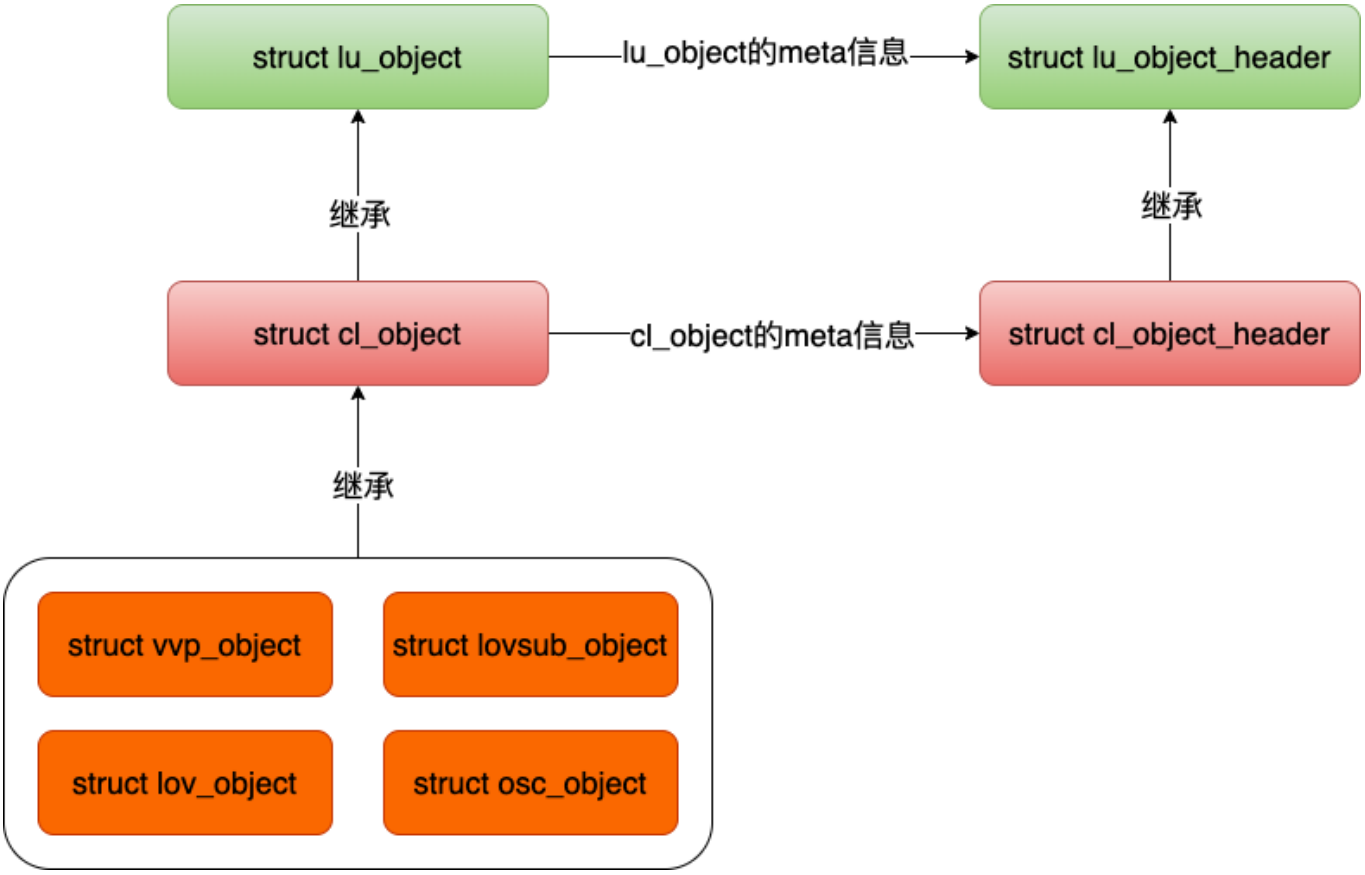
前言

- 文件或者文件stripe在lustre中都统称为`object`.客户端`stack`和MDT的`stack`复用一些对象，比如`struct lu_object`用来表示文件对象。`struct lu_object->>lo_linkage`链接到`struct lu_object_header->loh_layers`来表示全栈的对象.
- `struct lu_object`和`struct lu_object_header`在客户端和服务端提供 3个核心的功能；它们分别是a)每个文件对象采用`fid`作为唯一标识，所有对象都存储在以fid为索引的哈希表中；b)每个对象都会被引用计数，当对象release后就会被放到`cache`中，显示的标记删除对象立即被销毁；3)`cache`中的对象采用`LRU`算法来管理。
- 在客户端`struct lu_object`被`cl_object`继承作为客户端对象的基类，对于`struct cl_object`又被`vvp_object、lov_object、lovsub_object、osc_object`继承；在MDT端`struct lu_object`被`struct md_object`继承。

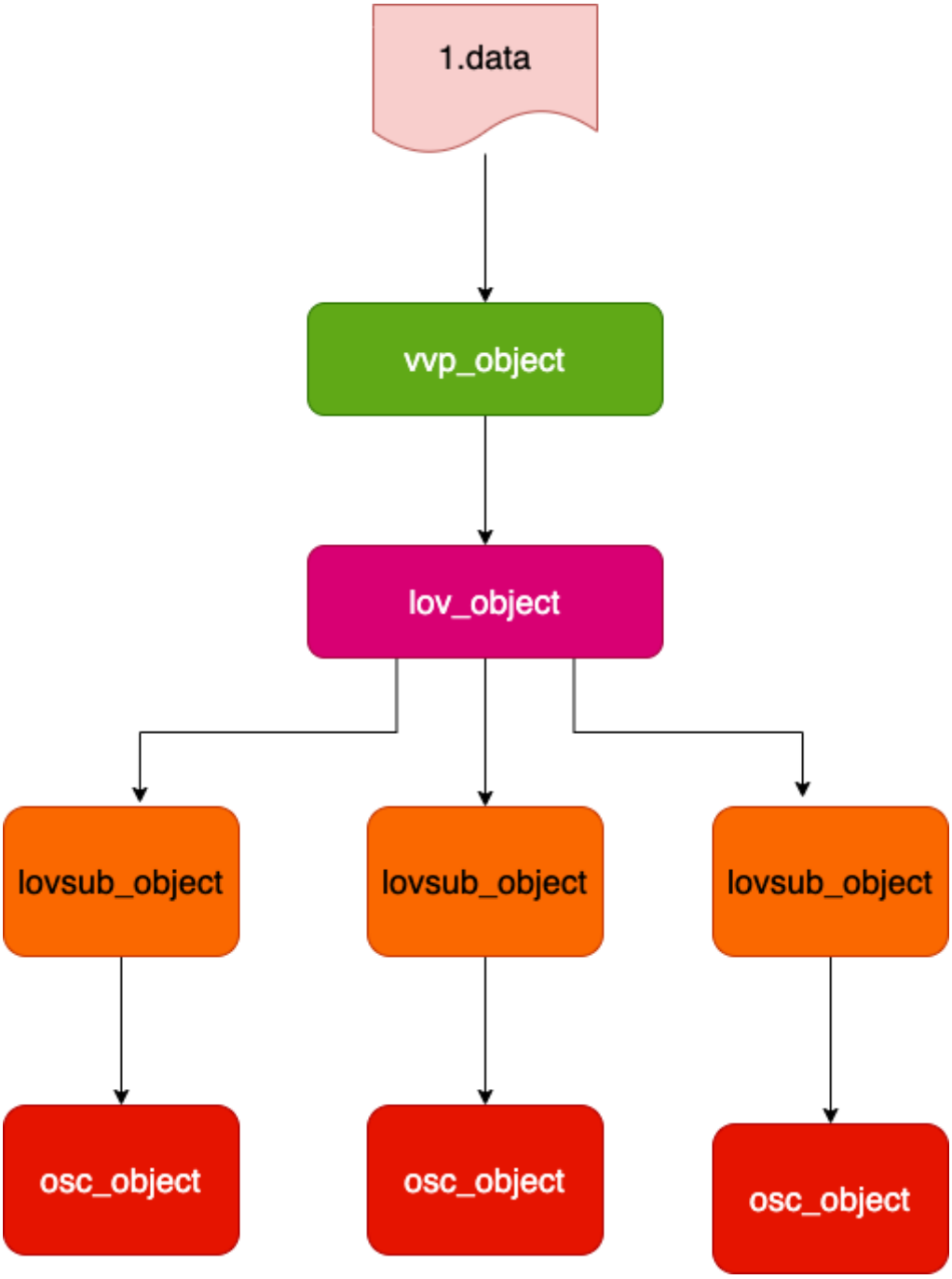



```
// 每一层的lu_object
struct lu_object {
            // 对象header
        struct lu_object_header           *lo_header;
        // 当前的device
        struct lu_device                  *lo_dev;
       // lu_object对象的操作函数表
```

```
        const struct lu_object_operations *lo_ops;
         // all layers的链接
                struct list_head                    lo_linkage;
                struct lu_ref_link                  lo_dev_ref;
};

// lu_object的header对象
struct lu_object_header {
        // 每个对象的唯一标识
        struct lu_fid           loh_fid;
        // 对象的flag
        unsigned long           loh_flags;
        // 对象的引用计数
        atomic_t                loh_ref;
        // 对象通用属性
        __u32                   loh_attr;
        // 连接到哈希表的字段
        struct rhash_head       loh_hash;
        // lru维护列表
        struct list_head        loh_lru;

        // 链接到layers的链表中
        struct list_head        loh_layers;

        struct lu_ref           loh_reference;
        struct rcu_head         loh_rcu;
};

struct cl_object {
        // super父类对象
        struct lu_object                    co_lu;
        // 本层的cl_object操作函数表
        const struct cl_object_operations *co_ops;
                int                                 co_slice_off;
};

// cl_object的扩展header
struct cl_object_header {
        // 内嵌lu_object_header
           struct lu_object_header      coh_lu;

        // 父对象
        struct cl_object_header *coh_parent;

         // 在父对象和子对象之间的属性维护的锁
                spinlock_t                coh_attr_guard;
```

```
                // cl_page和操作cl_page函数表大小
                unsigned short          coh_page_bufsize;

                // 是否是top-object的表示，0表示是；1表示sub-objects
                unsigned char           coh_nesting;
};
```

客户端中定义的`Object`



- `vvp_object`负责`vfs、vm、posix`三个层面的事情，这个对象包含了`Linux kernel`的`inode`

```
struct vvp_object {
        // 客户端对象的header用来链接下一层的处理object的device
        struct cl_object_header vob_header;
        //当前vvp_object的对应的客户端对象
        struct cl_object        vob_cl;
        // 文件对应的inode
        struct inode           *vob_inode;

         // 用于统计mmap的文件的计数
        atomic_t                vob_mmap_cnt;

        unsigned int            vob_discard_page_warned:1;
};
```

- `lov_object`用来描述每个文件或者文件对象的布局信息

```
struct lov_object {
  // 文件布局信息的队形
        struct cl_object        lo_cl;
        /**
         * Serializes object operations with transitions between layout
types.
         *
         * This semaphore is taken in shared mode by all object methods, and
         * is taken in exclusive mode when object type is changed.
         *
         * \see lov_object::lo_type
         */

        struct rw_semaphore     lo_type_guard;
        /**
         * Type of an object. Protected by lov_object::lo_type_guard.
         */
        enum lov_layout_type    lo_type;
        /**
         * Object flags.
         */
        unsigned long           lo_obj_flags
        /**
         * How many IOs are on going on this object. Layout can be changed
```

```
         * only if there is no active IO.
         */
        atomic_t                lo_active_ios;
        /**
         * Waitq - wait for no one else is using lo_lsm
         */
        wait_queue_head_t       lo_waitq;

        // 文件对象的布局信息
        struct lov_stripe_md  *lo_lsm;

        union lov_layout_state {
                struct lov_layout_state_empty {
                } empty;
                struct lov_layout_state_released {
                } released;
                struct lov_layout_composite {
                        /**
                         * flags of lov_comp_md_v1::lcm_flags. Mainly used
                         * by FLR.
                         */
                        uint32_t        lo_flags;

                         // FLR功能需要维护的对象
                        int             lo_preferred_mirror;

                        unsigned        lo_mirror_count;
                        struct lov_mirror_entry *lo_mirrors;

                        unsigned int    lo_entry_count;
                        struct lov_layout_entry *lo_entries;
                } composite;
        } u;
        /**
         * Thread that acquired lov_object::lo_type_guard in an exclusive
         * mode.
         */
        struct task_struct            *lo_owner;
};
```

- `lovsub_object`负责维护每个文件分片的信息对象

```
struct lovsub_object {
          // 当前lovsub_object的header
        struct cl_object_header lso_header;
        // 当前lovsub_object的对象
```

```
        struct cl_object        lso_cl;
        // lovsub_object对应的父对象
        struct lov_object      *lso_super;
        // 子对象对应的索引
        int                     lso_index;
};
```

- `osc_object`是连接到后端ost的维护的对象,这个与`lovsub_object`一一对应

```
// ost客户端维护的对象
struct osc_object {
        struct cl_object        oo_cl;
        struct lov_oinfo        *oo_oinfo;
        /**
         * True if locking against this stripe got -EUSERS.
         */
        int                     oo_contended;
        ktime_t                 oo_contention_time;
#ifdef CONFIG_LUSTRE_DEBUG_EXPENSIVE_CHECK
        /**
         * IO context used for invariant checks in osc_lock_has_pages().
         */
        struct cl_io            oo_debug_io;
        /** Serialization object for osc_object::oo_debug_io. */
        struct mutex            oo_debug_mutex;
#endif
        /**
         * used by the osc to keep track of what objects to build into rpcs.
         * Protected by client_obd->cli_loi_list_lock.
         */
        struct list_head        oo_ready_item;
        struct list_head        oo_hp_ready_item;
        struct list_head        oo_write_item;
        struct list_head        oo_read_item;

        /**
         * extent is a red black tree to manage (async) dirty pages.
         */
        struct rb_root          oo_root;
        /**
         * Manage write(dirty) extents.
         */
        struct list_head        oo_hp_exts;     /* list of hp extents */
        struct list_head        oo_urgent_exts; /* list of writeback extents
*/
        struct list_head        oo_full_exts;
```

```
        struct list_head        oo_reading_exts;

        atomic_t                oo_nr_reads;
        atomic_t                oo_nr_writes;

        /** Protect extent tree. Will be used to protect
         * oo_{read|write}_pages soon. */
        spinlock_t              oo_lock;

        /**
         * Radix tree for caching pages
         */
        spinlock_t              oo_tree_lock;
        struct radix_tree_root  oo_tree;
        unsigned long           oo_npages;

        /* Protect osc_lock this osc_object has */
        struct list_head        oo_ol_list;
        spinlock_t              oo_ol_spin;

        /** number of active IOs of this object */
        atomic_t                oo_nr_ios;
        wait_queue_head_t       oo_io_waitq;

        const struct osc_object_operations *oo_obj_ops;
        bool                    oo_initialized;
};
```

客户端中定义的`Object`的操作函数

```
/************vvp object操作函数************/
static const struct lu_device_operations vvp_lu_ops = {
        .ldo_object_alloc      = vvp_object_alloc
};

static const struct lu_object_operations vvp_lu_obj_ops = {
        .loo_object_init       = vvp_object_init,
        .loo_object_free       = vvp_object_free,
        .loo_object_print       = vvp_object_print,
};

/************lov object操作函数************/
static const struct lu_device_operations lov_lu_ops = {
```

```
        .ldo_object_alloc      = lov_object_alloc,
        .ldo_process_config    = lov_process_config,
};

static const struct lu_object_operations lov_lu_obj_ops = {
        .loo_object_init       = lov_object_init,
        .loo_object_delete       = lov_object_delete,
        .loo_object_release       = NULL,
        .loo_object_free       = lov_object_free,
        .loo_object_print       = lov_object_print,
        .loo_object_invariant       = NULL,
};

/************lovsub object操作函数************/

static const struct lu_device_operations lovsub_lu_ops = {
        .ldo_object_alloc      = lovsub_object_alloc,
        .ldo_process_config    = NULL,
        .ldo_recovery_complete = NULL
};


static const struct lu_object_operations lovsub_lu_obj_ops = {
        .loo_object_init      = lovsub_object_init,
        .loo_object_delete    = NULL,
        .loo_object_release   = NULL,
        .loo_object_free      = lovsub_object_free,
        .loo_object_print     = lovsub_object_print,
        .loo_object_invariant = NULL
};


/************osc object操作函数************/

static const struct lu_device_operations osc_lu_ops = {
        .ldo_object_alloc      = osc_object_alloc,
                .ldo_process_config    = osc_process_config,
        .ldo_recovery_complete = NULL
};

static const struct lu_object_operations osc_lu_obj_ops = {
        .loo_object_init      = osc_object_init,
        .loo_object_release   = NULL,
        .loo_object_free      = osc_object_free,
        .loo_object_print     = osc_object_print,
        .loo_object_invariant = NULL
```

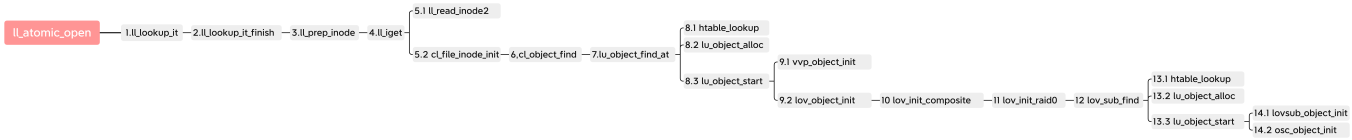
```
};
```

从`inode create`视角来看`object`过程

- `ll_atomic_open`提供文件`create&open`的函数，文件创建请求从用户发出,到了linux kernel中的vfs，最终进入vfs中已经被lustre文件系统赋值`ll_dir_inode_operations`中，发现是文件创建请求就直接走`atomic_open`指向的`ll_atomic_open`

```
const struct inode_operations ll_dir_inode_operations = {
        .atomic_open       = ll_atomic_open,
};
```

- 下面我们从`ll_atomic_open`开始来观测`object`创建的链路，整个链路中`lu_device_operations`是用来申请和配置`client stack`中对象；`lu_object_operations`用来初始化和处理函数。客户端的`device`部分是客户端加载时候load的；一部分是通过和MGS通信拿到llog然后解析llog加载到客户端，从而形成了整个`client device stack`.




```
// raid0模式下文件对象stripe处理函数
static struct lov_comp_layout_entry_ops raid0_ops = {
        .lco_init      = lov_init_raid0,
        .lco_fini      = lov_fini_raid0,
        .lco_getattr   = lov_attr_get_raid0,
};

// dom模式下文件对象stripe处理函数
static struct lov_comp_layout_entry_ops dom_ops = {
        .lco_init = lov_init_dom,
        .lco_fini = lov_fini_dom,
        .lco_getattr = lov_attr_get_dom,
};

//  如下是从inode create的角度分析客户端client的object,这里忽略了rpc和部分处理细节
 void ll_atomic_open() {
        ll_lookup_it(){
                ll_lookup_it_finish(){
                        ll_prep_inode() {
                                ll_iget() {
```

```
                                        // 设置inode的数据和元数据的处理函数
                                        ll_read_inode2()
                                        // 初始化客户端文件的inode
                                        cl_file_inode_init(){
                                                // 客户端对象的初始化函数入口
                                                cl_object_find(){
                                                        // lu_object查找和初始
化
                                                                lu_object_find_at(){
                                                                        // 哈希表中查
找
htable_lookup()
                                                                // lu_object
的申请
lu_object_alloc()
                                                                // 初始化
lu_object对象的vvp和lov对象
lu_object_start() {
                                                                        //
vvp_object的初始化
vvp_object_init()
                                                                        //
lov_object初始化
lov_object_init()
                                                                        {

//  这里指向的是lov_init_raid0函数
// ops = &lov_dispatch[lov->lo_type];
// rc = ops->llo_init(env, dev, lov, lsm, cconf, set);
lov_init_composite(){
for (i = 0, j = 0, mirror_count = 1; i < entry_count; i++) {
lle = &comp->lo_entries[i];
switch (lle->lle_type) {
case LOV_PATTERN_RAID0:
```

```
lle->lle_comp_ops = &raid0_ops;

break;

case LOV_PATTERN_MDT:

lle->lle_comp_ops = &dom_ops;

break;

}

// 处理lov对象的，stripe成lovub_object对象、初始化osc_object

lov_foreach_layout_entry(lov, lle) {

// 这里实际调用的是lov_init_raid0

// lle->lle_comp_ops->lco_init();

// 一个函数初始化lovsub_object和osc_object对象

lov_init_raid0()

{

for (i = 0; i < r0->lo_nr; ++i) {

lov_sub_find(){

// cache中查找

htable_lookup()

// lu_object申请

lu_object_alloc()

lu_object_start()

{

// do{ }whie()循环中初始化其他的object

lovsub_object_init()
```

```
osc_object_init()

}

}

}

}

}

}
                                                                    }
                                                                }
                                                            }
                                                        }
                                                    }
                                                }
                                            }
                                        }
                                    }

}
```