion_buffer_create(heap, dev, len, align, flags);
21. --snip
22.     }
23.     mutex_unlock(&dev->lock);
24.
25. --snip
26.     /*创建了buffer之后, 就相应地创建handle来管理buffer.*/
```

关闭

```

27.     handle = ion_handle_create(client, buffer);
28.
29. --snip
30. }
31.
32. 找到Heap之后调用ion_buffer_create:
33. static struct ion_buffer *ion_buffer_create(struct ion_heap *heap,
34.                                             struct ion_device *dev,
35.                                             unsigned long len,
36.                                             unsigned long align,
37.                                             unsigned long flags)
38. {
39.     struct ion_buffer *buffer;
40.     struct sg_table *table;
41.     int ret;
42.     /*分配struct ion buffer,用来管理buffer.*/
43.     buffer = kzalloc(sizeof(struct ion_buffer), GFP_KERNEL);
44.     if (!buffer)
45.         return ERR_PTR(-ENOMEM);
46.
47.     buffer->heap = heap;
48.     kref_init(&buffer->ref);
49.     /*调用相应heap type的ops allocate. 还记得前面有提到过不同种类的ops吗,
    如carveout_heap_ops, vmalloc_ops.*/
50.     ret = heap->ops->allocate(heap, buffer, len, align, flags);
51.     if (ret) {
52.         kfree(buffer);
53.         return ERR_PTR(ret);
54.     }
55.
56.     buffer->dev = dev;
57.     buffer->size = len;
58.     /*http://lwn.net/Articles/263343*/
59.     table = buffer->heap->ops->map_dma(buffer->heap, buffer);
60.     if (IS_ERR_OR_NULL(table)) {
61.         heap->ops->free(buffer);
62.         kfree(buffer);
63.         return ERR_PTR(PTR_ERR(table));
64.     }
65.     buffer->sg_table = table;
66.
67.     mutex_init(&buffer->lock);
68.     /*将当前ion buffer添加到idev 的buffers 树上统一管理.*/
69.     ion_buffer_add(dev, buffer);
70.     return buffer;
71. }
72. }

```

[cpp]

```

01. <span xmlns="http://www.w3.org
    /1999/xhtml" style="">struct ion_handle *ion_alloc(struct ion_client *client, size_t len,
    size_t align, unsigned int flags)
02. {
03. --snip
04.
05.     mutex_lock(&dev->lock);
06.     /*循环遍历当前Heap链表.*/
07.     for (n = rb_first(&dev->heaps); n != NULL; n = rb_next(n)) {
08.         struct ion_heap *heap = rb_entry(n, struct ion_heap, node);
09.         /*只有heap type和id都符合才去创建buffer.*/
10.         /* if the client doesn't support this heap type */
11.         if (!(1 << heap->type) & client->heap_mask))
12.             continue;
13.         /* if the caller didn't specify this heap type */
14.         if (!(1 << heap->id) & flags))
15.             continue;
16.         /* Do not allow un-secure heap if secure is specified */
17.         if (secure_allocation && (heap->type != ION_HEAP_TYPE_CP))
18.             continue;
19.         buffer = ion_buffer_create(heap, dev, len, align, flags);
20.
21. --snip
22.     }
23.     mutex_unlock(&dev->lock);
24.
25. --snip
26.     /*创建了buffer之后,就相应地创建handle来管理buffer.*/
27.     handle = ion_handle_create(client, buffer);
28.
29. --snip
30. }

```

关闭

```
31.
32. 找到Heap之后调用ion_buffer_create:
33. static struct ion_buffer *ion_buffer_create(struct ion_heap *heap,
34.                                             struct ion_device *dev,
35.                                             unsigned long len,
36.                                             unsigned long align,
37.                                             unsigned long flags)
38. {
39.     struct ion_buffer *buffer;
40.     struct sg_table *table;
41.     int ret;
42.     /*分配struct ion buffer,用来管理buffer.*/
43.     buffer = kzalloc(sizeof(struct ion_buffer), GFP_KERNEL);
44.     if (!buffer)
45.         return ERR_PTR(-ENOMEM);
46.
47.     buffer->heap = heap;
48.     kref_init(&buffer->ref);
49.     /*调用相应heap type的ops allocate. 还记得前面有提到过不同种类的ops吗,
50. 如carveout_heap_ops ,vmalloc_ops .*/
51.     ret = heap->ops->allocate(heap, buffer, len, align, flags);
52.     if (ret) {
53.         kfree(buffer);
54.         return ERR_PTR(ret);
55.     }
56.
57.     buffer->dev = dev;
58.     buffer->size = len;
59.     /*http://lwn.net/Articles/263343*/
60.     table = buffer->heap->ops->map_dma(buffer->heap, buffer);
61.     if (IS_ERR_OR_NULL(table)) {
62.         heap->ops->free(buffer);
63.         kfree(buffer);
64.         return ERR_PTR(PTR_ERR(table));
65.     }
66.     buffer->sg_table = table;
67.
68.     mutex_init(&buffer->lock);
69.     /*将当前ion buffer添加到idev 的buffers 树上统一管理.*/
70.     ion_buffer_add(dev, buffer);
71.     return buffer;
72. }
```

[cpp] 

```
01. <p>static struct ion_handle *ion_handle_create(struct ion_client *client,
02.                                             struct ion_buffer *buffer)
03. {
04.     struct ion_handle *handle;
05.     /*分配struct ion_handle.*/
06.     handle = kzalloc(sizeof(struct ion_handle), GFP_KERNEL);
07.     if (!handle)
08.         return ERR_PTR(-ENOMEM);
09.     kref_init(&handle->ref);
10.     rb_init_node(&handle->node);
11.     handle->client = client; //client放入handle中
12.     ion_buffer_get(buffer); //引用计数加1
13.     handle->buffer = buffer; //buffer也放入handle中</p><p> return handle;
14. }
15. </p>
```

[cpp]

```
01. <p><span xmlns="http://www.w3.org
02. /1999/xhtml" style="">static struct ion_handle *ion_handle_create(struct ion_client *cl:
03.                                             struct ion_buffer *buffer)
04. {
05.     struct ion_handle *handle;
06.     /*分配struct ion_handle.*/
07.     handle = kzalloc(sizeof(struct ion_handle), GFP_KERNEL);
08.     if (!handle)
09.         return ERR_PTR(-ENOMEM);
10.     kref_init(&handle->ref);
11.     rb_init_node(&handle->node);
12.     handle->client = client; //client放入handle中
13.     ion_buffer_get(buffer); //引用计数加1
14.     handle->buffer = buffer; //buffer也放入handle中</span></p><p><span xmlns="http:
15. //www.w3.org/1999/xhtml" style=""> return handle;
    }
    </span></p>
```

关闭

先拿heap type为ION_HEAP_TYPE_CARVEOUT为例，看下它是如何分配buffer的。
allocate对应ion_carveout_heap_allocate。

```
[cpp]
01. static int ion_carveout_heap_allocate(struct ion_heap *heap,
02.                                     struct ion_buffer *buffer,
03.                                     unsigned long size, unsigned long align,
04.                                     unsigned long flags)
05. {
06.     buffer->priv_phys = ion_carveout_allocate(heap, size, align);
07.     return buffer->priv_phys == ION_CARVEOUT_ALLOCATE_FAIL ? -ENOMEM : 0;
08. }
09. ion_phys_addr_t ion_carveout_allocate(struct ion_heap *heap,
10.                                     unsigned long size,
11.                                     unsigned long align)
12. {
13.     struct ion_carveout_heap *carveout_heap =
14.         container_of(heap, struct ion_carveout_heap, heap);
15.     /*通过创建的mem pool来管理buffer,由于这块buffer在初始化的
16. 时候就预留了,现在只要从上面拿一块区域就可以了。*/
17.     unsigned long offset = gen_pool_alloc_aligned(carveout_heap->pool,
18.                                                  size, ilog2(align));
19.     /*分配不成功可能是没有内存空间可供分配了或者是有碎片导致的。*/
20.     if (!offset) {
21.         if ((carveout_heap->total_size -
22.             carveout_heap->allocated_bytes) >= size)
23.             pr_debug("%s: heap %s has enough memory (%lx) but"
24.                    " the allocation of size %lx still failed."
25.                    " Memory is probably fragmented.",
26.                    __func__, heap->name,
27.                    carveout_heap->total_size -
28.                    carveout_heap->allocated_bytes, size);
29.         return ION_CARVEOUT_ALLOCATE_FAIL;
30.     }
31.     /*已经分配掉的内存字节。*/
32.     carveout_heap->allocated_bytes += size;
33.     return offset;
34. }
```

```
[cpp]
01. <span xmlns="http://www.w3.org
/1999/xhtml" style="">static int ion_carveout_heap_allocate(struct ion_heap *heap,
02.     struct ion_buffer *buffer,
03.     unsigned long size, unsigned long align,
04.     unsigned long flags)
05. {
06.     buffer->priv_phys = ion_carveout_allocate(heap, size, align);
07.     return buffer->priv_phys == ION_CARVEOUT_ALLOCATE_FAIL ? -ENOMEM : 0;
08. }
09. ion_phys_addr_t ion_carveout_allocate(struct ion_heap *heap,
10.                                     unsigned long size,
11.                                     unsigned long align)
12. {
13.     struct ion_carveout_heap *carveout_heap =
14.         container_of(heap, struct ion_carveout_heap, heap);
15.     /*通过创建的mem pool来管理buffer,由于这块buffer在初始化的
16. 时候就预留了,现在只要从上面拿一块区域就可以了。*/
17.     unsigned long offset = gen_pool_alloc_aligned(carveout_heap->pool,
18.                                                  size, ilog2(align));
19.     /*分配不成功可能是没有内存空间可供分配了或者是有碎片导致的。*/
20.     if (!offset) {
21.         if ((carveout_heap->total_size -
22.             carveout_heap->allocated_bytes) >= size)
23.             pr_debug("%s: heap %s has enough memory (%lx) but"
24.                    " the allocation of size %lx still failed."
25.                    " Memory is probably fragmented.",
26.                    __func__, heap->name,
27.                    carveout_heap->total_size -
28.                    carveout_heap->allocated_bytes, size);
29.         return ION_CARVEOUT_ALLOCATE_FAIL;
30.     }
31.     /*已经分配掉的内存字节。*/
32.     carveout_heap->allocated_bytes += size;
33.     return offset;
34. }</span>
```

[关闭](#)

同样地，对于heap type为ION_HEAP_TYPE_SYSTEM的分配函数是ion_system_heap_allocate。

```
[cpp]
01. static int ion_system_contig_heap_allocate(struct ion_heap *heap,
02.                                           struct ion_buffer *buffer,
03.                                           unsigned long len,
04.                                           unsigned long align,
05.                                           unsigned long flags)
06. {
07.     /*通过kzalloc分配。*/
08.     buffer->priv_virt = kzalloc(len, GFP_KERNEL);
09.     if (!buffer->priv_virt)
10.         return -ENOMEM;
11.     atomic_add(len, &system_contig_heap_allocated);
12.     return 0;
13. }

[cpp]
01. <span xmlns="http://www.w3.org
/1999/xhtml" style="">static int ion_system_contig_heap_allocate(struct ion_heap *heap,
02.                                           struct ion_buffer *buffer,
03.                                           unsigned long len,
04.                                           unsigned long align,
05.                                           unsigned long flags)
06. {
07.     /*通过kzalloc分配。*/
08.     buffer->priv_virt = kzalloc(len, GFP_KERNEL);
09.     if (!buffer->priv_virt)
10.         return -ENOMEM;
11.     atomic_add(len, &system_contig_heap_allocated);
12.     return 0;
13. }</span>
```

其他的几种Heap type可自行研究，接着调用ion_buffer_add将buffer添加到dev的buffers树上去

```
[cpp]
01. static void ion_buffer_add(struct ion_device *dev,
02.                             struct ion_buffer *buffer)
03. {
04.     struct rb_node **p = &dev->buffers.rb_node;
05.     struct rb_node *parent = NULL;
06.     struct ion_buffer *entry;
07.
08.     while (*p) {
09.         parent = *p;
10.         entry = rb_entry(parent, struct ion_buffer, node);
11.
12.         if (buffer < entry) {
13.             p = &(*p)->rb_left;
14.         } else if (buffer > entry) {
15.             p = &(*p)->rb_right;
16.         } else {
17.             pr_err("%s: buffer already found.", __func__);
18.             BUG();
19.         }
20.     }
21.     /*又是使用红黑树哦！*/
22.     rb_link_node(&buffer->node, parent, p);
23.     rb_insert_color(&buffer->node, &dev->buffers);
24. }
```

```
[cpp]
01. <span xmlns="http://www.w3.org
/1999/xhtml" style="">static void ion_buffer_add(struct ion_device *dev,
02.                                           struct ion_buffer *buffer)
03. {
04.     struct rb_node **p = &dev->buffers.rb_node;
05.     struct rb_node *parent = NULL;
06.     struct ion_buffer *entry;
07.
08.     while (*p) {
09.         parent = *p;
10.         entry = rb_entry(parent, struct ion_buffer, node);
11.
12.         if (buffer < entry) {
```

关闭

```

13.         p = &(*p)->rb_left;
14.     } else if (buffer > entry) {
15.         p = &(*p)->rb_right;
16.     } else {
17.         pr_err("%s: buffer already found.", __func__);
18.         BUG();
19.     }
20. }
21. /*又是使用红黑树哦!*/
22. rb_link_node(&buffer->node, parent, p);
23. rb_insert_color(&buffer->node, &dev->buffers);
24. }</span>

```

至此，已经得到client和handle，buffer分配完成！

ION_IOC_MAP/ ION_IOC_SHARE

```

[cpp] C {}
01. int ion_share_dma_buf(struct ion_client *client, struct ion_handle *handle)
02. {
03.     struct ion_buffer *buffer;
04.     struct dma_buf *dmabuf;
05.     bool valid_handle;
06.     int fd;
07.
08.     mutex_lock(&client->lock);
09.     valid_handle = ion_handle_validate(client, handle);
10.     mutex_unlock(&client->lock);
11.     if (!valid_handle) {
12.         WARN(1, "%s: invalid handle passed to share.\n", __func__);
13.         return -EINVAL;
14.     }
15.
16.     buffer = handle->buffer;
17.     ion_buffer_get(buffer);
18.     /*生成一个新的file描述符*/
19.     dmabuf = dma_buf_export(buffer, &dma_buf_ops, buffer->size, 0_RDWR);
20.     if (IS_ERR(dmabuf)) {
21.         ion_buffer_put(buffer);
22.         return PTR_ERR(dmabuf);
23.     }
24.     /*将file转换为用户空间识别的fd描述符。*/
25.     fd = dma_buf_fd(dmabuf, 0_CLOEXEC);
26.     if (fd < 0)
27.         dma_buf_put(dmabuf);
28.
29.     return fd;
30. }
31. struct dma_buf *dma_buf_export(void *priv, const struct dma_buf_ops *ops,
32.                                size_t size, int flags)
33. {
34.     struct dma_buf *dmabuf;
35.     struct file *file;
36.     --snip
37.     /*分配struct dma_buf.*/
38.     dmabuf = kzalloc(sizeof(struct dma_buf), GFP_KERNEL);
39.     if (dmabuf == NULL)
40.         return ERR_PTR(-ENOMEM);
41.     /*保存信息到dmabuf，注意ops为dma_buf_ops，后面mmap为调用到。*/
42.     dmabuf->priv = priv;
43.     dmabuf->ops = ops;
44.     dmabuf->size = size;
45.     /*产生新的file*/
46.     file = anon_inode_getfile("dmabuf", &dma_buf_fops, dmabuf, flags);
47.
48.     dmabuf->file = file;
49.
50.     mutex_init(&dmabuf->lock);
51.     INIT_LIST_HEAD(&dmabuf->attachments);
52.
53.     return dmabuf;
54. }

[cpp]
01. <span xmlns="http://www.w3.org
02. /1999/xhtml" style="">int ion_share_dma_buf(struct ion_client *client, struct ion_handl
03.     struct ion_buffer *buffer;

```

关闭

```
04.     struct dma_buf *dmabuf;
05.     bool valid_handle;
06.     int fd;
07.
08.     mutex_lock(&client->lock);
09.     valid_handle = ion_handle_validate(client, handle);
10.     mutex_unlock(&client->lock);
11.     if (!valid_handle) {
12.         WARN(1, "%s: invalid handle passed to share.\n", __func__);
13.         return -EINVAL;
14.     }
15.
16.     buffer = handle->buffer;
17.     ion_buffer_get(buffer);
18.     /*生成一个新的file描述符*/
19.     dmabuf = dma_buf_export(buffer, &dma_buf_ops, buffer->size, 0_RDWR);
20.     if (IS_ERR(dmabuf)) {
21.         ion_buffer_put(buffer);
22.         return PTR_ERR(dmabuf);
23.     }
24.     /*将file转换为用户空间识别的fd描述符。*/
25.     fd = dma_buf_fd(dmabuf, O_CLOEXEC);
26.     if (fd < 0)
27.         dma_buf_put(dmabuf);
28.
29.     return fd;
30. }
31. struct dma_buf *dma_buf_export(void *priv, const struct dma_buf_ops *ops,
32.                                size_t size, int flags)
33. {
34.     struct dma_buf *dmabuf;
35.     struct file *file;
36.     --snip
37.     /*分配struct dma_buf.*/
38.     dmabuf = kzalloc(sizeof(struct dma_buf), GFP_KERNEL);
39.     if (dmabuf == NULL)
40.         return ERR_PTR(-ENOMEM);
41.     /*保存信息到dmabuf, 注意ops为dma_buf_ops, 后面mmap为调用到。*/
42.     dmabuf->priv = priv;
43.     dmabuf->ops = ops;
44.     dmabuf->size = size;
45.     /*产生新的file*/
46.     file = anon_inode_getfile("dmabuf", &dma_buf_fops, dmabuf, flags);
47.
48.     dmabuf->file = file;
49.
50.     mutex_init(&dmabuf->lock);
51.     INIT_LIST_HEAD(&dmabuf->attachments);
52.
53.     return dmabuf;
54. }</span>
```

通过上述过程, 用户空间就得到了新的fd,重新生成一个新的fd的目的是考虑了两个用户空间进程想共享这块heap内存的情况。然后再对fd作mmap, 相应地kernel空间就调用到了file 的dma_buf_fops中的dma_buf_mmap_internal。

```
[cpp]  C  }>
01. static const struct file_operations dma_buf_fops = {
02.     .release    = dma_buf_release,
03.     .mmap       = dma_buf_mmap_internal,
04. };
05. static int dma_buf_mmap_internal(struct file *file, struct vm_area_struct *vma)
06. {
07.     struct dma_buf *dmabuf;
08.
09.     if (!is_dma_buf_file(file))
10.         return -EINVAL;
11.
12.     dmabuf = file->private_data;
13.     /*检查用户空间要映射的size是否比目前dmabuf也就是当前heap的size
14.     还要大, 如果是就返回无效。*/
15.     /* check for overflowing the buffer's size */
16.     if (vma->vm_pgoff + ((vma->vm_end - vma->vm_start) >> PAGE_SHIFT) >
17.         dmabuf->size >> PAGE_SHIFT)
18.         return -EINVAL;
19.     /*调用的是dma_buf_ops 的mmap函数*/
20.     return dmabuf->ops->mmap(dmabuf, vma);
```

[关闭](#)

```
21.     }
22.
23.     struct dma_buf_ops dma_buf_ops = {
24.         .map_dma_buf = ion_map_dma_buf,
25.         .unmap_dma_buf = ion_unmap_dma_buf,
26.         .mmap = ion_mmap,
27.         .release = ion_dma_buf_release,
28.         .begin_cpu_access = ion_dma_buf_begin_cpu_access,
29.         .end_cpu_access = ion_dma_buf_end_cpu_access,
30.         .kmap_atomic = ion_dma_buf_kmap,
31.         .kunmap_atomic = ion_dma_buf_kunmap,
32.         .kmap = ion_dma_buf_kmap,
33.         .kunmap = ion_dma_buf_kunmap,
34.     };
35.     static int ion_mmap(struct dma_buf *dmabuf, struct vm_area_struct *vma)
36.     {
37.         struct ion_buffer *buffer = dmabuf->priv;
38.         int ret;
39.
40.         if (!buffer->heap->ops->map_user) {
41.             pr_err("%s: this heap does not define a method for mapping "
42.                 "to userspace\n", __func__);
43.             return -EINVAL;
44.         }
45.
46.         mutex_lock(&buffer->lock);
47.         /* now map it to userspace */
48.         /*调用的是相应heap的map_user,如carveout_heap_ops 调用的是
49.         ion_carveout_heap_map_user,此函数就是一般的mmap实现,不追下去了。*/
50.         ret = buffer->heap->ops->map_user(buffer->heap, buffer, vma);
51.
52.         if (ret) {
53.             mutex_unlock(&buffer->lock);
54.             pr_err("%s: failure mapping buffer to userspace\n",
55.                 __func__);
56.         } else {
57.             buffer->umap_cnt++;
58.             mutex_unlock(&buffer->lock);
59.
60.             vma->vm_ops = &ion_vm_ops;
61.             /*
62.              * move the buffer into the vm_private_data so we can access it
63.              * from vma_open/close
64.              */
65.             vma->vm_private_data = buffer;
66.         }
67.         return ret;
68.     }
```

[cpp]

```
01. <span xmlns="http://www.w3.org
02. /1999/xhtml" style="">static const struct file_operations dma_buf_fops = {
03.     .release = dma_buf_release,
04.     .mmap = dma_buf_mmap_internal,
05. };
06. static int dma_buf_mmap_internal(struct file *file, struct vm_area_struct *vma)
07. {
08.     struct dma_buf *dmabuf;
09.
10.     if (!is_dma_buf_file(file))
11.         return -EINVAL;
12.
13.     dmabuf = file->private_data;
14.     /*检查用户空间要映射的size是否比目前dmabuf也就是当前heap的size
15.     还要大,如果是就返回无效。*/
16.     /* check for overflowing the buffer's size */
17.     if (vma->vm_pgoff + ((vma->vm_end - vma->vm_start) >> PAGE_SHIFT) >
18.         dmabuf->size >> PAGE_SHIFT)
19.         return -EINVAL;
20.     /*调用的是dma_buf_ops 的mmap函数*/
21.     return dmabuf->ops->mmap(dmabuf, vma);
22. }
23. struct dma_buf_ops dma_buf_ops = {
24.     .map_dma_buf = ion_map_dma_buf,
25.     .unmap_dma_buf = ion_unmap_dma_buf,
26.     .mmap = ion_mmap,
27.     .release = ion_dma_buf_release,
28.     .begin_cpu_access = ion_dma_buf_begin_cpu_access,
```

关闭


```

29.         .end_cpu_access = ion_dma_buf_end_cpu_access,
30.         .kmap_atomic = ion_dma_buf_kmap,
31.         .kunmap_atomic = ion_dma_buf_kunmap,
32.         .kmap = ion_dma_buf_kmap,
33.         .kunmap = ion_dma_buf_kunmap,
34.     };
35. static int ion_mmap(struct dma_buf *dmabuf, struct vm_area_struct *vma)
36. {
37.     struct ion_buffer *buffer = dmabuf->priv;
38.     int ret;
39.
40.     if (!buffer->heap->ops->map_user) {
41.         pr_err("%s: this heap does not define a method for mapping "
42.             "to userspace\n", __func__);
43.         return -EINVAL;
44.     }
45.
46.     mutex_lock(&buffer->lock);
47.     /* now map it to userspace */
48.     /*调用的是相应heap的map_user,如carveout_heap_ops 调用的是
49.     ion_carveout_heap_map_user,此函数就是一般的mmap实现,不追下去了。*/
50.     ret = buffer->heap->ops->map_user(buffer->heap, buffer, vma);
51.
52.     if (ret) {
53.         mutex_unlock(&buffer->lock);
54.         pr_err("%s: failure mapping buffer to userspace\n",
55.             __func__);
56.     } else {
57.         buffer->umap_cnt++;
58.         mutex_unlock(&buffer->lock);
59.
60.         vma->vm_ops = &ion_vm_ops;
61.         /*
62.          * move the buffer into the vm_private_data so we can access it
63.          * from vma_open/close
64.          */
65.         vma->vm_private_data = buffer;
66.     }
67.     return ret;
68. }</span>

```

至此，用户空间就得到了bufferaddress，然后可以使用了！

ION_IOC_IMPORT

当用户空间另一个进程需要这块heap的时候，ION_IOC_IMPORT就派上用场了！注意，传进去的fd为在ION_IOC_SHARE中得到的。

```

[cpp]
01. struct ion_handle *ion_import_dma_buf(struct ion_client *client, int fd)
02. {
03.
04.     struct dma_buf *dmabuf;
05.     struct ion_buffer *buffer;
06.     struct ion_handle *handle;
07.
08.     dmabuf = dma_buf_get(fd);
09.     if (IS_ERR_OR_NULL(dmabuf))
10.         return ERR_PTR(PTR_ERR(dmabuf));
11.     /* if this memory came from ion */
12.     --snip
13.     buffer = dmabuf->priv;
14.
15.     mutex_lock(&client->lock);
16.     /* if a handle exists for this buffer just take it
17.     /*查找是否已经存在对应的handle了，没有则创建。因为另外一个进程只是
18.     调用了open 接口，对应的只创建了client，并没有handle。
19.     */
20.     handle = ion_handle_lookup(client, buffer);
21.     if (!IS_ERR_OR_NULL(handle)) {
22.         ion_handle_get(handle);
23.         goto end;
24.     }
25.     handle = ion_handle_create(client, buffer);
26.     if (IS_ERR_OR_NULL(handle))
27.         goto end;
28.     ion_handle_add(client, handle);
29. end:
30.     mutex_unlock(&client->lock);

```

关闭

```
31.     dma_buf_put(dmabuf);
32.     return handle;
33. }

[cpp]
01. <span xmlns="http://www.w3.org
/1999/xhtml" style="">struct ion_handle *ion_import_dma_buf(struct ion_client *client, :
02. {
03.
04.     struct dma_buf *dmabuf;
05.     struct ion_buffer *buffer;
06.     struct ion_handle *handle;
07.
08.     dmabuf = dma_buf_get(fd);
09.     if (IS_ERR_OR_NULL(dmabuf))
10.         return ERR_PTR(PTR_ERR(dmabuf));
11.     /* if this memory came from ion */
12.     --snip
13.     buffer = dmabuf->priv;
14.
15.     mutex_lock(&client->lock);
16.     /* if a handle exists for this buffer just take a reference to it */
17.     /*查找是否已经存在对应的handle了, 没有则创建。因为另外一个进程只是
18.     调用了open 接口, 对应的只创建了client, 并没有handle。
19.     */
20.     handle = ion_handle_lookup(client, buffer);
21.     if (!IS_ERR_OR_NULL(handle)) {
22.         ion_handle_get(handle);
23.         goto end;
24.     }
25.     handle = ion_handle_create(client, buffer);
26.     if (IS_ERR_OR_NULL(handle))
27.         goto end;
28.     ion_handle_add(client, handle);
29. end:
30.     mutex_unlock(&client->lock);
31.     dma_buf_put(dmabuf);
32.     return handle;
33. }</span>
```

这样, 用户空间另一个进程也得到了对应的bufferHandle, client/buffer/handle之间连接起来了! 然后另一个一个进程也可以使用mmap来操作这块heap buffer了。

和一般的进程使用ION区别就是共享的进程之间struction_buffer是共享的, 而struct ion_handle是各自的。

可见, ION的使用流程还是比较清晰的。不过要记得的是, 使用好了ION, 一定要释放掉, 否则会导致内存泄露。

ION内核空间使用

内核空间使用ION也是大同小异, 按照创建client,buffer,handle的流程, 只是它的使用对用户空间来说是透明的罢了!

ion_client_create在kernel空间被Qualcomm给封装了下。

```
[cpp]  C  8
01. struct ion_client *msm_ion_client_create(unsigned int heap_mask,
02.     const char *name)
03. {
04.     return ion_client_create(idev, heap_mask, name);
05. }

[cpp]
01. <span xmlns="http://www.w3.org
/1999/xhtml" style="">struct ion_client *msm_ion_client_create(unsigned int heap_mask,
02.     const char *name)
03. {
04.     return ion_client_create(idev, heap_mask, name);
05. }</span>
```

关闭

调用的流程也类似, 不过map的时候调用的是heap对应的map_kernel()而不是map_user()。

msm_ion_client_create -> ion_alloc -> ion_map_kernel

参考文档：

<http://lwn.net/Articles/480055/>

《ARM体系结构与编程》存储系统章节。

其handle纳入进程file desc空间而不是/dev/ion设备内单独的handle空间，方便之处如下：

每个buffer一个handle，便于更灵活地细粒度地控制每个buffer的使用周期；

向用户进程输出fd，细粒度地对每个buffer进行mmap；

使用struct file可以重用已有struct file_operations进行mmap；

在binder driver中以BINDER_TYPE_FD类型为不同进程传递提供支撑，并借助fget/fput从struct file级别进行kref控制；

当不需要在用户态访问时，是不需要与struct file关联的，内核结构ion_handle/ion_buffer唯一的表征了该buffer，所以与struct file关联的工作是在ioctl(ion, ION_IOC_SHARE/ION_IOC_MAP, &share)中完成并输出的，用于后续的mmap调用；或者该进程不需要mmap而是仅仅向别的进程binder transfer，这就实现了用户态进行buffer流转控制，而内核态完成buffer数据流转。

转自http://blog.csdn.net/kris_fei/article/details/8588661 & http://blog.csdn.net/kris_fei/article/details/20707751

考察平台：

chipset: MSM8X25Q

codebase: Android 4.1

ION概念：

ION是Google的下一代内存管理器，用来支持不同的内存分配机制，如CARVOUT(PMEM)，物理连续内存(kmalloc)，虚拟地址连续但物理不连续内存(vmalloc)， IOMMU等。

用户空间和内核空间都可以使用ION，用户空间是通过/dev/ion来创建client的。

说到client, 顺便看下ION相关比较重要的几个概念。

Heap: 用来表示内存分配的相关信息，包括id, type, name等。用struct ion_heap表示。

Client: Ion的使用者，用户空间和内核控件要使用ION的buffer,必须先创建一个client,一个client可以有多个buffer，用struct ion_buffer表示。

Handle: 将buffer该抽象出来，可以认为ION用handle来管理buffer，一般用户直接拿到的是handle,而不是buffer。用struct ion_handle表示。

heap类型：

由于ION可以使用多种memory分配机制，例如物理连续和不连续的，所以ION使用enum ion_heap_type表示。

```
[cpp]
01. /**
02.  * enum ion_heap_types - list of all possible types of heaps
03.  * @ION_HEAP_TYPE_SYSTEM: memory allocated via vmalloc
04.  * @ION_HEAP_TYPE_SYSTEM_CONTIG: memory allocated via kmalloc
05.  * @ION_HEAP_TYPE_CARVEOUT: memory allocated from a prereserved
06.  *                          carveout heap, allocations are physically
07.  *                          contiguous
08.  * @ION_HEAP_TYPE_IOMMU: IOMMU memory
09.  * @ION_HEAP_TYPE_CP: memory allocated from a prereserved
10.  *                     carveout heap, allocations are physically
11.  *                     contiguous. Used for content protection.
12.  * @ION_HEAP_TYPE_DMA: memory allocated via DMA API
13.  * @ION_HEAP_END: helper for iterating over heaps
14.  */
15. enum ion_heap_type {
16.     ION_HEAP_TYPE_SYSTEM,
17.     ION_HEAP_TYPE_SYSTEM_CONTIG,
18.     ION_HEAP_TYPE_CARVEOUT,
19.     ION_HEAP_TYPE_IOMMU,
20.     ION_HEAP_TYPE_CP,
21.     ION_HEAP_TYPE_DMA,
22.     ION_HEAP_TYPE_CUSTOM, /* must be last so device specific heaps always
23.                            are at the end of this enum */
24.     ION_NUM_HEAPS,
25. };
```

```
[cpp]
01. /**
02.  * enum ion_heap_types - list of all possible types of heaps
03.  * @ION_HEAP_TYPE_SYSTEM: memory allocated via vmalloc
04.  * @ION_HEAP_TYPE_SYSTEM_CONTIG: memory allocated via kmalloc
05.  * @ION_HEAP_TYPE_CARVEOUT: memory allocated from a prereserved
06.  *                          carveout heap, allocations are physically
07.  *                          contiguous
08.  * @ION_HEAP_TYPE_IOMMU: IOMMU memory
09.  * @ION_HEAP_TYPE_CP: memory allocated from a prereserved
10.  *                     carveout heap, allocations are physically
11.  *                     contiguous. Used for content protection.
```

关闭

```
12.  * @ION_HEAP_TYPE_DMA:          memory allocated via DMA API
13.  * @ION_HEAP_END:              helper for iterating over heaps
14.  */
15.  enum ion_heap_type {
16.      ION_HEAP_TYPE_SYSTEM,
17.      ION_HEAP_TYPE_SYSTEM_CONTIG,
18.      ION_HEAP_TYPE_CARVEOUT,
19.      ION_HEAP_TYPE_IOMMU,
20.      ION_HEAP_TYPE_CP,
21.      ION_HEAP_TYPE_DMA,
22.      ION_HEAP_TYPE_CUSTOM, /* must be last so device specific heaps always
23.                             are at the end of this enum */
24.      ION_NUM_HEAPS,
25.  };
```

代码中的注释很明确地说明了哪种type对应的是分配哪种memory。不同type的heap需要不同的map，不过都是用struct ion_heap_ops来表示的。如以下例子：

```
[cpp]  C  88

01.  static struct ion_heap_ops carveout_heap_ops = {
02.      .allocate = ion_carveout_heap_allocate,
03.      .free = ion_carveout_heap_free,
04.      .phys = ion_carveout_heap_phys,
05.      .map_user = ion_carveout_heap_map_user,
06.      .map_kernel = ion_carveout_heap_map_kernel,
07.      .unmap_user = ion_carveout_heap_unmap_user,
08.      .unmap_kernel = ion_carveout_heap_unmap_kernel,
09.      .map_dma = ion_carveout_heap_map_dma,
10.      .unmap_dma = ion_carveout_heap_unmap_dma,
11.      .cache_op = ion_carveout_cache_ops,
12.      .print_debug = ion_carveout_print_debug,
13.      .map_iommu = ion_carveout_heap_map_iommu,
14.      .unmap_iommu = ion_carveout_heap_unmap_iommu,
15.  };
16.
17.  static struct ion_heap_ops kmalloc_ops = {
18.      .allocate = ion_system_contig_heap_allocate,
19.      .free = ion_system_contig_heap_free,
20.      .phys = ion_system_contig_heap_phys,
21.      .map_dma = ion_system_contig_heap_map_dma,
22.      .unmap_dma = ion_system_heap_unmap_dma,
23.      .map_kernel = ion_system_heap_map_kernel,
24.      .unmap_kernel = ion_system_heap_unmap_kernel,
25.      .map_user = ion_system_contig_heap_map_user,
26.      .cache_op = ion_system_contig_heap_cache_ops,
27.      .print_debug = ion_system_contig_print_debug,
28.      .map_iommu = ion_system_contig_heap_map_iommu,
29.      .unmap_iommu = ion_system_heap_unmap_iommu,
30.  };
```

```
[cpp]

01.  static struct ion_heap_ops carveout_heap_ops = {
02.      .allocate = ion_carveout_heap_allocate,
03.      .free = ion_carveout_heap_free,
04.      .phys = ion_carveout_heap_phys,
05.      .map_user = ion_carveout_heap_map_user,
06.      .map_kernel = ion_carveout_heap_map_kernel,
07.      .unmap_user = ion_carveout_heap_unmap_user,
08.      .unmap_kernel = ion_carveout_heap_unmap_kernel,
09.      .map_dma = ion_carveout_heap_map_dma,
10.      .unmap_dma = ion_carveout_heap_unmap_dma,
11.      .cache_op = ion_carveout_cache_ops,
12.      .print_debug = ion_carveout_print_debug,
13.      .map_iommu = ion_carveout_heap_map_iommu,
14.      .unmap_iommu = ion_carveout_heap_unmap_iommu,
15.  };
16.
17.  static struct ion_heap_ops kmalloc_ops = {
18.      .allocate = ion_system_contig_heap_allocate,
19.      .free = ion_system_contig_heap_free,
20.      .phys = ion_system_contig_heap_phys,
21.      .map_dma = ion_system_contig_heap_map_dma,
22.      .unmap_dma = ion_system_heap_unmap_dma,
23.      .map_kernel = ion_system_heap_map_kernel,
24.      .unmap_kernel = ion_system_heap_unmap_kernel,
```

关闭

```
25.     .map_user = ion_system_contig_heap_map_user,  
26.     .cache_op = ion_system_contig_heap_cache_ops,  
27.     .print_debug = ion_system_contig_print_debug,  
28.     .map_iommu = ion_system_contig_heap_map_iommu,  
29.     .unmap_iommu = ion_system_heap_unmap_iommu,  
30. };
```

Heap ID :

同一种type的heap上当然可以分为若干个chunk供用户使用，所以ION又使用ID来区分了。例如在type为ION_HEAP_TYPE_CARVEOUT的heap上，audio和display部分都需要使用，ION就用ID来区分。

Heap id用enum_ion_heap_ids表示。

```
[cpp] 88  
  
01. /**  
02.  * These are the only ids that should be used for Ion heap ids.  
03.  * The ids listed are the order in which allocation will be attempted  
04.  * if specified. Don't swap the order of heap ids unless you know what  
05.  * you are doing!  
06.  * Id's are spaced by purpose to allow new Id's to be inserted in-between (f  
07.  * possible fallbacks)  
08.  */  
09.  
10. enum ion_heap_ids {  
11.     INVALID_HEAP_ID = -1,  
12.     ION_CP_MM_HEAP_ID = 8,  
13.     ION_CP_MFC_HEAP_ID = 12,  
14.     ION_CP_WB_HEAP_ID = 16, /* 8660 only */  
15.     ION_CAMERA_HEAP_ID = 20, /* 8660 only */  
16.     ION_SF_HEAP_ID = 24,  
17.     ION_IOMMU_HEAP_ID = 25,  
18.     ION_QSECOM_HEAP_ID = 26,  
19.     ION_AUDIO_HEAP_BL_ID = 27,  
20.     ION_AUDIO_HEAP_ID = 28,  
21.  
22.     ION_MM_FIRMWARE_HEAP_ID = 29,  
23.     ION_SYSTEM_HEAP_ID = 30,  
24.  
25.     ION_HEAP_ID_RESERVED = 31 /** Bit reserved for ION_SECURE flag */  
26. };
```

```
[cpp]  
  
01. /**  
02.  * These are the only ids that should be used for Ion heap ids.  
03.  * The ids listed are the order in which allocation will be attempted  
04.  * if specified. Don't swap the order of heap ids unless you know what  
05.  * you are doing!  
06.  * Id's are spaced by purpose to allow new Id's to be inserted in-between (for  
07.  * possible fallbacks)  
08.  */  
09.  
10. enum ion_heap_ids {  
11.     INVALID_HEAP_ID = -1,  
12.     ION_CP_MM_HEAP_ID = 8,  
13.     ION_CP_MFC_HEAP_ID = 12,  
14.     ION_CP_WB_HEAP_ID = 16, /* 8660 only */  
15.     ION_CAMERA_HEAP_ID = 20, /* 8660 only */  
16.     ION_SF_HEAP_ID = 24,  
17.     ION_IOMMU_HEAP_ID = 25,  
18.     ION_QSECOM_HEAP_ID = 26,  
19.     ION_AUDIO_HEAP_BL_ID = 27,  
20.     ION_AUDIO_HEAP_ID = 28,  
21.  
22.     ION_MM_FIRMWARE_HEAP_ID = 29,  
23.     ION_SYSTEM_HEAP_ID = 30,  
24.  
25.     ION_HEAP_ID_RESERVED = 31 /** Bit reserved for ION_SECURE flag */  
26. };
```

关闭

Heap 定义 :

了解了heap type和id，看看如何被用到了，本平台使用的文件为board-qrd7627a.c，有如下定义：

```
[cpp]
01. /**
02.  * These heaps are listed in the order they will be allocated.
03.  * Don't swap the order unless you know what you are doing!
04.  */
05. struct ion_platform_heap msm7627a_heaps[] = {
06.     {
07.         .id = ION_SYSTEM_HEAP_ID,
08.         .type = ION_HEAP_TYPE_SYSTEM,
09.         .name = ION_VMALLOC_HEAP_NAME,
10.     },
11. #ifdef CONFIG_MSM_MULTIMEDIA_USE_ION
12.     /* PMEM_ADSP = CAMERA */
13.     {
14.         .id = ION_CAMERA_HEAP_ID,
15.         .type = CAMERA_HEAP_TYPE,
16.         .name = ION_CAMERA_HEAP_NAME,
17.         .memory_type = ION_EBI_TYPE,
18.         .extra_data = (void *)&co_mm_ion_pdata,
19.         .priv = (void *)&ion_cma_device.dev,
20.     },
21.     /* AUDIO HEAP 1*/
22.     {
23.         .id = ION_AUDIO_HEAP_ID,
24.         .type = ION_HEAP_TYPE_CARVEOUT,
25.         .name = ION_AUDIO_HEAP_NAME,
26.         .memory_type = ION_EBI_TYPE,
27.         .extra_data = (void *)&co_ion_pdata,
28.     },
29.     /* PMEM_MDP = SF */
30.     {
31.         .id = ION_SF_HEAP_ID,
32.         .type = ION_HEAP_TYPE_CARVEOUT,
33.         .name = ION_SF_HEAP_NAME,
34.         .memory_type = ION_EBI_TYPE,
35.         .extra_data = (void *)&co_ion_pdata,
36.     },
37.     /* AUDIO HEAP 2*/
38.     {
39.         .id = ION_AUDIO_HEAP_BL_ID,
40.         .type = ION_HEAP_TYPE_CARVEOUT,
41.         .name = ION_AUDIO_BL_HEAP_NAME,
42.         .memory_type = ION_EBI_TYPE,
43.         .extra_data = (void *)&co_ion_pdata,
44.         .base = BOOTLOADER_BASE_ADDR,
45.     },
46. #endif
47. };
```

```
[cpp]
01. /**
02.  * These heaps are listed in the order they will be allocated.
03.  * Don't swap the order unless you know what you are doing!
04.  */
05. struct ion_platform_heap msm7627a_heaps[] = {
06.     {
07.         .id = ION_SYSTEM_HEAP_ID,
08.         .type = ION_HEAP_TYPE_SYSTEM,
09.         .name = ION_VMALLOC_HEAP_NAME,
10.     },
11. #ifdef CONFIG_MSM_MULTIMEDIA_USE_ION
12.     /* PMEM_ADSP = CAMERA */
13.     {
14.         .id = ION_CAMERA_HEAP_ID,
15.         .type = CAMERA_HEAP_TYPE,
16.         .name = ION_CAMERA_HEAP_NAME,
17.         .memory_type = ION_EBI_TYPE,
18.         .extra_data = (void *)&co_mm_ion_pdata,
19.         .priv = (void *)&ion_cma_device.dev,
20.     },
21.     /* AUDIO HEAP 1*/
22.     {
23.         .id = ION_AUDIO_HEAP_ID,
24.         .type = ION_HEAP_TYPE_CARVEOUT,
25.         .name = ION_AUDIO_HEAP_NAME,
26.         .memory_type = ION_EBI_TYPE,
27.         .extra_data = (void *)&co_ion_pdata,
```

关闭

```
28.     },
29.     /* PMEM_MDP = SF */
30.     {
31.         .id = ION_SF_HEAP_ID,
32.         .type = ION_HEAP_TYPE_CARVEOUT,
33.         .name = ION_SF_HEAP_NAME,
34.         .memory_type = ION_EBI_TYPE,
35.         .extra_data = (void *)&co_ion_pdata,
36.     },
37.     /* AUDIO_HEAP 2 */
38.     {
39.         .id = ION_AUDIO_HEAP_BL_ID,
40.         .type = ION_HEAP_TYPE_CARVEOUT,
41.         .name = ION_AUDIO_HEAP_NAME,
42.         .memory_type = ION_EBI_TYPE,
43.         .extra_data = (void *)&co_ion_pdata,
44.         .base = BOOTLOADER_BASE_ADDR,
45.     },
46.
47. #endif
48. };
```

ION Handle :

当Ion client分配buffer时，相应的一个唯一的handle也会被指定，当然client可以多次申请ion buffer。申请好buffer之后，返回的是一个ion handle，不过要知道Ion buffer才和实际的内存相关，包括size, address等信息。

Struct ion_handle和struct ion_buffer如下：

```
[cpp]
01. /**
02.  * ion_handle - a client local reference to a buffer
03.  * @ref:         reference count
04.  * @client:      back pointer to the client the buffer resides in
05.  * @buffer:      pointer to the buffer
06.  * @node:        node in the client's handle rbtree
07.  * @kmap_cnt:    count of times this client has mapped to kernel
08.  * @dmap_cnt:    count of times this client has mapped for dma
09.  *
10.  * Modifications to node, map_cnt or mapping should be protected by the
11.  * lock in the client. Other fields are never changed after initialization.
12.  */
13. struct ion_handle {
14.     struct kref ref;
15.     struct ion_client *client;
16.     struct ion_buffer *buffer;
17.     struct rb_node node;
18.     unsigned int kmap_cnt;
19.     unsigned int iommu_map_cnt;
20. };
21.
22. /**
23.  * struct ion_buffer - metadata for a particular buffer
24.  * @ref:         reference count
25.  * @node:        node in the ion_device buffers tree
26.  * @dev:         back pointer to the ion_device
27.  * @heap:        back pointer to the heap the buffer came from
28.  * @flags:       buffer specific flags
29.  * @size:        size of the buffer
30.  * @priv_virt:   private data to the buffer representable as
31.  *               a void *
32.  * @priv_phys:   private data to the buffer representable as
33.  *               an ion_phys_addr_t (and someday a phys_addr_t)
34.  * @lock:        protects the buffers cnt fields
35.  * @kmap_cnt:    number of times the buffer is mapped to the kernel
36.  * @vaddr:       the kernel mapping if kmap_cnt is not zero
37.  * @dmap_cnt:    number of times the buffer is mapped for dma
38.  * @sg_table:    the sg table for the buffer if dmap_cnt is not zero
39.  */
40. struct ion_buffer {
41.     struct kref ref;
42.     struct rb_node node;
43.     struct ion_device *dev;
44.     struct ion_heap *heap;
45.     unsigned long flags;
46.     size_t size;
47.     union {
```

关闭

```
48.         void *priv_virt;
49.         ion_phys_addr_t priv_phys;
50.     };
51.     struct mutex lock;
52.     int kmap_cnt;
53.     void *vaddr;
54.     int dmap_cnt;
55.     struct sg_table *sg_table;
56.     int umap_cnt;
57.     unsigned int iommu_map_cnt;
58.     struct rb_root iommu_maps;
59.     int marked;
60. };

[cpp]

01. /**
02.  * ion_handle - a client local reference to a buffer
03.  * @ref:         reference count
04.  * @client:       back pointer to the client the buffer resides in
05.  * @buffer:       pointer to the buffer
06.  * @node:         node in the client's handle rbtree
07.  * @kmap_cnt:     count of times this client has mapped to kernel
08.  * @dmap_cnt:     count of times this client has mapped for dma
09.  *
10.  * Modifications to node, map_cnt or mapping should be protected by the
11.  * lock in the client. Other fields are never changed after initialization.
12.  */
13. struct ion_handle {
14.     struct kref ref;
15.     struct ion_client *client;
16.     struct ion_buffer *buffer;
17.     struct rb_node node;
18.     unsigned int kmap_cnt;
19.     unsigned int iommu_map_cnt;
20. };
21.
22. /**
23.  * struct ion_buffer - metadata for a particular buffer
24.  * @ref:         reference count
25.  * @node:         node in the ion_device buffers tree
26.  * @dev:          back pointer to the ion_device
27.  * @heap:         back pointer to the heap the buffer came from
28.  * @flags:        buffer specific flags
29.  * @size:         size of the buffer
30.  * @priv_virt:    private data to the buffer representable as
31.  *                a void *
32.  * @priv_phys:    private data to the buffer representable as
33.  *                an ion_phys_addr_t (and someday a phys_addr_t)
34.  * @lock:         protects the buffers cnt fields
35.  * @kmap_cnt:     number of times the buffer is mapped to the kernel
36.  * @vaddr:        the kernel mapping if kmap_cnt is not zero
37.  * @dmap_cnt:     number of times the buffer is mapped for dma
38.  * @sg_table:     the sg table for the buffer if dmap_cnt is not zero
39.  */
40. struct ion_buffer {
41.     struct kref ref;
42.     struct rb_node node;
43.     struct ion_device *dev;
44.     struct ion_heap *heap;
45.     unsigned long flags;
46.     size_t size;
47.     union {
48.         void *priv_virt;
49.         ion_phys_addr_t priv_phys;
50.     };
51.     struct mutex lock;
52.     int kmap_cnt;
53.     void *vaddr;
54.     int dmap_cnt;
55.     struct sg_table *sg_table;
56.     int umap_cnt;
57.     unsigned int iommu_map_cnt;
58.     struct rb_root iommu_maps;
59.     int marked;
60. };
```

关闭

ION Client :

用户空间和内核空间都可以成为client, 不过创建的方法稍稍有点区别, 先了解下基本的操作流程吧。

内核空间:

先创建client:

```
[cpp] 1. struct ion_client *ion_client_create(struct ion_device *dev,
2. unsigned int heap_mask,
3. const char *name)
```

```
[cpp] 1. struct ion_client *ion_client_create(struct ion_device *dev,
2. unsigned int heap_mask,
3. const char *name)
```

heap_mask: 可以分配的heap type, 如carveout, system heap, iommu等。

高通使用msm_ion_client_create函数封装了下。

有了client之后就可以分配内存:

```
[cpp] 1. struct ion_handle *ion_alloc(struct ion_client *client, size_t len,
2. size_t align, unsigned int flags)
```

```
[cpp] 1. struct ion_handle *ion_alloc(struct ion_client *client, size_t len,
2. size_t align, unsigned int flags)
```

flags: 分配的heap id.

有了handle也就是buffer之后就准备使用了, 不过还是物理地址, 需要map:

```
[cpp] 1. void *ion_map_kernel(struct ion_client *client, struct ion_handle *handle,
2. unsigned long flags)
```

```
[cpp] 1. void *ion_map_kernel(struct ion_client *client, struct ion_handle *handle,
2. unsigned long flags)
```

用户空间:

用户空间如果想使用ION, 也必须先要创建client, 不过它是打开/dev/ion, 实际上它最终也会调用ion_client_create。

不过和内核空间创建client的一点区别是, 用户空间不能选择heap type (使用预订的heap id隐含heap type), 但是内核空间却可以。

另外, 用户空间是通过IOCTL来分配内存的, cmd为ION_IOC_ALLOC。

```
[cpp] 1. ion_fd = open("/dev/ion", O_RDONLY | O_SYNC);
2. ioctl(ion_fd, ION_IOC_ALLOC, alloc);
```

```
[cpp] 1. ion_fd = open("/dev/ion", O_RDONLY | O_SYNC);
2. ioctl(ion_fd, ION_IOC_ALLOC, alloc);
```

alloc为struct ion_allocation_data, len是申请buffer的长度, flags是heap id。

```
[cpp] 1. /**
2.  * struct ion_allocation_data - metadata passed from userspace for allocations
3.  * @len: size of the allocation
4.  * @align: required alignment of the allocation
5.  * @flags: flags passed to heap
6.  * @handle: pointer that will be populated with a cookie to use to refer
7.  * to this allocation
8.  */
```

关闭

```
09.  * Provided by userspace as an argument to the ioctl
10.  */
11.  struct ion_allocation_data {
12.      size_t len;
13.      size_t align;
14.      unsigned int flags;
15.      struct ion_handle *handle;
16.  };

[cpp]

01.  /**
02.   * struct ion_allocation_data - metadata passed from userspace for allocations
03.   * @len:    size of the allocation
04.   * @align:  required alignment of the allocation
05.   * @flags:  flags passed to heap
06.   * @handle: pointer that will be populated with a cookie to use to refer
07.   *         to this allocation
08.   *
09.   * Provided by userspace as an argument to the ioctl
10.   */
11.  struct ion_allocation_data {
12.      size_t len;
13.      size_t align;
14.      unsigned int flags;
15.      struct ion_handle *handle;
16.  };
```

分配好了buffer之后，如果用户空间想使用buffer，先需要mmap。ION是通过先调用IOCTL中的ION_IOC_SHARE/ION_IOC_MAP来得到可以mmap的fd,然后再执行mmap得到bufferaddress。

然后，你也可以将此fd传给另一个进程，如通过binder传递。在另一个进程中通过ION_IOC_IMPORT这个IOCTL来得到这块共享buffer了。

来看一个例子：

```
[cpp] ❏

01.  进程A:
02.  int ionfd = open("/dev/ion", O_RDONLY | O_DSYNC);
03.  alloc_data.len = 0x1000;
04.  alloc_data.align = 0x1000;
05.  alloc_data.flags = ION_HEAP(ION_CP_MM_HEAP_ID);
06.  rc = ioctl(ionfd, ION_IOC_ALLOC, &alloc_data);
07.  fd_data.handle = alloc_data.handle;
08.  rc = ioctl(ionfd, ION_IOC_SHARE, &fd_data);
09.  shared_fd = fd_data.fd;
10.
11.  进程B:
12.  fd_data.fd = shared_fd;
13.  rc = ioctl(ionfd, ION_IOC_IMPORT, &fd_data);

[cpp]

01.  进程A:
02.  int ionfd = open("/dev/ion", O_RDONLY | O_DSYNC);
03.  alloc_data.len = 0x1000;
04.  alloc_data.align = 0x1000;
05.  alloc_data.flags = ION_HEAP(ION_CP_MM_HEAP_ID);
06.  rc = ioctl(ionfd, ION_IOC_ALLOC, &alloc_data);
07.  fd_data.handle = alloc_data.handle;
08.  rc = ioctl(ionfd, ION_IOC_SHARE, &fd_data);
09.  shared_fd = fd_data.fd;
10.
11.  进程B:
12.  fd_data.fd = shared_fd;
13.  rc = ioctl(ionfd, ION_IOC_IMPORT, &fd_data);
```

关闭

从上一篇ION基本概念中，我们了解了heap type, heap id, client, handle以及如何使用，本篇再从原理上分析下ION的运作流程。

MSM8x25Q平台使用的是board-qrd7627.c，ION相关定义如下：

```
[cpp] ❏

01.  /**
```

```
02.  * These heaps are listed in the order they will be allocated.
03.  * Don't swap the order unless you know what you are doing!
04.  */
05.  struct ion_platform_heap msm7627a_heaps[] = {
06.      {
07.          .id = ION_SYSTEM_HEAP_ID,
08.          .type = ION_HEAP_TYPE_SYSTEM,
09.          .name = ION_VMALLOC_HEAP_NAME,
10.      },
11. #ifdef CONFIG_MSM_MULTIMEDIA_USE_ION
12.     /* PMEM_ADSP = CAMERA */
13.     {
14.         .id = ION_CAMERA_HEAP_ID,
15.         .type = CAMERA_HEAP_TYPE,
16.         .name = ION_CAMERA_HEAP_NAME,
17.         .memory_type = ION_EBI_TYPE,
18.         .extra_data = (void *)&co_mm_ion_pdata,
19.         .priv = (void *)&ion_cma_device.dev,
20.     },
21.     /* AUDIO HEAP 1*/
22.     {
23.         .id = ION_AUDIO_HEAP_ID,
24.         .type = ION_HEAP_TYPE_CARVEOUT,
25.         .name = ION_AUDIO_HEAP_NAME,
26.         .memory_type = ION_EBI_TYPE,
27.         .extra_data = (void *)&co_ion_pdata,
28.     },
29.     /* PMEM_MDP = SF */
30.     {
31.         .id = ION_SF_HEAP_ID,
32.         .type = ION_HEAP_TYPE_CARVEOUT,
33.         .name = ION_SF_HEAP_NAME,
34.         .memory_type = ION_EBI_TYPE,
35.         .extra_data = (void *)&co_ion_pdata,
36.     },
37.     /* AUDIO HEAP 2*/
38.     {
39.         .id = ION_AUDIO_HEAP_BL_ID,
40.         .type = ION_HEAP_TYPE_CARVEOUT,
41.         .name = ION_AUDIO_BL_HEAP_NAME,
42.         .memory_type = ION_EBI_TYPE,
43.         .extra_data = (void *)&co_ion_pdata,
44.         .base = BOOTLOADER_BASE_ADDR,
45.     },
46. #endif
47. };
48.
49.
50. static struct ion_co_heap_pdata co_ion_pdata = {
51.     .adjacent_mem_id = INVALID_HEAP_ID,
52.     .align = PAGE_SIZE,
53. };
54.
55. static struct ion_co_heap_pdata co_mm_ion_pdata = {
56.     .adjacent_mem_id = INVALID_HEAP_ID,
57.     .align = PAGE_SIZE,
58. };
59.
60. static u64 msm_dmask = DMA_BIT_MASK(32);
61.
62. static struct platform_device ion_cma_device = {
63.     .name = "ion-cma-device",
64.     .id = -1,
65.     .dev = {
66.         .dma_mask = &msm_dmask,
67.         .coherent_dma_mask = DMA_BIT_MASK(32),
68.     }
69. };
```

[cpp]

```
01. /**
02.  * These heaps are listed in the order they will be allocated.
03.  * Don't swap the order unless you know what you are doing!
04.  */
05.  struct ion_platform_heap msm7627a_heaps[] = {
06.      {
07.          .id = ION_SYSTEM_HEAP_ID,
08.          .type = ION_HEAP_TYPE_SYSTEM,
09.          .name = ION_VMALLOC_HEAP_NAME,
```

关闭

```
10.     },
11.     #ifdef CONFIG_MSM_MULTIMEDIA_USE_ION
12.         /* PMEM_ADSP = CAMERA */
13.         {
14.             .id = ION_CAMERA_HEAP_ID,
15.             .type = CAMERA_HEAP_TYPE,
16.             .name = ION_CAMERA_HEAP_NAME,
17.             .memory_type = ION_EBI_TYPE,
18.             .extra_data = (void *)&co_mm_ion_pdata,
19.             .priv = (void *)&ion_cma_device.dev,
20.         },
21.         /* AUDIO_HEAP_1 */
22.         {
23.             .id = ION_AUDIO_HEAP_ID,
24.             .type = ION_HEAP_TYPE_CARVEOUT,
25.             .name = ION_AUDIO_HEAP_NAME,
26.             .memory_type = ION_EBI_TYPE,
27.             .extra_data = (void *)&co_ion_pdata,
28.         },
29.         /* PMEM_MDP = SF */
30.         {
31.             .id = ION_SF_HEAP_ID,
32.             .type = ION_HEAP_TYPE_CARVEOUT,
33.             .name = ION_SF_HEAP_NAME,
34.             .memory_type = ION_EBI_TYPE,
35.             .extra_data = (void *)&co_ion_pdata,
36.         },
37.         /* AUDIO_HEAP_2 */
38.         {
39.             .id = ION_AUDIO_HEAP_BL_ID,
40.             .type = ION_HEAP_TYPE_CARVEOUT,
41.             .name = ION_AUDIO_BL_HEAP_NAME,
42.             .memory_type = ION_EBI_TYPE,
43.             .extra_data = (void *)&co_ion_pdata,
44.             .base = BOOTLOADER_BASE_ADDR,
45.         },
46.     },
47. #endif
48. };
49.
50. static struct ion_co_heap_pdata co_ion_pdata = {
51.     .adjacent_mem_id = INVALID_HEAP_ID,
52.     .align = PAGE_SIZE,
53. };
54.
55. static struct ion_co_heap_pdata co_mm_ion_pdata = {
56.     .adjacent_mem_id = INVALID_HEAP_ID,
57.     .align = PAGE_SIZE,
58. };
59.
60. static u64 msm_dmask = DMA_BIT_MASK(32);
61.
62. static struct platform_device ion_cma_device = {
63.     .name = "ion-cma-device",
64.     .id = -1,
65.     .dev = {
66.         .dma_mask = &msm_dmask,
67.         .coherent_dma_mask = DMA_BIT_MASK(32),
68.     }
69. };
```

Qualcomm提示了不要轻易调换顺序，因为后面代码处理是将顺序定死了的，一旦你调换了，代码就无法正常运行了。

另外，本系统中只使用了ION_HEAP_TYPE_CARVEOUT和ION_HEAP_TYPE_SYSTEM这两种heap type。

对于ION_HEAP_TYPE_CARVEOUT的内存分配，后面将会发现，其实就是之前讲述过的使用mem pool来分配的。

Platform device如下,在msm_ion.c中用到。

```
[cpp] 10.
11. static struct ion_platform_data ion_pdata = {
12.     .nr = MSM_ION_HEAP_NUM,
13.     .has_outer_cache = 1,
14.     .heaps = msm7627a_heaps,
15. };
```

[关闭](#)

```
06.
07. static struct platform_device ion_dev = {
08.     .name = "ion-msm",
09.     .id = 1,
10.     .dev = { .platform_data = &ion_pdata },
11. };

[cpp]

01. static struct ion_platform_data ion_pdata = {
02.     .nr = MSM_ION_HEAP_NUM,
03.     .has_outer_cache = 1,
04.     .heaps = msm7627a_heaps,
05. };
06.
07. static struct platform_device ion_dev = {
08.     .name = "ion-msm",
09.     .id = 1,
10.     .dev = { .platform_data = &ion_pdata },
11. };
```

ION初始化

转到msm_ion.c, ion.c的某些函数也被重新封装了下.万事都从设备匹配开始:

```
[cpp]  C  ?

01. static struct platform_driver msm_ion_driver = {
02.     .probe = msm_ion_probe,
03.     .remove = msm_ion_remove,
04.     .driver = { .name = "ion-msm" }
05. };
06. static int __init msm_ion_init(void)
07. {
08.     /*调用msm_ion_probe */
09.     return platform_driver_register(&msm_ion_driver);
10. }
11.
12. static int msm_ion_probe(struct platform_device *pdev)
13. {
14.     /*即board-qrd7627a.c中的ion_pdata */
15.     struct ion_platform_data *pdata = pdev->dev.platform_data;
16.     int err;
17.     int i;
18.
19.     /*heap数量*/
20.     num_heaps = pdata->nr;
21.     /*分配struct ion_heap */
22.     heaps = kcalloc(pdata->nr, sizeof(struct ion_heap *), GFP_KERNEL);
23.
24.     if (!heaps) {
25.         err = -ENOMEM;
26.         goto out;
27.     }
28.     /*创建节点, 最终是/dev/ion,供用户空间操作.*/
29.     idev = ion_device_create(NULL);
30.     if (IS_ERR_OR_NULL(idev)) {
31.         err = PTR_ERR(idev);
32.         goto freeheaps;
33.     }
34.     /*最终是根据adjacent_mem_id 是否定义了来分配相邻内存,
35. 我们没用到,忽略此函数.*/
36.     msm_ion_heap_fixup(pdata->heaps, num_heaps);
37.
38.     /* create the heaps as specified in the board file */
39.     for (i = 0; i < num_heaps; i++) {
40.         struct ion_platform_heap *heap_data = &pdata->heaps[i];
41.         /*分配ion*/
42.         msm_ion_allocate(heap_data);
43.
44.         heap_data->has_outer_cache = pdata->has_outer_cache;
45.         /*创建ion heap.*/
46.         heaps[i] = ion_heap_create(heap_data);
47.         if (IS_ERR_OR_NULL(heaps[i])) {
48.             heaps[i] = 0;
49.             continue;
50.         } else {
51.             if (heap_data->size)
52.                 pr_info("ION heap %s created at %lx "
53.                     "with size %x\n", heap_data->name,
```

关闭

```
54.             heap_data->base,
55.             heap_data->size);
56.         else
57.             pr_info("ION heap %s created\n",
58.                 heap_data->name);
59.     }
60.     /*创建的heap添加到idev中,以便后续使用。*/
61.     ion_device_add_heap(idev, heaps[i]);
62. }
63. /*检查heap之间是否有重叠部分*/
64. check_for_heap_overlap(pdata->heaps, num_heaps);
65. platform_set_drvdata(pdev, idev);
66. return 0;
67.
68. freeheaps:
69.     kfree(heaps);
70. out:
71.     return err;
72. }
73.
74. 通过ion_device_create创建/dev/ion节点:
75. struct ion_device *ion_device_create(long (*custom_ioctl)
76.     (struct ion_client *client,
77.     unsigned int cmd,
78.     unsigned long arg))
79. {
80.     struct ion_device *idev;
81.     int ret;
82.
83.     idev = kzalloc(sizeof(struct ion_device), GFP_KERNEL);
84.     if (!idev)
85.         return ERR_PTR(-ENOMEM);
86.     /*是个misc设备*/
87.     idev->dev.minor = MISC_DYNAMIC_MINOR;
88.     /*节点名字为ion*/
89.     idev->dev.name = "ion";
90.     /*fops为ion_fops,所以对ion的操作都会调用ion_fops的函数指针。*/
91.     idev->dev.fops = &ion_fops;
92.     idev->dev.parent = NULL;
93.     ret = misc_register(&idev->dev);
94.     if (ret) {
95.         pr_err("ion: failed to register misc device.\n");
96.         return ERR_PTR(ret);
97.     }
98.     /*创建debugfs目录,路径为/sys/kernel/debug/ion*/
99.     idev->debug_root = debugfs_create_dir("ion", NULL);
100.    if (IS_ERR_OR_NULL(idev->debug_root))
101.        pr_err("ion: failed to create debug files.\n");
102.
103.    idev->custom_ioctl = custom_ioctl;
104.    idev->buffers = RB_ROOT;
105.    mutex_init(&idev->lock);
106.    idev->heaps = RB_ROOT;
107.    idev->clients = RB_ROOT;
108.    /*在ion目录下创建一个check_leaked_fds文件,用来检查Ion的使用是否有内存泄漏。如果申请了ion之后
    不需要使用却没有释放,就会导致memory leak。*/
109.    debugfs_create_file("check_leaked_fds", 0664, idev->debug_root, idev,
110.        &debug_leak_fops);
111.    return idev;
112. }
113.
114. msm_ion_allocate:
115. static void msm_ion_allocate(struct ion_platform_heap *heap)
116. {
117.
118.     if (!heap->base && heap->extra_data) {
119.         unsigned int align = 0;
120.         switch (heap->type) {
121.             /*获取align参数*/
122.             case ION_HEAP_TYPE_CARVEOUT:
123.                 align =
124.                     ((struct ion_co_heap_pdata *) heap->extra_data)->align;
125.                 break;
126.             /*此type我们没使用到。*/
127.             case ION_HEAP_TYPE_CP:
128.                 {
129.                     struct ion_cp_heap_pdata *data =
130.                         (struct ion_cp_heap_pdata *)
131.                         heap->extra_data;
132.                     if (data->reusable) {
```

关闭

```
133.         const struct fmem_data *fmem_info =
134.             fmem_get_info();
135.         heap->base = fmem_info->phys;
136.         data->virt_addr = fmem_info->virt;
137.         pr_info("ION heap %s using FMEM\n", heap->name);
138.     } else if (data->mem_is_fmem) {
139.         const struct fmem_data *fmem_info =
140.             fmem_get_info();
141.         heap->base = fmem_info->phys + fmem_info->size;
142.     }
143.     align = data->align;
144.     break;
145. }
146. default:
147.     break;
148. }
149. if (align && !heap->base) {
150.     /*获取heap的base address.*/
151.     heap->base = msm_ion_get_base(heap->size,
152.         heap->memory_type,
153.         align);
154.     if (!heap->base)
155.         pr_err("%s: could not get memory for heap %s "
156.             "(id %x)\n", __func__, heap->name, heap->id);
157. }
158. }
159. }
160.
161. static unsigned long msm_ion_get_base(unsigned long size, int memory_type,
162.     unsigned int align)
163. {
164.     switch (memory_type) {
165.         /*我们定义的是ebi type, 看见没, 此函数在mem pool中分析过了.
166.         原理就是使用Mempool 来管理分配内存.*/
167.         case ION_EBI_TYPE:
168.             return allocate_contiguous_ebi_nomap(size, align);
169.             break;
170.         case ION_SMI_TYPE:
171.             return allocate_contiguous_memory_nomap(size, MEMTYPE_SMI,
172.                 align);
173.             break;
174.         default:
175.             pr_err("%s: Unknown memory type %d\n", __func__, memory_type);
176.             return 0;
177.     }
178. }
179. ion_heap_create:
180. struct ion_heap *ion_heap_create(struct ion_platform_heap *heap_data)
181. {
182.     struct ion_heap *heap = NULL;
183.     /*根据Heap type调用相应的创建函数.*/
184.     switch (heap_data->type) {
185.         case ION_HEAP_TYPE_SYSTEM_CONTIG:
186.             heap = ion_system_contig_heap_create(heap_data);
187.             break;
188.         case ION_HEAP_TYPE_SYSTEM:
189.             heap = ion_system_heap_create(heap_data);
190.             break;
191.         case ION_HEAP_TYPE_CARVEOUT:
192.             heap = ion_carveout_heap_create(heap_data);
193.             break;
194.         case ION_HEAP_TYPE_IOMMU:
195.             heap = ion_iommu_heap_create(heap_data);
196.             break;
197.         case ION_HEAP_TYPE_CP:
198.             heap = ion_cp_heap_create(heap_data);
199.             break;
200. #ifdef CONFIG_CMA
201.         case ION_HEAP_TYPE_DMA:
202.             heap = ion_cma_heap_create(heap_data);
203.             break;
204. #endif
205.         default:
206.             pr_err("%s: Invalid heap type %d\n", __func__,
207.                 heap_data->type);
208.             return ERR_PTR(-EINVAL);
209.     }
210.
211.     if (IS_ERR_OR_NULL(heap)) {
212.         pr_err("%s: error creating heap %s type %d base %lu size %u\n",
```

关闭

```

213.         __func__, heap_data->name, heap_data->type,
214.         heap_data->base, heap_data->size);
215.         return ERR_PTR(-EINVAL);
216.     }
217.     /*保存Heap的name,id和私有数据。*/
218.     heap->name = heap_data->name;
219.     heap->id = heap_data->id;
220.     heap->priv = heap_data->priv;
221.     return heap;
222. }

[cpp]

01. static struct platform_driver msm_ion_driver = {
02.     .probe = msm_ion_probe,
03.     .remove = msm_ion_remove,
04.     .driver = { .name = "ion-msm" }
05. };
06. static int __init msm_ion_init(void)
07. {
08.     /*调用msm_ion_probe */
09.     return platform_driver_register(&msm_ion_driver);
10. }
11.
12. static int msm_ion_probe(struct platform_device *pdev)
13. {
14.     /*即board-qrd7627a.c中的ion_pdata */
15.     struct ion_platform_data *pdata = pdev->dev.platform_data;
16.     int err;
17.     int i;
18.
19.     /*heap数量*/
20.     num_heaps = pdata->nr;
21.     /*分配struct ion_heap */
22.     heaps = kcalloc(pdata->nr, sizeof(struct ion_heap *), GFP_KERNEL);
23.
24.     if (!heaps) {
25.         err = -ENOMEM;
26.         goto out;
27.     }
28.     /*创建节点, 最终是/dev/ion, 供用户空间操作。*/
29.     idev = ion_device_create(NULL);
30.     if (IS_ERR_OR_NULL(idev)) {
31.         err = PTR_ERR(idev);
32.         goto freeheaps;
33.     }
34.     /*最终是根据adjacent_mem_id 是否定义了来分配相邻内存,
35. 我们没用到, 忽略此函数。*/
36.     msm_ion_heap_fixup(pdata->heaps, num_heaps);
37.
38.     /* create the heaps as specified in the board file */
39.     for (i = 0; i < num_heaps; i++) {
40.         struct ion_platform_heap *heap_data = &pdata->heaps[i];
41.         /*分配ion*/
42.         msm_ion_allocate(heap_data);
43.
44.         heap_data->has_outer_cache = pdata->has_outer_cache;
45.         /*创建ion heap。*/
46.         heaps[i] = ion_heap_create(heap_data);
47.         if (IS_ERR_OR_NULL(heaps[i])) {
48.             heaps[i] = 0;
49.             continue;
50.         } else {
51.             if (heap_data->size)
52.                 pr_info("ION heap %s created at %lx "
53.                     "with size %x\n", heap_data->name,
54.                     heap_data->base,
55.                     heap_data->size);
56.             else
57.                 pr_info("ION heap %s created\n",
58.                     heap_data->name);
59.         }
60.         /*创建的heap添加到idev中, 以便后续使用。*/
61.         ion_device_add_heap(idev, heaps[i]);
62.     }
63.     /*检查heap之间是否有重叠部分*/
64.     check_for_heap_overlap(pdata->heaps, num_heaps);
65.     platform_set_drvdata(pdev, idev);
66.     return 0;
67. }

```

关闭


```
68.     freeheaps:
69.         kfree(heaps);
70.     out:
71.         return err;
72.     }
73.
74. 通过ion_device_create创建/dev/ion节点:
75.     struct ion_device *ion_device_create(long (*custom_ioctl)
76.         (struct ion_client *client,
77.          unsigned int cmd,
78.          unsigned long arg))
79.     {
80.         struct ion_device *idev;
81.         int ret;
82.
83.         idev = kzalloc(sizeof(struct ion_device), GFP_KERNEL);
84.         if (!idev)
85.             return ERR_PTR(-ENOMEM);
86.         /*是个misc设备*/
87.         idev->dev.minor = MISC_DYNAMIC_MINOR;
88.         /*节点名字为ion*/
89.         idev->dev.name = "ion";
90.         /*fops为ion_fops,所以对ion的操作都会调用ion_fops的函数指针。*/
91.         idev->dev.fops = &ion_fops;
92.         idev->dev.parent = NULL;
93.         ret = misc_register(&idev->dev);
94.         if (ret) {
95.             pr_err("ion: failed to register misc device.\n");
96.             return ERR_PTR(ret);
97.         }
98.         /*创建debugfs目录, 路径为/sys/kernel/debug/ion*/
99.         idev->debug_root = debugfs_create_dir("ion", NULL);
100.        if (IS_ERR_OR_NULL(idev->debug_root))
101.            pr_err("ion: failed to create debug files.\n");
102.
103.        idev->custom_ioctl = custom_ioctl;
104.        idev->buffers = RB_ROOT;
105.        mutex_init(&idev->lock);
106.        idev->heaps = RB_ROOT;
107.        idev->clients = RB_ROOT;
108.        /*在ion目录下创建一个check_leaked_fds文件, 用来检查Ion的使用是否有内存泄漏。如果申请了ion之后
不需要使用却没有释放, 就会导致memory leak。*/
109.        debugfs_create_file("check_leaked_fds", 0664, idev->debug_root, idev,
110.                            &debug_leak_fops);
111.        return idev;
112.    }
113.
114.    msm_ion_allocate:
115.    static void msm_ion_allocate(struct ion_platform_heap *heap)
116.    {
117.
118.        if (!heap->base && heap->extra_data) {
119.            unsigned int align = 0;
120.            switch (heap->type) {
121.                /*获取align参数*/
122.                case ION_HEAP_TYPE_CARVEOUT:
123.                    align =
124.                        ((struct ion_co_heap_pdata *) heap->extra_data)->align;
125.                    break;
126.                /*此type我们没使用到。*/
127.                case ION_HEAP_TYPE_CP:
128.                    {
129.                        struct ion_cp_heap_pdata *data =
130.                            (struct ion_cp_heap_pdata *)
131.                            heap->extra_data;
132.                        if (data->reusable) {
133.                            const struct fmem_data *fmem_info =
134.                                fmem_get_info();
135.                            heap->base = fmem_info->phys;
136.                            data->virt_addr = fmem_info->virt;
137.                            pr_info("ION heap %s using FMEM\n", heap->name);
138.                        } else if (data->mem_is_fmem) {
139.                            const struct fmem_data *fmem_info =
140.                                fmem_get_info();
141.                            heap->base = fmem_info->phys + fmem_info->size;
142.                        }
143.                        align = data->align;
144.                        break;
145.                    }
146.                default:
```

关闭

```
147.         break;
148.     }
149.     if (align && !heap->base) {
150.         /*获取heap的base address。*/
151.         heap->base = msm_ion_get_base(heap->size,
152.                                     heap->memory_type,
153.                                     align);
154.         if (!heap->base)
155.             pr_err("%s: could not get memory for heap %s "
156.                   "(id %x)\n", __func__, heap->name, heap->id);
157.     }
158. }
159. }
160.
161. static unsigned long msm_ion_get_base(unsigned long size, int memory_type,
162.                                       unsigned int align)
163. {
164.     switch (memory_type) {
165.         /*我们定义的是ebi_type, 看见没, 此函数在mem pool中分析过了。
166.         原理就是使用Mempool 来管理分配内存。*/
167.         case ION_EBI_TYPE:
168.             return allocate_contiguous_ebi_nomap(size, align);
169.             break;
170.         case ION_SMI_TYPE:
171.             return allocate_contiguous_memory_nomap(size, MEMTYPE_SMI,
172.                                                     align);
173.             break;
174.         default:
175.             pr_err("%s: Unknown memory type %d\n", __func__, memory_type);
176.             return 0;
177.     }
178. }
179. ion_heap_create:
180. struct ion_heap *ion_heap_create(struct ion_platform_heap *heap_data)
181. {
182.     struct ion_heap *heap = NULL;
183.     /*根据Heap type调用相应的创建函数。*/
184.     switch (heap_data->type) {
185.         case ION_HEAP_TYPE_SYSTEM_CONTIG:
186.             heap = ion_system_contig_heap_create(heap_data);
187.             break;
188.         case ION_HEAP_TYPE_SYSTEM:
189.             heap = ion_system_heap_create(heap_data);
190.             break;
191.         case ION_HEAP_TYPE_CARVEOUT:
192.             heap = ion_carveout_heap_create(heap_data);
193.             break;
194.         case ION_HEAP_TYPE_IOMMU:
195.             heap = ion_iommu_heap_create(heap_data);
196.             break;
197.         case ION_HEAP_TYPE_CP:
198.             heap = ion_cp_heap_create(heap_data);
199.             break;
200. #ifdef CONFIG_CMA
201.         case ION_HEAP_TYPE_DMA:
202.             heap = ion_cma_heap_create(heap_data);
203.             break;
204. #endif
205.         default:
206.             pr_err("%s: Invalid heap type %d\n", __func__,
207.                   heap_data->type);
208.             return ERR_PTR(-EINVAL);
209.     }
210.
211.     if (IS_ERR_OR_NULL(heap)) {
212.         pr_err("%s: error creating heap %s type %d b:
213.             __func__, heap_data->name, heap_data->type,
214.             heap_data->base, heap_data->size);
215.         return ERR_PTR(-EINVAL);
216.     }
217.     /*保存Heap的name,id和私有数据。*/
218.     heap->name = heap_data->name;
219.     heap->id = heap_data->id;
220.     heap->priv = heap_data->priv;
221.     return heap;
222. }
```

关闭

从下面的代码可以得知, ION_HEAP_TYPE_SYSTEM_CONTIG使用kmalloc创建的, ION_HEAP_TYPE_SYSTEM使用的是vmalloc,而ion_carveout_heap_create就是系统预分配了一片内存区域

供其使用。Ion在申请使用的时候，会根据当前的type来操作各自的heap->ops。分别看下三个函数：

```
[cpp]
01. struct ion_heap *ion_system_contig_heap_create(struct ion_platform_heap *pheap)
02. {
03.     struct ion_heap *heap;
04.
05.     heap = kzalloc(sizeof(struct ion_heap), GFP_KERNEL);
06.     if (!heap)
07.         return ERR_PTR(-ENOMEM);
08.     /*使用的是kmalloc_ops, 上篇有提到哦*/
09.     heap->ops = &kmalloc_ops;
10.     heap->type = ION_HEAP_TYPE_SYSTEM_CONTIG;
11.     system_heap_contig_has_outer_cache = pheap->has_outer_cache;
12.     return heap;
13. }
14. struct ion_heap *ion_system_heap_create(struct ion_platform_heap *pheap)
15. {
16.     struct ion_heap *heap;
17.
18.     heap = kzalloc(sizeof(struct ion_heap), GFP_KERNEL);
19.     if (!heap)
20.         return ERR_PTR(-ENOMEM);
21.     /*和上面函数的区别仅在于ops*/
22.     heap->ops = &vmalloc_ops;
23.     heap->type = ION_HEAP_TYPE_SYSTEM;
24.     system_heap_has_outer_cache = pheap->has_outer_cache;
25.     return heap;
26. }
27. struct ion_heap *ion_carveout_heap_create(struct ion_platform_heap *heap_data)
28. {
29.     struct ion_carveout_heap *carveout_heap;
30.     int ret;
31.
32.     carveout_heap = kzalloc(sizeof(struct ion_carveout_heap), GFP_KERNEL);
33.     if (!carveout_heap)
34.         return ERR_PTR(-ENOMEM);
35.     /* 重新创建一个新的pool, 这里有点想不通的是为什么不直接使用全局的mempools呢? */
36.     carveout_heap->pool = gen_pool_create(12, -1);
37.     if (!carveout_heap->pool) {
38.         kfree(carveout_heap);
39.         return ERR_PTR(-ENOMEM);
40.     }
41.     carveout_heap->base = heap_data->base;
42.     ret = gen_pool_add(carveout_heap->pool, carveout_heap->base,
43.         heap_data->size, -1);
44.     if (ret < 0) {
45.         gen_pool_destroy(carveout_heap->pool);
46.         kfree(carveout_heap);
47.         return ERR_PTR(-EINVAL);
48.     }
49.     carveout_heap->heap.ops = &carveout_heap_ops;
50.     carveout_heap->heap.type = ION_HEAP_TYPE_CARVEOUT;
51.     carveout_heap->allocated_bytes = 0;
52.     carveout_heap->total_size = heap_data->size;
53.     carveout_heap->has_outer_cache = heap_data->has_outer_cache;
54.
55.     if (heap_data->extra_data) {
56.         struct ion_co_heap_pdata *extra_data =
57.             heap_data->extra_data;
58.
59.         if (extra_data->setup_region)
60.             carveout_heap->bus_id = extra_data->setup_region();
61.         if (extra_data->request_region)
62.             carveout_heap->request_region =
63.                 extra_data->request_region;
64.         if (extra_data->release_region)
65.             carveout_heap->release_region =
66.                 extra_data->release_region;
67.     }
68.     return &carveout_heap->heap;
69. }
70.
71. Heap创建完成，然后保存到idev中：
72. void ion_device_add_heap(struct ion_device *dev, struct ion_heap *heap)
73. {
74.     struct rb_node **p = &dev->heaps.rb_node;
75.     struct rb_node *parent = NULL;
```

关闭

```
76.     struct ion_heap *entry;
77.
78.     if (!heap->ops->allocate || !heap->ops->free || !heap->ops->map_dma ||
79.         !heap->ops->unmap_dma)
80.         pr_err("%s: can not add heap with invalid ops struct.\n",
81.             __func__);
82.
83.     heap->dev = dev;
84.     mutex_lock(&dev->lock);
85.     while (*p) {
86.         parent = *p;
87.         entry = rb_entry(parent, struct ion_heap, node);
88.
89.         if (heap->id < entry->id) {
90.             p = &(*p)->rb_left;
91.         } else if (heap->id > entry->id) {
92.             p = &(*p)->rb_right;
93.         } else {
94.             pr_err("%s: can not insert multiple heaps with "
95.                 "id %d\n", __func__, heap->id);
96.             goto end;
97.         }
98.     }
99.     /*使用红黑树保存*/
100.    rb_link_node(&heap->node, parent, p);
101.    rb_insert_color(&heap->node, &dev->heaps);
102.    /*以heap name创建fs,位于ion目录下。如vamlloc, camera_preview, audio 等*/
103.    debugfs_create_file(heap->name, 0664, dev->debug_root, heap,
104.        &debug_heap_fops);
105.    end:
106.    mutex_unlock(&dev->lock);
107. }
```

[cpp]

```
01. struct ion_heap *ion_system_contig_heap_create(struct ion_platform_heap *pheap)
02. {
03.     struct ion_heap *heap;
04.
05.     heap = kzalloc(sizeof(struct ion_heap), GFP_KERNEL);
06.     if (!heap)
07.         return ERR_PTR(-ENOMEM);
08.     /*使用的是kmalloc_ops, 上篇有提到哦*/
09.     heap->ops = &kmalloc_ops;
10.     heap->type = ION_HEAP_TYPE_SYSTEM_CONTIG;
11.     system_heap_contig_has_outer_cache = pheap->has_outer_cache;
12.     return heap;
13. }
14. struct ion_heap *ion_system_heap_create(struct ion_platform_heap *pheap)
15. {
16.     struct ion_heap *heap;
17.
18.     heap = kzalloc(sizeof(struct ion_heap), GFP_KERNEL);
19.     if (!heap)
20.         return ERR_PTR(-ENOMEM);
21.     /*和上面函数的区别仅在于ops*/
22.     heap->ops = &vmalloc_ops;
23.     heap->type = ION_HEAP_TYPE_SYSTEM;
24.     system_heap_has_outer_cache = pheap->has_outer_cache;
25.     return heap;
26. }
27. struct ion_heap *ion_carveout_heap_create(struct ion_platform_heap *heap_data)
28. {
29.     struct ion_carveout_heap *carveout_heap;
30.     int ret;
31.
32.     carveout_heap = kzalloc(sizeof(struct ion_carveout_heap), GFP_KERNEL);
33.     if (!carveout_heap)
34.         return ERR_PTR(-ENOMEM);
35.     /*重新创建一个新的pool, 这里有点想不通的是为什么不直接使用全局的mempools呢?*/
36.     carveout_heap->pool = gen_pool_create(12, -1);
37.     if (!carveout_heap->pool) {
38.         kfree(carveout_heap);
39.         return ERR_PTR(-ENOMEM);
40.     }
41.     carveout_heap->base = heap_data->base;
42.     ret = gen_pool_add(carveout_heap->pool, carveout_heap->base,
43.         heap_data->size, -1);
44.     if (ret < 0) {
45.         gen_pool_destroy(carveout_heap->pool);
```

关闭

```
46.         kfree(carveout_heap);
47.         return ERR_PTR(-EINVAL);
48.     }
49.     carveout_heap->heap.ops = &carveout_heap_ops;
50.     carveout_heap->heap.type = ION_HEAP_TYPE_CARVEOUT;
51.     carveout_heap->allocated_bytes = 0;
52.     carveout_heap->total_size = heap_data->size;
53.     carveout_heap->has_outer_cache = heap_data->has_outer_cache;
54.
55.     if (heap_data->extra_data) {
56.         struct ion_co_heap_pdata *extra_data =
57.             heap_data->extra_data;
58.
59.         if (extra_data->setup_region)
60.             carveout_heap->bus_id = extra_data->setup_region();
61.         if (extra_data->request_region)
62.             carveout_heap->request_region =
63.                 extra_data->request_region;
64.         if (extra_data->release_region)
65.             carveout_heap->release_region =
66.                 extra_data->release_region;
67.     }
68.     return &carveout_heap->heap;
69. }
70.
71. Heap创建完成，然后保存到idev中：
72. void ion_device_add_heap(struct ion_device *dev, struct ion_heap *heap)
73. {
74.     struct rb_node **p = &dev->heaps.rb_node;
75.     struct rb_node *parent = NULL;
76.     struct ion_heap *entry;
77.
78.     if (!heap->ops->allocate || !heap->ops->free || !heap->ops->map_dma ||
79.         !heap->ops->unmap_dma)
80.         pr_err("%s: can not add heap with invalid ops struct.\n",
81.             __func__);
82.
83.     heap->dev = dev;
84.     mutex_lock(&dev->lock);
85.     while (*p) {
86.         parent = *p;
87.         entry = rb_entry(parent, struct ion_heap, node);
88.
89.         if (heap->id < entry->id) {
90.             p = &(*p)->rb_left;
91.         } else if (heap->id > entry->id) {
92.             p = &(*p)->rb_right;
93.         } else {
94.             pr_err("%s: can not insert multiple heaps with "
95.                 "id %d\n", __func__, heap->id);
96.             goto end;
97.         }
98.     }
99.     /*使用红黑树保存*/
100.    rb_link_node(&heap->node, parent, p);
101.    rb_insert_color(&heap->node, &dev->heaps);
102.    /*以heap_name创建fs,位于ion目录下。如vamlloc, camera_preview, audio 等*/
103.    debugfs_create_file(heap->name, 0664, dev->debug_root, heap,
104.        &debug_heap_fops);
105.    end:
106.    mutex_unlock(&dev->lock);
107. }
```

到此，ION初始化已经完成了。接下来该如何使用呢？嗯，通过前面创建的misc设备也就是idev了！还记得里面有个fops为ion_fops吗？先来看下用户空间如何使用ION，最后看内核空

[关闭](#)

ION用户空间使用

```
[cpp] 18
01. Ion_fops结构如下：
02. static const struct file_operations ion_fops = {
03.     .owner          = THIS_MODULE,
04.     .open           = ion_open,
05.     .release        = ion_release,
06.     .unlocked_ioctl = ion_ioctl,
07. };
08.
09. 用户空间都是通过ioctl来控制。先看ion_open.
```

```
10.
11. static int ion_open(struct inode *inode, struct file *file)
12. {
13.     struct miscdevice *miscdev = file->private_data;
14.     struct ion_device *dev = container_of(miscdev, struct ion_device, dev);
15.     struct ion_client *client;
16.     char debug_name[64];
17.
18.     pr_debug("%s: %d\n", __func__, __LINE__);
19.     snprintf(debug_name, 64, "%u", task_pid_nr(current->group_leader));
20.     /*根据idev和task pid为name创建ion client*/
21.     client = ion_client_create(dev, -1, debug_name);
22.     if (IS_ERR_OR_NULL(client))
23.         return PTR_ERR(client);
24.     file->private_data = client;
25.
26.     return 0;
27. }
```

[cpp]

01. Ion_fops结构如下：

```
02. static const struct file_operations ion_fops = {
03.     .owner          = THIS_MODULE,
04.     .open           = ion_open,
05.     .release        = ion_release,
06.     .unlocked_ioctl = ion_ioctl,
07. };
08.
```

09. 用户空间都是通过ioctl来控制。先看ion_open.

```
10.
11. static int ion_open(struct inode *inode, struct file *file)
12. {
13.     struct miscdevice *miscdev = file->private_data;
14.     struct ion_device *dev = container_of(miscdev, struct ion_device, dev);
15.     struct ion_client *client;
16.     char debug_name[64];
17.
18.     pr_debug("%s: %d\n", __func__, __LINE__);
19.     snprintf(debug_name, 64, "%u", task_pid_nr(current->group_leader));
20.     /*根据idev和task pid为name创建ion client*/
21.     client = ion_client_create(dev, -1, debug_name);
22.     if (IS_ERR_OR_NULL(client))
23.         return PTR_ERR(client);
24.     file->private_data = client;
25.
26.     return 0;
27. }
```

前一篇文章有说到，要使用ION，必须要先创建ion_client，因此用户空间在open ion的时候创建了client.

[cpp]



```
01. struct ion_client *ion_client_create(struct ion_device *dev,
02.     unsigned int heap_mask,
03.     const char *name)
04. {
05.     struct ion_client *client;
06.     struct task_struct *task;
07.     struct rb_node **p;
08.     struct rb_node *parent = NULL;
09.     struct ion_client *entry;
10.     pid_t pid;
11.     unsigned int name_len;
12.
13.     if (!name) {
14.         pr_err("%s: Name cannot be null\n", __func__);
15.         return ERR_PTR(-EINVAL);
16.     }
17.     name_len = strlen(name, 64);
18.
19.     get_task_struct(current->group_leader);
20.     task_lock(current->group_leader);
21.     pid = task_pid_nr(current->group_leader);
22.     /* don't bother to store task struct for kernel threads,
23.        they can't be killed anyway */
24.     if (current->group_leader->flags & PF_KTHREAD) {
25.         put_task_struct(current->group_leader);
26.         task = NULL;
```

关闭

```

27.     } else {
28.         task = current->group_leader;
29.     }
30.     task_unlock(current->group_leader);
31.     /*分配ion client struct.*/
32.     client = kzalloc(sizeof(struct ion_client), GFP_KERNEL);
33.     if (!client) {
34.         if (task)
35.             put_task_struct(current->group_leader);
36.         return ERR_PTR(-ENOMEM);
37.     }
38.     /*下面就是保存一系列参数了。*/
39.     client->dev = dev;
40.     client->handles = RB_ROOT;
41.     mutex_init(&client->lock);
42.
43.     client->name = kzalloc(name_len+1, GFP_KERNEL);
44.     if (!client->name) {
45.         put_task_struct(current->group_leader);
46.         kfree(client);
47.         return ERR_PTR(-ENOMEM);
48.     } else {
49.         strcpy(client->name, name, name_len+1);
50.     }
51.
52.     client->heap_mask = heap_mask;
53.     client->task = task;
54.     client->pid = pid;
55.
56.     mutex_lock(&dev->lock);
57.     p = &dev->clients.rb_node;
58.     while (*p) {
59.         parent = *p;
60.         entry = rb_entry(parent, struct ion_client, node);
61.
62.         if (client < entry)
63.             p = &(*p)->rb_left;
64.         else if (client > entry)
65.             p = &(*p)->rb_right;
66.     }
67.     /*当前client添加到idev的clients根树上去。*/
68.     rb_link_node(&client->node, parent, p);
69.     rb_insert_color(&client->node, &dev->clients);
70.
71.     /*在ION先创建的文件名字是以pid命名的。*/
72.     client->debug_root = debugfs_create_file(name, 0664,
73.         dev->debug_root, client,
74.         &debug_client_fops);
75.     mutex_unlock(&dev->lock);
76.
77.     return client;
78. }

```

[cpp]

```

01. struct ion_client *ion_client_create(struct ion_device *dev,
02.     unsigned int heap_mask,
03.     const char *name)
04. {
05.     struct ion_client *client;
06.     struct task_struct *task;
07.     struct rb_node **p;
08.     struct rb_node *parent = NULL;
09.     struct ion_client *entry;
10.     pid_t pid;
11.     unsigned int name_len;
12.
13.     if (!name) {
14.         pr_err("%s: Name cannot be null\n", __func__);
15.         return ERR_PTR(-EINVAL);
16.     }
17.     name_len = strlen(name, 64);
18.
19.     get_task_struct(current->group_leader);
20.     task_lock(current->group_leader);
21.     pid = task_pid_nr(current->group_leader);
22.     /* don't bother to store task struct for kernel threads,
23.        they can't be killed anyway */
24.     if (current->group_leader->flags & PF_KTHREAD) {
25.         put_task_struct(current->group_leader);

```

关闭

```
26.         task = NULL;
27.     } else {
28.         task = current->group_leader;
29.     }
30.     task_unlock(current->group_leader);
31.     /*分配ion client struct.*/
32.     client = kzalloc(sizeof(struct ion_client), GFP_KERNEL);
33.     if (!client) {
34.         if (task)
35.             put_task_struct(current->group_leader);
36.         return ERR_PTR(-ENOMEM);
37.     }
38.     /*下面就是保存一系列参数了。*/
39.     client->dev = dev;
40.     client->handles = RB_ROOT;
41.     mutex_init(&client->lock);
42.
43.     client->name = kzalloc(name_len+1, GFP_KERNEL);
44.     if (!client->name) {
45.         put_task_struct(current->group_leader);
46.         kfree(client);
47.         return ERR_PTR(-ENOMEM);
48.     } else {
49.         strcpy(client->name, name, name_len+1);
50.     }
51.
52.     client->heap_mask = heap_mask;
53.     client->task = task;
54.     client->pid = pid;
55.
56.     mutex_lock(&dev->lock);
57.     p = &dev->clients.rb_node;
58.     while (*p) {
59.         parent = *p;
60.         entry = rb_entry(parent, struct ion_client, node);
61.
62.         if (client < entry)
63.             p = &(*p)->rb_left;
64.         else if (client > entry)
65.             p = &(*p)->rb_right;
66.     }
67.     /*当前client添加到idev的clients根树上去。*/
68.     rb_link_node(&client->node, parent, p);
69.     rb_insert_color(&client->node, &dev->clients);
70.
71.     /*在ION先创建的文件名字是以pid命名的。*/
72.     client->debug_root = debugfs_create_file(name, 0664,
73.                                              dev->debug_root, client,
74.                                              &debug_client_fops);
75.     mutex_unlock(&dev->lock);
76.
77.     return client;
78. }
```

有了client之后，用户程序就可以开始申请分配ION buffer了！通过ioctl命令实现。

ion_ioctl函数有若干个cmd，ION_IOC_ALLOC和ION_IOC_FREE相对应，表示申请和释放buffer。用户空间程序使用前要先调用ION_IOC_MAP才能得到buffer address，而ION_IOC_IMPORT是为了将这块内存共享给用户空间另一个进程。

```
[cpp] C {}
01. static long ion_ioctl(struct file *filp, unsigned int cmd, unsigned long arg)
02. {
03.     struct ion_client *client = filp->private_data;
04.
05.     switch (cmd) {
06.     case ION_IOC_ALLOC:
07.     {
08.         struct ion_allocation_data data;
09.
10.         if (copy_from_user(&data, (void __user *)arg, sizeof(data)))
11.             return -EFAULT;
12.         /*分配buffer.*/
13.         data.handle = ion_alloc(client, data.len, data.align,
14.                                data.flags);
15.
16.         if (IS_ERR(data.handle))
17.             return PTR_ERR(data.handle);
```

关闭


```
18.
19.         if (copy_to_user((void __user *)arg, &data, sizeof(data))) {
20.             ion_free(client, data.handle);
21.             return -EFAULT;
22.         }
23.         break;
24.     }
25. case ION_IOC_FREE:
26.     {
27.         struct ion_handle_data data;
28.         bool valid;
29.
30.         if (copy_from_user(&data, (void __user *)arg,
31.             sizeof(struct ion_handle_data)))
32.             return -EFAULT;
33.         mutex_lock(&client->lock);
34.         valid = ion_handle_validate(client, data.handle);
35.         mutex_unlock(&client->lock);
36.         if (!valid)
37.             return -EINVAL;
38.         ion_free(client, data.handle);
39.         break;
40.     }
41. case ION_IOC_MAP:
42. case ION_IOC_SHARE:
43.     {
44.         struct ion_fd_data data;
45.         int ret;
46.         if (copy_from_user(&data, (void __user *)arg, sizeof(data)))
47.             return -EFAULT;
48.         /*判断当前cmd是否被调用过了, 调用过就返回, 否则设置flags.*/
49.         ret = ion_share_set_flags(client, data.handle, filp->f_flags);
50.         if (ret)
51.             return ret;
52.
53.         data.fd = ion_share_dma_buf(client, data.handle);
54.         if (copy_to_user((void __user *)arg, &data, sizeof(data)))
55.             return -EFAULT;
56.         if (data.fd < 0)
57.             return data.fd;
58.         break;
59.     }
60. case ION_IOC_IMPORT:
61.     {
62.         struct ion_fd_data data;
63.         int ret = 0;
64.         if (copy_from_user(&data, (void __user *)arg,
65.             sizeof(struct ion_fd_data)))
66.             return -EFAULT;
67.         data.handle = ion_import_dma_buf(client, data.fd);
68.         if (IS_ERR(data.handle))
69.             data.handle = NULL;
70.         if (copy_to_user((void __user *)arg, &data,
71.             sizeof(struct ion_fd_data)))
72.             return -EFAULT;
73.         if (ret < 0)
74.             return ret;
75.         break;
76.     }
77. case ION_IOC_CUSTOM:
78.     __snip
79.     case ION_IOC_CLEAN_CACHES:
80.     case ION_IOC_INV_CACHES:
81.     case ION_IOC_CLEAN_INV_CACHES:
82.     __snip
83.     case ION_IOC_GET_FLAGS:
84.     __snip
85.     default:
86.         return -ENOTTY;
87.     }
88.     return 0;
89. }
```

[cpp]

```
01. static long ion_ioctl(struct file *filp, unsigned int cmd, unsigned long arg)
02. {
03.     struct ion_client *client = filp->private_data;
04.
05.     switch (cmd) {
```

关闭

```
06.     case ION_IOC_ALLOC:
07.     {
08.         struct ion_allocation_data data;
09.
10.         if (copy_from_user(&data, (void __user *)arg, sizeof(data)))
11.             return -EFAULT;
12.         /*分配buffer.*/
13.         data.handle = ion_alloc(client, data.len, data.align,
14.                                 data.flags);
15.
16.         if (IS_ERR(data.handle))
17.             return PTR_ERR(data.handle);
18.
19.         if (copy_to_user((void __user *)arg, &data, sizeof(data))) {
20.             ion_free(client, data.handle);
21.             return -EFAULT;
22.         }
23.         break;
24.     }
25.     case ION_IOC_FREE:
26.     {
27.         struct ion_handle_data data;
28.         bool valid;
29.
30.         if (copy_from_user(&data, (void __user *)arg,
31.                             sizeof(struct ion_handle_data)))
32.             return -EFAULT;
33.         mutex_lock(&client->lock);
34.         valid = ion_handle_validate(client, data.handle);
35.         mutex_unlock(&client->lock);
36.         if (!valid)
37.             return -EINVAL;
38.         ion_free(client, data.handle);
39.         break;
40.     }
41.     case ION_IOC_MAP:
42.     case ION_IOC_SHARE:
43.     {
44.         struct ion_fd_data data;
45.         int ret;
46.         if (copy_from_user(&data, (void __user *)arg, sizeof(data)))
47.             return -EFAULT;
48.         /*判断当前cmd是否被调用过了, 调用过就返回, 否则设置flags.*/
49.         ret = ion_share_set_flags(client, data.handle, filp->f_flags);
50.         if (ret)
51.             return ret;
52.
53.         data.fd = ion_share_dma_buf(client, data.handle);
54.         if (copy_to_user((void __user *)arg, &data, sizeof(data)))
55.             return -EFAULT;
56.         if (data.fd < 0)
57.             return data.fd;
58.         break;
59.     }
60.     case ION_IOC_IMPORT:
61.     {
62.         struct ion_fd_data data;
63.         int ret = 0;
64.         if (copy_from_user(&data, (void __user *)arg,
65.                             sizeof(struct ion_fd_data)))
66.             return -EFAULT;
67.         data.handle = ion_import_dma_buf(client, data.fd);
68.         if (IS_ERR(data.handle))
69.             data.handle = NULL;
70.         if (copy_to_user((void __user *)arg, &data,
71.                             sizeof(struct ion_fd_data)))
72.             return -EFAULT;
73.         if (ret < 0)
74.             return ret;
75.         break;
76.     }
77.     case ION_IOC_CUSTOM:
78.     --snip
79.     case ION_IOC_CLEAN_CACHES:
80.     case ION_IOC_INV_CACHES:
81.     case ION_IOC_CLEAN_INV_CACHES:
82.     --snip
83.     case ION_IOC_GET_FLAGS:
84.     --snip
85.     default:
```

关闭

```
86.         return -ENOTTY;
87.     }
88.     return 0;
89. }
```

下面分小节说明分配和共享的原理。

ION_IOC_ALLOC

```
[cpp] C {}

01. struct ion_handle *ion_alloc(struct ion_client *client, size_t len,
02.                             size_t align, unsigned int flags)
03. {
04.     --snip
05.
06.     mutex_lock(&dev->lock);
07.     /*循环遍历当前Heap链表。*/
08.     for (n = rb_first(&dev->heaps); n != NULL; n = rb_next(n)) {
09.         struct ion_heap *heap = rb_entry(n, struct ion_heap, node);
10.         /*只有heap type和id都符合才去创建buffer。*/
11.         /* if the client doesn't support this heap type */
12.         if (!(1 <= heap->type) & client->heap_mask))
13.             continue;
14.         /* if the caller didn't specify this heap type */
15.         if (!(1 <= heap->id) & flags))
16.             continue;
17.         /* Do not allow un-secure heap if secure is specified */
18.         if (secure_allocation && (heap->type != ION_HEAP_TYPE_CP))
19.             continue;
20.         buffer = ion_buffer_create(heap, dev, len, align, flags);
21.     --snip
22.     }
23.     mutex_unlock(&dev->lock);
24.
25.     --snip
26.     /*创建了buffer之后,就相应地创建handle来管理buffer。*/
27.     handle = ion_handle_create(client, buffer);
28.
29.     --snip
30. }
31.
32. 找到Heap之后调用ion_buffer_create:
33. static struct ion_buffer *ion_buffer_create(struct ion_heap *heap,
34.                                             struct ion_device *dev,
35.                                             unsigned long len,
36.                                             unsigned long align,
37.                                             unsigned long flags)
38. {
39.     struct ion_buffer *buffer;
40.     struct sg_table *table;
41.     int ret;
42.     /*分配struct ion buffer,用来管理buffer。*/
43.     buffer = kzalloc(sizeof(struct ion_buffer), GFP_KERNEL);
44.     if (!buffer)
45.         return ERR_PTR(-ENOMEM);
46.
47.     buffer->heap = heap;
48.     kref_init(&buffer->ref);
49.     /*调用相应heap type的ops allocate,还记得前面有提到过不同种类的ops吗,
50.     如carveout_heap_ops, vmalloc_ops。*/
51.     ret = heap->ops->allocate(heap, buffer, len, align, flags);
52.     if (ret) {
53.         kfree(buffer);
54.         return ERR_PTR(ret);
55.     }
56.
57.     buffer->dev = dev;
58.     buffer->size = len;
59.     /*http://lwn.net/Articles/263343*/
60.     table = buffer->heap->ops->map_dma(buffer->heap, buffer);
61.     if (IS_ERR_OR_NULL(table)) {
62.         heap->ops->free(buffer);
63.         kfree(buffer);
64.         return ERR_PTR(PTR_ERR(table));
65.     }
66.     buffer->sg_table = table;
67.
68.     mutex_init(&buffer->lock);
```

关闭

```
69.     /*将当前ion buffer添加到idev 的buffers 树上统一管理。*/
70.     ion_buffer_add(dev, buffer);
71.     return buffer;
72. }

[cpp]

01. struct ion_handle *ion_alloc(struct ion_client *client, size_t len,
02.                             size_t align, unsigned int flags)
03. {
04.     --snip
05.
06.     mutex_lock(&dev->lock);
07.     /*循环遍历当前Heap链表。*/
08.     for (n = rb_first(&dev->heaps); n != NULL; n = rb_next(n)) {
09.         struct ion_heap *heap = rb_entry(n, struct ion_heap, node);
10.         /*只有heap type和id都符合才去创建buffer。*/
11.         /* if the client doesn't support this heap type */
12.         if (!(1 <= heap->type & client->heap_mask))
13.             continue;
14.         /* if the caller didn't specify this heap type */
15.         if (!(1 <= heap->id & flags))
16.             continue;
17.         /* Do not allow un-secure heap if secure is specified */
18.         if (secure_allocation && (heap->type != ION_HEAP_TYPE_CP))
19.             continue;
20.         buffer = ion_buffer_create(heap, dev, len, align, flags);
21.     --snip
22.     }
23.     mutex_unlock(&dev->lock);
24.
25.     --snip
26.     /*创建了buffer之后,就相应地创建handle来管理buffer。*/
27.     handle = ion_handle_create(client, buffer);
28.
29.     --snip
30. }
31.
32. 找到Heap之后调用ion_buffer_create:
33. static struct ion_buffer *ion_buffer_create(struct ion_heap *heap,
34.                                             struct ion_device *dev,
35.                                             unsigned long len,
36.                                             unsigned long align,
37.                                             unsigned long flags)
38. {
39.     struct ion_buffer *buffer;
40.     struct sg_table *table;
41.     int ret;
42.     /*分配struct ion buffer,用来管理buffer。*/
43.     buffer = kzalloc(sizeof(struct ion_buffer), GFP_KERNEL);
44.     if (!buffer)
45.         return ERR_PTR(-ENOMEM);
46.
47.     buffer->heap = heap;
48.     kref_init(&buffer->ref);
49.     /*调用相应heap type的ops allocate. 还记得前面有提到过不同种类的ops吗,
50.     如carveout_heap_ops ,vmalloc_ops 。*/
51.     ret = heap->ops->allocate(heap, buffer, len, align, flags);
52.     if (ret) {
53.         kfree(buffer);
54.         return ERR_PTR(ret);
55.     }
56.
57.     buffer->dev = dev;
58.     buffer->size = len;
59.     /*http://lwn.net/Articles/263343*/
60.     table = buffer->heap->ops->map_dma(buffer->heap, buffer);
61.     if (IS_ERR_OR_NULL(table)) {
62.         heap->ops->free(buffer);
63.         kfree(buffer);
64.         return ERR_PTR(PTR_ERR(table));
65.     }
66.     buffer->sg_table = table;
67.
68.     mutex_init(&buffer->lock);
69.     /*将当前ion buffer添加到idev 的buffers 树上统一管理。*/
70.     ion_buffer_add(dev, buffer);
71.     return buffer;
72. }
```

关闭

```
[cpp]
01. <p>static struct ion_handle *ion_handle_create(struct ion_client *client,
02.         struct ion_buffer *buffer)
03. {
04.     struct ion_handle *handle;
05.     /*分配struct ion_handle.*/
06.     handle = kzalloc(sizeof(struct ion_handle), GFP_KERNEL);
07.     if (!handle)
08.         return ERR_PTR(-ENOMEM);
09.     kref_init(&handle->ref);
10.     rb_init_node(&handle->node);
11.     handle->client = client; //client放入handle中
12.     ion_buffer_get(buffer); //引用计数加1
13.     handle->buffer = buffer; //buffer也放入handle中</p><p> return handle;
14. }
15. </p>

[cpp]
01. <p>static struct ion_handle *ion_handle_create(struct ion_client *client,
02.         struct ion_buffer *buffer)
03. {
04.     struct ion_handle *handle;
05.     /*分配struct ion_handle.*/
06.     handle = kzalloc(sizeof(struct ion_handle), GFP_KERNEL);
07.     if (!handle)
08.         return ERR_PTR(-ENOMEM);
09.     kref_init(&handle->ref);
10.     rb_init_node(&handle->node);
11.     handle->client = client; //client放入handle中
12.     ion_buffer_get(buffer); //引用计数加1
13.     handle->buffer = buffer; //buffer也放入handle中</p><p> return handle;
14. }
15. </p>
```

先拿heap type为ION_HEAP_TYPE_CARVEOUT为例，看下它是如何分配buffer的。

allocate对应ion_carveout_heap_allocate。

```
[cpp]
01. static int ion_carveout_heap_allocate(struct ion_heap *heap,
02.         struct ion_buffer *buffer,
03.         unsigned long size, unsigned long align,
04.         unsigned long flags)
05. {
06.     buffer->priv_phys = ion_carveout_allocate(heap, size, align);
07.     return buffer->priv_phys == ION_CARVEOUT_ALLOCATE_FAIL ? -ENOMEM : 0;
08. }
09. ion_phys_addr_t ion_carveout_allocate(struct ion_heap *heap,
10.         unsigned long size,
11.         unsigned long align)
12. {
13.     struct ion_carveout_heap *carveout_heap =
14.         container_of(heap, struct ion_carveout_heap, heap);
15.     /*通过创建的mem pool来管理buffer,由于这块buffer在初始化的
16.     时候就预留了，现在只要从上面拿一块区域就可以了。*/
17.     unsigned long offset = gen_pool_alloc_aligned(carveout_heap->pool,
18.         size, ilog2(align));
19.     /*分配不成功可能是没有内存空间可供分配了或者是有碎片导致的。*/
20.     if (!offset) {
21.         if ((carveout_heap->total_size -
22.             carveout_heap->allocated_bytes) >= size)
23.             pr_debug("%s: heap %s has enough memory (%lx) but"
24.                 " the allocation of size %lx still fa"
25.                 " Memory is probably fragmented.",
26.                 __func__, heap->name,
27.                 carveout_heap->total_size -
28.                 carveout_heap->allocated_bytes, size);
29.         return ION_CARVEOUT_ALLOCATE_FAIL;
30.     }
31.     /*已经分配掉的内存字节。*/
32.     carveout_heap->allocated_bytes += size;
33.     return offset;
34. }

[cpp]
01. static int ion_carveout_heap_allocate(struct ion_heap *heap,
```

关闭

```
02.         struct ion_buffer *buffer,
03.         unsigned long size, unsigned long align,
04.         unsigned long flags)
05. {
06.     buffer->priv_phys = ion_carveout_allocate(heap, size, align);
07.     return buffer->priv_phys == ION_CARVEOUT_ALLOCATE_FAIL ? -ENOMEM : 0;
08. }
09. ion_phys_addr_t ion_carveout_allocate(struct ion_heap *heap,
10.         unsigned long size,
11.         unsigned long align)
12. {
13.     struct ion_carveout_heap *carveout_heap =
14.         container_of(heap, struct ion_carveout_heap, heap);
15.     /*通过创建的mem pool来管理buffer,由于这块buffer在初始化的
16. 时候就预留了,现在只要从上面拿一块区域就可以了。*/
17.     unsigned long offset = gen_pool_alloc_aligned(carveout_heap->pool,
18.         size, ilog2(align));
19.     /*分配不成功可能是没有内存空间可供分配了或者是有碎片导致的。*/
20.     if (!offset) {
21.         if ((carveout_heap->total_size -
22.             carveout_heap->allocated_bytes) >= size)
23.             pr_debug("%s: heap %s has enough memory (%lx) but"
24.                 " the allocation of size %lx still failed."
25.                 " Memory is probably fragmented.",
26.                 __func__, heap->name,
27.                 carveout_heap->total_size -
28.                 carveout_heap->allocated_bytes, size);
29.         return ION_CARVEOUT_ALLOCATE_FAIL;
30.     }
31.     /*已经分配掉的内存字节。*/
32.     carveout_heap->allocated_bytes += size;
33.     return offset;
34. }
```

同样地,对于heap type为ION_HEAP_TYPE_SYSTEM的分配函数是ion_system_heap_allocate。

```
[cpp] C {
01. static int ion_system_contig_heap_allocate(struct ion_heap *heap,
02.         struct ion_buffer *buffer,
03.         unsigned long len,
04.         unsigned long align,
05.         unsigned long flags)
06. {
07.     /*通过kzalloc分配。*/
08.     buffer->priv_virt = kzalloc(len, GFP_KERNEL);
09.     if (!buffer->priv_virt)
10.         return -ENOMEM;
11.     atomic_add(len, &system_contig_heap_allocated);
12.     return 0;
13. }
```

```
[cpp]
01. static int ion_system_contig_heap_allocate(struct ion_heap *heap,
02.         struct ion_buffer *buffer,
03.         unsigned long len,
04.         unsigned long align,
05.         unsigned long flags)
06. {
07.     /*通过kzalloc分配。*/
08.     buffer->priv_virt = kzalloc(len, GFP_KERNEL);
09.     if (!buffer->priv_virt)
10.         return -ENOMEM;
11.     atomic_add(len, &system_contig_heap_allocated);
12.     return 0;
13. }
```

关闭

其他的几种Heap type可自行研究,接着调用ion_buffer_add将buffer添加到dev的buffers树上去

```
[cpp] C {
01. static void ion_buffer_add(struct ion_device *dev,
02.         struct ion_buffer *buffer)
03. {
04.     struct rb_node **p = &dev->buffers.rb_node;
05.     struct rb_node *parent = NULL;
06.     struct ion_buffer *entry;
07. }
```

```
08.     while (*p) {
09.         parent = *p;
10.         entry = rb_entry(parent, struct ion_buffer, node);
11.
12.         if (buffer < entry) {
13.             p = &(*p)->rb_left;
14.         } else if (buffer > entry) {
15.             p = &(*p)->rb_right;
16.         } else {
17.             pr_err("%s: buffer already found.", __func__);
18.             BUG();
19.         }
20.     }
21.     /*又是使用红黑树哦!*/
22.     rb_link_node(&buffer->node, parent, p);
23.     rb_insert_color(&buffer->node, &dev->buffers);
24. }
```

[cpp]

```
01. static void ion_buffer_add(struct ion_device *dev,
02.                             struct ion_buffer *buffer)
03. {
04.     struct rb_node **p = &dev->buffers.rb_node;
05.     struct rb_node *parent = NULL;
06.     struct ion_buffer *entry;
07.
08.     while (*p) {
09.         parent = *p;
10.         entry = rb_entry(parent, struct ion_buffer, node);
11.
12.         if (buffer < entry) {
13.             p = &(*p)->rb_left;
14.         } else if (buffer > entry) {
15.             p = &(*p)->rb_right;
16.         } else {
17.             pr_err("%s: buffer already found.", __func__);
18.             BUG();
19.         }
20.     }
21.     /*又是使用红黑树哦!*/
22.     rb_link_node(&buffer->node, parent, p);
23.     rb_insert_color(&buffer->node, &dev->buffers);
24. }
```

至此，已经得到client和handle，buffer分配完成！

ION_IOC_MAP/ION_IOC_SHARE

[cpp] C { }

```
01. int ion_share_dma_buf(struct ion_client *client, struct ion_handle *handle)
02. {
03.     struct ion_buffer *buffer;
04.     struct dma_buf *dmabuf;
05.     bool valid_handle;
06.     int fd;
07.
08.     mutex_lock(&client->lock);
09.     valid_handle = ion_handle_validate(client, handle);
10.     mutex_unlock(&client->lock);
11.     if (!valid_handle) {
12.         WARN(1, "%s: invalid handle passed to share.\n", __func__);
13.         return -EINVAL;
14.     }
15.
16.     buffer = handle->buffer;
17.     ion_buffer_get(buffer);
18.     /*生成一个新的file描述符*/
19.     dmabuf = dma_buf_export(buffer, &dma_buf_ops, buffer->size, 0_RDWR);
20.     if (IS_ERR(dmabuf)) {
21.         ion_buffer_put(buffer);
22.         return PTR_ERR(dmabuf);
23.     }
24.     /*将file转换为用户空间识别的fd描述符。*/
25.     fd = dma_buf_fd(dmabuf, 0_CLOEXEC);
26.     if (fd < 0)
27.         dma_buf_put(dmabuf);
28.
29.     return fd;
```

关闭

```
30. }
31. struct dma_buf *dma_buf_export(void *priv, const struct dma_buf_ops *ops,
32.                                size_t size, int flags)
33. {
34.     struct dma_buf *dmabuf;
35.     struct file *file;
36.     --snip
37.     /*分配struct dma_buf.*/
38.     dmabuf = kzalloc(sizeof(struct dma_buf), GFP_KERNEL);
39.     if (dmabuf == NULL)
40.         return ERR_PTR(-ENOMEM);
41.     /*保存信息到dmabuf, 注意ops为dma_buf_ops, 后面mmap为调用到.*/
42.     dmabuf->priv = priv;
43.     dmabuf->ops = ops;
44.     dmabuf->size = size;
45.     /*产生新的file*/
46.     file = anon_inode_getfile("dmabuf", &dma_buf_fops, dmabuf, flags);
47.
48.     dmabuf->file = file;
49.
50.     mutex_init(&dmabuf->lock);
51.     INIT_LIST_HEAD(&dmabuf->attachments);
52.
53.     return dmabuf;
54. }
```

[cpp]

```
01. int ion_share_dma_buf(struct ion_client *client, struct ion_handle *handle)
02. {
03.     struct ion_buffer *buffer;
04.     struct dma_buf *dmabuf;
05.     bool valid_handle;
06.     int fd;
07.
08.     mutex_lock(&client->lock);
09.     valid_handle = ion_handle_validate(client, handle);
10.     mutex_unlock(&client->lock);
11.     if (!valid_handle) {
12.         WARN(1, "%s: invalid handle passed to share.\n", __func__);
13.         return -EINVAL;
14.     }
15.
16.     buffer = handle->buffer;
17.     ion_buffer_get(buffer);
18.     /*生成一个新的file描述符*/
19.     dmabuf = dma_buf_export(buffer, &dma_buf_ops, buffer->size, O_RDWR);
20.     if (IS_ERR(dmabuf)) {
21.         ion_buffer_put(buffer);
22.         return PTR_ERR(dmabuf);
23.     }
24.     /*将file转换为用户空间识别的fd描述符.*/
25.     fd = dma_buf_fd(dmabuf, O_CLOEXEC);
26.     if (fd < 0)
27.         dma_buf_put(dmabuf);
28.
29.     return fd;
30. }
31. struct dma_buf *dma_buf_export(void *priv, const struct dma_buf_ops *ops,
32.                                size_t size, int flags)
33. {
34.     struct dma_buf *dmabuf;
35.     struct file *file;
36.     --snip
37.     /*分配struct dma_buf.*/
38.     dmabuf = kzalloc(sizeof(struct dma_buf), GFP_KERNEL);
39.     if (dmabuf == NULL)
40.         return ERR_PTR(-ENOMEM);
41.     /*保存信息到dmabuf, 注意ops为dma_buf_ops, 后面mmap为调用到.*/
42.     dmabuf->priv = priv;
43.     dmabuf->ops = ops;
44.     dmabuf->size = size;
45.     /*产生新的file*/
46.     file = anon_inode_getfile("dmabuf", &dma_buf_fops, dmabuf, flags);
47.
48.     dmabuf->file = file;
49.
50.     mutex_init(&dmabuf->lock);
51.     INIT_LIST_HEAD(&dmabuf->attachments);
52. }
```

关闭


```
53.     return dmabuf;
54. }
```

通过上述过程，用户空间就得到了新的fd,重新生成一个新的fd的目的是考虑了两个用户空间进程想共享这块heap内存的情况。然后再对fd作mmap，相应地kernel空间就调用到了file的dma_buf_fops中的dma_buf_mmap_internal。

```
[cpp]
01. static const struct file_operations dma_buf_fops = {
02.     .release    = dma_buf_release,
03.     .mmap       = dma_buf_mmap_internal,
04. };
05. static int dma_buf_mmap_internal(struct file *file, struct vm_area_struct *
06. {
07.     struct dma_buf *dmabuf;
08.
09.     if (!is_dma_buf_file(file))
10.         return -EINVAL;
11.
12.     dmabuf = file->private_data;
13.     /*检查用户空间要映射的size是否比目前dmabuf也就是当前heap的size
14.     还要大，如果是就返回无效。*/
15.     /* check for overflowing the buffer's size */
16.     if (vma->vm_pgoff + ((vma->vm_end - vma->vm_start) >> PAGE_SHIFT) >
17.         dmabuf->size >> PAGE_SHIFT)
18.         return -EINVAL;
19.     /*调用的是dma_buf_ops的mmap函数*/
20.     return dmabuf->ops->mmap(dmabuf, vma);
21. }
22.
23. struct dma_buf_ops dma_buf_ops = {
24.     .map_dma_buf = ion_map_dma_buf,
25.     .unmap_dma_buf = ion_unmap_dma_buf,
26.     .mmap = ion_mmap,
27.     .release = ion_dma_buf_release,
28.     .begin_cpu_access = ion_dma_buf_begin_cpu_access,
29.     .end_cpu_access = ion_dma_buf_end_cpu_access,
30.     .kmap_atomic = ion_dma_buf_kmap,
31.     .kunmap_atomic = ion_dma_buf_kunmap,
32.     .kmap = ion_dma_buf_kmap,
33.     .kunmap = ion_dma_buf_kunmap,
34. };
35. static int ion_mmap(struct dma_buf *dmabuf, struct vm_area_struct *vma)
36. {
37.     struct ion_buffer *buffer = dmabuf->priv;
38.     int ret;
39.
40.     if (!buffer->heap->ops->map_user) {
41.         pr_err("%s: this heap does not define a method for mapping "
42.             "to userspace\n", __func__);
43.         return -EINVAL;
44.     }
45.
46.     mutex_lock(&buffer->lock);
47.     /* now map it to userspace */
48.     /*调用的是相应heap的map_user，如carveout_heap_ops调用的是
49.     ion_carveout_heap_map_user，此函数就是一般的mmap实现，不追下去了。*/
50.     ret = buffer->heap->ops->map_user(buffer->heap, buffer, vma);
51.
52.     if (ret) {
53.         mutex_unlock(&buffer->lock);
54.         pr_err("%s: failure mapping buffer to userspace\n",
55.             __func__);
56.     } else {
57.         buffer->umap_cnt++;
58.         mutex_unlock(&buffer->lock);
59.
60.         vma->vm_ops = &ion_vm_ops;
61.         /*
62.          * move the buffer into the vm_private_data so we can access it
63.          * from vma_open/close
64.          */
65.         vma->vm_private_data = buffer;
66.     }
67.     return ret;
68. }
```

关闭

```
[cpp]
01. static const struct file_operations dma_buf_fops = {
02.     .release    = dma_buf_release,
03.     .mmap       = dma_buf_mmap_internal,
04. };
05. static int dma_buf_mmap_internal(struct file *file, struct vm_area_struct *vma)
06. {
07.     struct dma_buf *dmabuf;
08.
09.     if (!is_dma_buf_file(file))
10.         return -EINVAL;
11.
12.     dmabuf = file->private_data;
13.     /*检查用户空间要映射的size是否比目前dmabuf也就是当前heap的size
14. 还要大,如果是就返回无效。*/
15.     /* check for overflowing the buffer's size */
16.     if (vma->vm_pgoff + ((vma->vm_end - vma->vm_start) >> PAGE_SHIFT) >
17.         dmabuf->size >> PAGE_SHIFT)
18.         return -EINVAL;
19.     /*调用的是dma_buf_ops 的mmap函数*/
20.     return dmabuf->ops->mmap(dmabuf, vma);
21. }
22.
23. struct dma_buf_ops dma_buf_ops = {
24.     .map_dma_buf = ion_map_dma_buf,
25.     .unmap_dma_buf = ion_unmap_dma_buf,
26.     .mmap = ion_mmap,
27.     .release = ion_dma_buf_release,
28.     .begin_cpu_access = ion_dma_buf_begin_cpu_access,
29.     .end_cpu_access = ion_dma_buf_end_cpu_access,
30.     .kmap_atomic = ion_dma_buf_kmap,
31.     .kunmap_atomic = ion_dma_buf_kunmap,
32.     .kmap = ion_dma_buf_kmap,
33.     .kunmap = ion_dma_buf_kunmap,
34. };
35. static int ion_mmap(struct dma_buf *dmabuf, struct vm_area_struct *vma)
36. {
37.     struct ion_buffer *buffer = dmabuf->priv;
38.     int ret;
39.
40.     if (!buffer->heap->ops->map_user) {
41.         pr_err("%s: this heap does not define a method for mapping "
42.             "to userspace\n", __func__);
43.         return -EINVAL;
44.     }
45.
46.     mutex_lock(&buffer->lock);
47.     /* now map it to userspace */
48.     /*调用的是相应heap的map_user,如carveout_heap_ops 调用的是
49.     ion_carveout_heap_map_user,此函数就是一般的mmap实现,不追下去了。*/
50.     ret = buffer->heap->ops->map_user(buffer->heap, buffer, vma);
51.
52.     if (ret) {
53.         mutex_unlock(&buffer->lock);
54.         pr_err("%s: failure mapping buffer to userspace\n",
55.             __func__);
56.     } else {
57.         buffer->umap_cnt++;
58.         mutex_unlock(&buffer->lock);
59.
60.         vma->vm_ops = &ion_vm_ops;
61.         /*
62.          * move the buffer into the vm_private_data so we can access it
63.          * from vma_open/close
64.          */
65.         vma->vm_private_data = buffer;
66.     }
67.     return ret;
68. }
```

关闭

至此,用户空间就得到了bufferaddress,然后可以使用了!

ION_IOC_IMPORT

当用户空间另一个进程需要这块heap的时候,ION_IOC_IMPORT就派上用场了!注意,传进去的fd为在ION_IOC_SHARE中得到的。

[cpp]



```
01. struct ion_handle *ion_import_dma_buf(struct ion_client *client, int fd)
02. {
03.
04.     struct dma_buf *dmabuf;
05.     struct ion_buffer *buffer;
06.     struct ion_handle *handle;
07.
08.     dmabuf = dma_buf_get(fd);
09.     if (IS_ERR_OR_NULL(dmabuf))
10.         return ERR_PTR(PTR_ERR(dmabuf));
11.     /* if this memory came from ion */
12.     --snip
13.     buffer = dmabuf->priv;
14.
15.     mutex_lock(&client->lock);
16.     /* if a handle exists for this buffer just take a reference to it */
17.     /*查找是否已经存在对应的handle了, 没有则创建。因为另外一个进程只是
18.     调用了open 接口, 对应的只创建了client, 并没有handle。
19.     */
20.     handle = ion_handle_lookup(client, buffer);
21.     if (!IS_ERR_OR_NULL(handle)) {
22.         ion_handle_get(handle);
23.         goto end;
24.     }
25.     handle = ion_handle_create(client, buffer);
26.     if (IS_ERR_OR_NULL(handle))
27.         goto end;
28.     ion_handle_add(client, handle);
29. end:
30.     mutex_unlock(&client->lock);
31.     dma_buf_put(dmabuf);
32.     return handle;
33. }
```

[cpp]

```
01. struct ion_handle *ion_import_dma_buf(struct ion_client *client, int fd)
02. {
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04.     struct dma_buf *dmabuf;
05.     struct ion_buffer *buffer;
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26.     if (IS_ERR_OR_NULL(handle))
27.         goto end;
28.     ion_handle_add(client, handle);
29. end:
30.     mutex_unlock(&client->lock);
31.     dma_buf_put(dmabuf);
32.     return handle;
33. }
```

关闭

这样, 用户空间另一个进程也得到了对应的bufferHandle, client/buffer/handle之间连接起来了! 然后另一个一个进程也可以使用mmap来操作这块heap buffer了。

和一般的进程使用ION区别就是共享的进程之间struction_buffer是共享的, 而struct ion_handle是各自的。

可见, ION的使用流程还是比较清晰的。不过要记得的是, 使用好了ION, 一定要释放掉, 否则会导致内存泄露。

ION内核空间使用

内核空间使用ION也是大同小异, 按照创建client,buffer,handle的流程, 只是它的使用对用户空间来说是透明的罢

了！

ion_client_create在kernel空间被Qualcomm给封装了下。

```
[cpp]
01. struct ion_client *msm_ion_client_create(unsigned int heap_mask,
02.                                         const char *name)
03. {
04.     return ion_client_create(iddev, heap_mask, name);
05. }
```

```
[cpp]
01. struct ion_client *msm_ion_client_create(unsigned int heap_mask,
02.                                         const char *name)
03. {
04.     return ion_client_create(iddev, heap_mask, name);
05. }
```

调用的流程也类似，不过map的时候调用的是heap对应的map_kernel()而不是map_user().

msm_ion_client_create -> ion_alloc -> ion_map_kernel

参考文档：

<http://wn.net/Articles/480055/>

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