MFS1.6.11源码剖析

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系统体系结构的介绍

- MFS基于FUSE（File system for user space）实现。（一些其他的文件系统也是基于这套机制来实现的，例如gluster/ZFS等）
- 一般操作系统的文件系统，都是在内核态实现的：
  - 优点：运行效率高，内核态task之间是共享物理内存的。
  - 缺点：开发难度大，代码和版本难以维护，影响范围甚广，甚至导致kernel panic等严重问题。
- FUSE包括内核模块和用户态的动态链接库两部分。
  - 优点：开发难度小，用户态开发，代码和版本容易维护，影响范围小，用户态进程地址空间相互独立（虚拟内存管理）。
  - 执行效率较内核态程序低，内核态和用户态需要数据交互。（中断，系统调用，内存映射等手段，需要耗费额外的时钟周期）

http://fuse.sourceforge.net/

系统体系结构介绍

VFS, virtual file system, 是内核态向用户态提供统一的interface。重要的数据结构包括:

1. Super block, 存储文件系统信息
2. inode, 文件控制块的信息
3. file，用户态进程打开的文件信息，同inode是多对一。
4. dentry，目录缓存。

系统体系结构介绍

- FUSE应用的开发很简单，整个FUSE的开发框架类似于Linux Driver的框架。

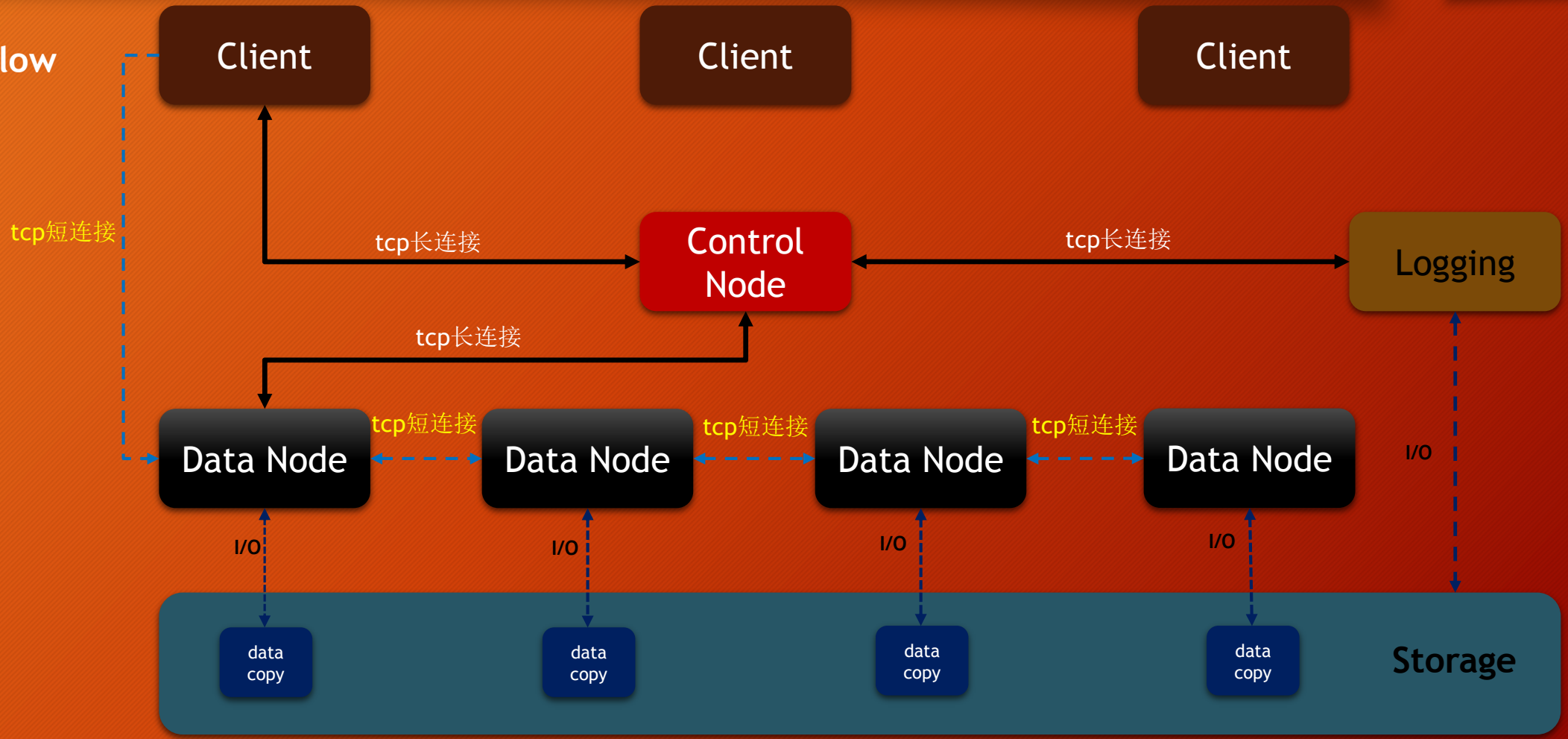
```
00080: static struct fuse_lowlevel_ops mfs_oper = {
00081:     .init           = mfs_fsinit,
00082:     .statfs      = mfs_statfs,
00083:     .lookup      = mfs_lookup,
00084:     .getattr     = mfs_getattr,
00085:     .setattr     = mfs_setattr,
00086:     .mknod       = mfs_mknod,
00087:     .unlink      = mfs_unlink,
00088:     .mkdir       = mfs_mkdir,
00089:     .rmdir       = mfs_rmdir,
00090:     .symlink     = mfs_symlink,
00091:     .readlink    = mfs_readlink,
00092:     .rename      = mfs_rename,
00093:     .link        = mfs_link,
00094:     .opendir     = mfs_opendir,
00095:     .readdir     = mfs_readdir,
00096:     .releasedir = mfs_releasedir,
00097:     .create      = mfs_create,
00098:     .open        = mfs_open,
00099:     .release     = mfs_release,
00100:     .flush       = mfs_flush,
00101:     .fsync       = mfs_fsync,
00102:     .read        = mfs_read,
00103:     .write       = mfs_write,
00104:     .access      = mfs_access,
00105: #if FUSE_VERSION >= 26
00106: /* locks are still in development
00107:     .getlk       = mfs_getlk,
00108:     .setlk       = mfs_setlk,
00109: */
00110: #endif
00111: };
```

系统体系结构的介绍

- MFS包括四个主要的模块：Client，Data Node，Control Node和Logging。
  - Client（mfsmount）：FUSE应用，负责接受用户文件系统请求以及转发。
  - Data Node（mfschunkserver）：数据节点的代理进程，执行具体的数据I/O操作。
  - Control Node（mfsmaster）：文件系统资源分配，I/O操作的控制以及负责集群进程的管理。
  - Logging（mfsmetalogger）：负责接受Control Node发送过来的change log的记录。

系统体系结构的介绍

主要的data flow



系统模块的主要数据结构和算法介绍

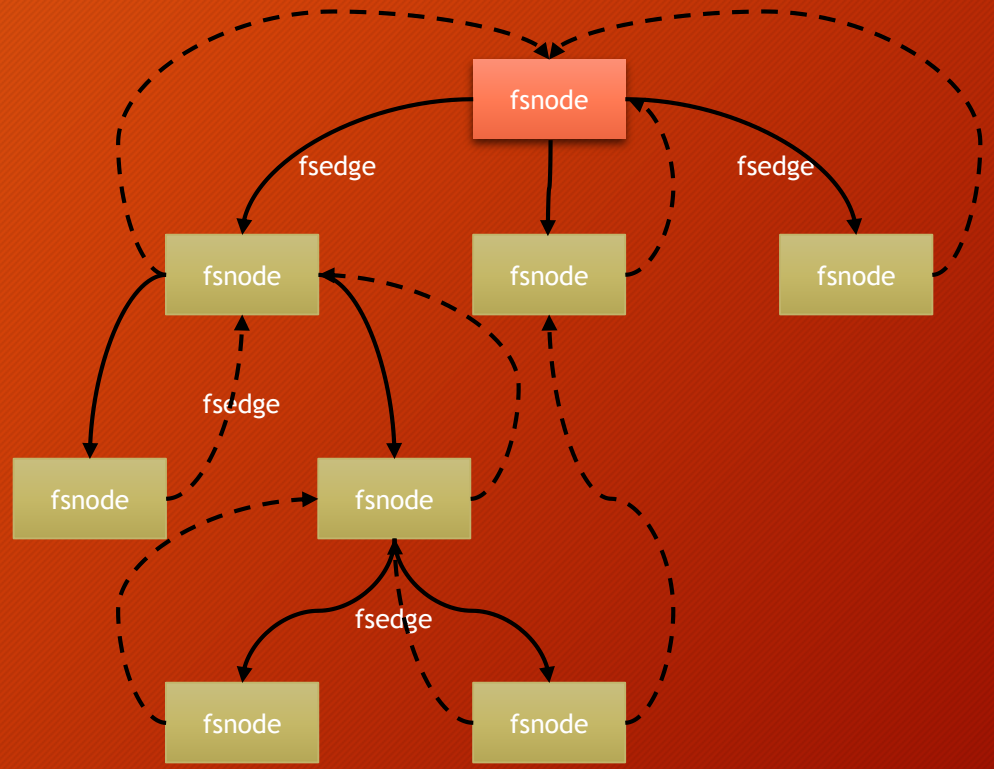
- mfsmaster是文件系统在分布式环境下的资源分配和管理者，也是文件I/O操作的中央调度者。
- 每一个挂载目录，I/O操作接收者，mfsmount进程都将同mfsmaster建立TCP长连接通信信道。
- 每一个I/O操作的执行者和路由者，mfschunkserver，都将同mfsmaster建立TCP长连接通信信道。
- 每一个metalogger进程实例，都将同mfsmaster建立TCP长连接通信信道，mfsmaster会将change log实时的发送到metalogger进程，进行异步change log存储。

系统模块的主要数据结构和算法介绍

- Mfsmaster文件系统主要数据结构，fsnode，fsedge，freenode，freebitmask，chunk和statistic data，也组成了MFS的Meta data。

逻辑结构

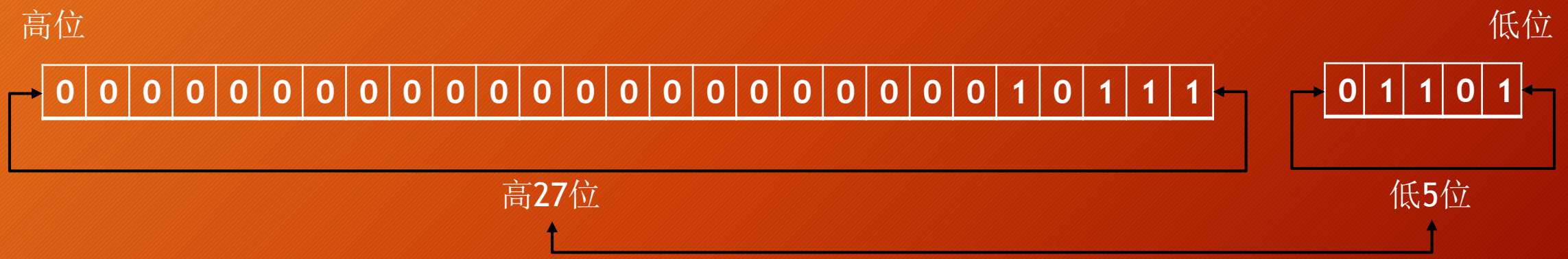
M-叉树



fsnode: 文件的控制信息
fsedge: 文件控制节点的关联关系
chunk: 文件的数据信息
freenode：文件控制节点缓存
freebitmask：文件系统的空闲资源

系统模块的主要数据结构和算法介绍

- 空闲资源位图，freebitmask
  - 管理整个文件系统控制节点fsnode资源状态。
  - 为控制节点fsnode分配node id



32位 nodeId

Node Id：0x02DD
Hash position：0x1D
Mask position：0x0B

```
00455: void fsnodes_used_inode (uint32_t id) {
00456:     uint32_t pos,mask;
00457:     pos = id>>5;
00458:     mask = 1<<(id&0x1F);
00459:     freebitmask[pos]|=mask;
00460: }
```

系统模块的主要数据结构和算法介绍

- 空闲资源位图，freebitmask（续）
  - 空闲fsnode的初始数量为：256到2^20+256
  - 空闲fsnode的动态增长

```
00447: void fsnodes_init_freebitmask (void) {
00448:     bitmasksize = 0x100+(((maxnodeid)>>5)&0xFFFFFF80);
00449:     freebitmask = (uint32_t*)malloc(bitmasksize*sizeof(uint32_t));
00450:     memset(freebitmask,0,bitmasksize*sizeof(uint32_t));
00451:     freebitmask[0]=1;    // reserve inode 0
00452:     searchpos = 0;
00453: }
```

```
00369: uint32_t fsnodes_get_next_id() {
00370:     uint32_t i,mask;
00371:     while (searchpos<bitmasksize && freebitmask[searchpos]==0xFFFFFFFF) {
00372:         searchpos++;
00373:     }
00374:     if (searchpos==bitmasksize) {    // no more freeinodes
00375:         bitmasksize+=0x80;
00376:         freebitmask = (uint32_t*)realloc(freebitmask,bitmasksize*sizeof(uint32_t));
00377:         memset(freebitmask+searchpos,0,0x80*sizeof(uint32_t));
00378:     }
00379:     mask = freebitmask[searchpos];
00380:     i=0;
00381:     while (mask&1) {
00382:         i++;
00383:         mask>>=1;
00384:     }
00385:     mask = 1<<i;
00386:     freebitmask[searchpos] |= mask;
00387:     i+=(searchpos<<5);
00388:     if (i>maxnodeid) {
00389:         maxnodeid=i;
00390:     }
00391:     return i;
00392: } ? end fsnodes_get_next_id ?
```

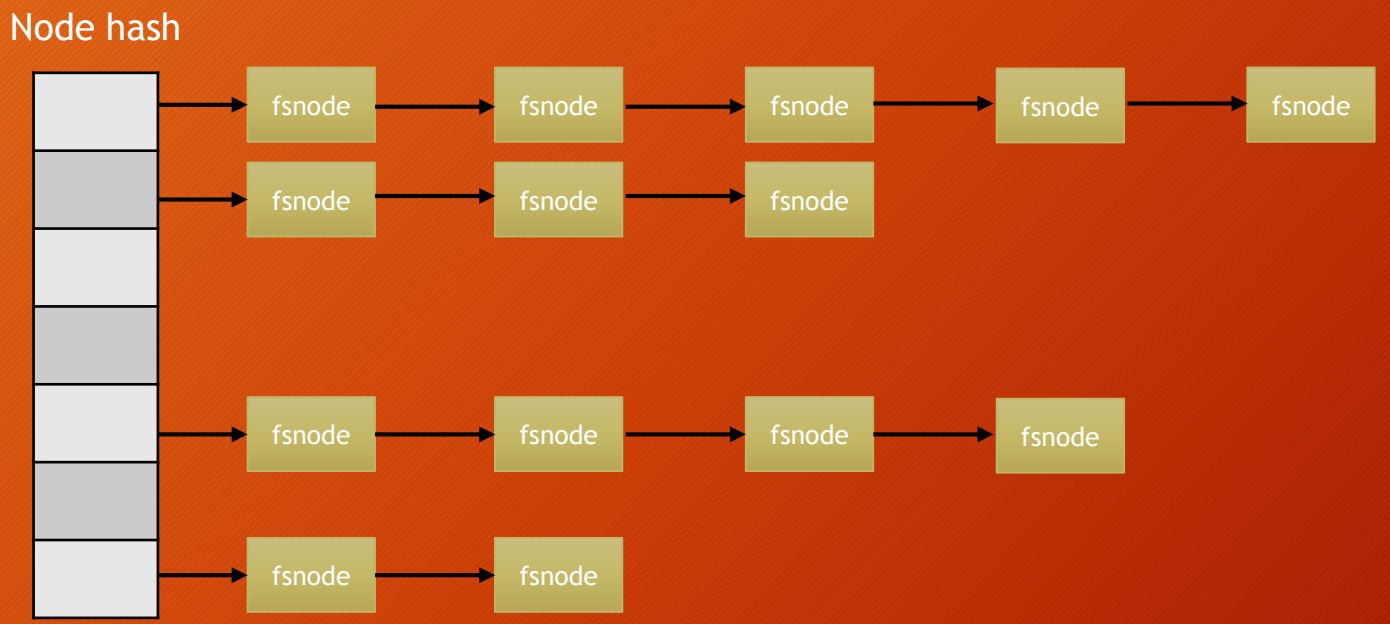
系统模块的主要数据结构和算法介绍

- Mfsmaster核心数据结构，fsnode（续）

```
00137: typedef struct _fsnode {
00138:     uint32_t id;
00139:     uint32_t ctime,mtime,atime;
00140:     uint8_t type;
00141:     uint8_t goal;
00142:     uint16_t mode;   // only 12 lowest bits are used for mode, in unix standard upper 4 are used for object type, but since there is field "type" this bits can be used as extra flags
00143:     uint32_t uid;
00144:     uint32_t gid;
00145:     uint32_t trashtime;
00146:     union _data {
00147:         struct _ddata {             // type==TYPE_DIRECTORY
00148:             fsedge *children;
00149:             uint32_t nlink;
00150:             uint32_t elements;
00151: //          uint8_t quotaexceeded:1;    // quota exceeded
00152: #ifndef METARESTORE
00153:             statsrecord *stats;
00154:             quotanode *quota;
00155: #endif
00156:         } ddata;
00157:         struct _sdata {             // type==TYPE_SYMLINK
00158:             uint32_t pleng;
00159:             uint8_t *path;
00160:         } sdata;
00161:         uint32_t rdev;              // type==TYPE_BLOCKDEV ; type==TYPE_CHARDEV
00162:         struct _fdata {             // type==TYPE_FILE
00163:             uint64_t length;
00164:             uint64_t *chunktab;
00165:             uint32_t chunks;
00166:             sessionidrec *sessionids;
00167:         } fdata;
00168:     } ? end _data ?  data;
00169:     fsedge *parents;
00170:     struct _fsnode *next;
00171: } ? end _fsnode ?  fsnode;
```

系统模块的主要数据结构和算法介绍

- Mfsmaster核心数据结构，fsnode（续）



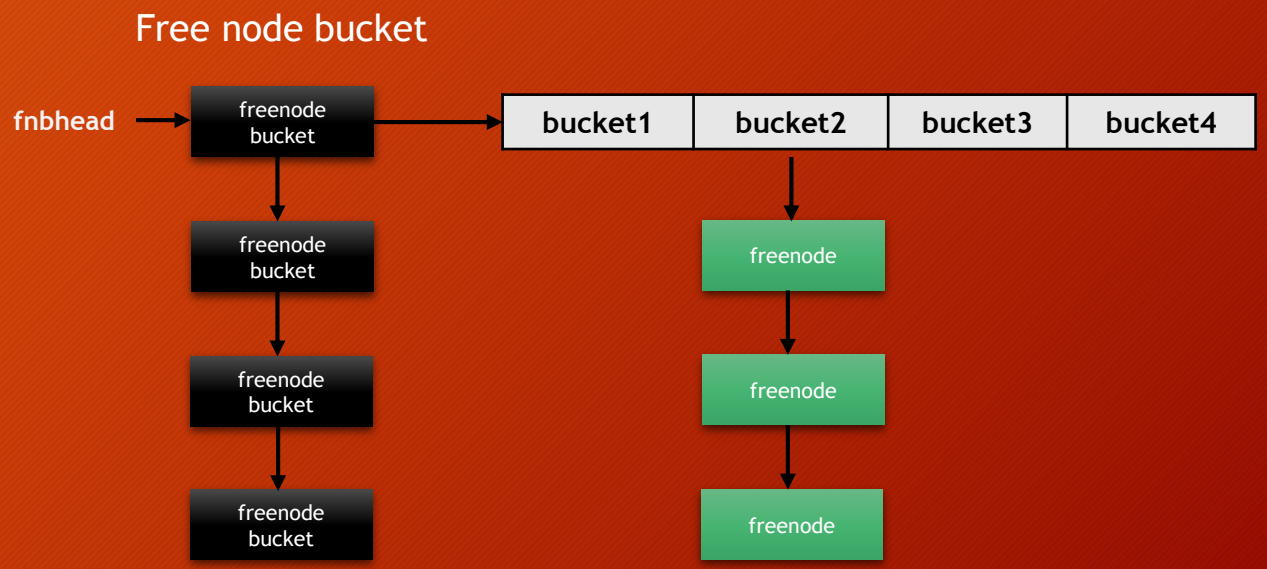

```
00057: #define NODEHASHBITS (22)
00058: #define NODEHASHSIZE (1<<NODEHASHBITS)
00059: #define NODEHASHPOS(nodeid) ((nodeid)&(NODEHASHSIZE-1))
```

系统模块的主要数据结构和算法介绍

- Mfsmaster核心数据结构，freenode（续）
  - 当remove/unlink/purge掉fsnode时，除了会释放fsnode的内存空间之外，还会将已释放的node id和free time保存在free node cache中。（并没有真正释放资源）
  - 有一个定时器线程，每一秒执行一次，将超过一天的freenode进行释放，并且重置freebitmask。

```
00173: typedef struct _freenode {
00174:     uint32_t id;
00175:     uint32_t ftime;
00176:     struct _freenode *next;
00177: } freenode;
```

```
00276: #define FREENODE_BUCKET_SIZE 5000
00277:
00278: typedef struct _freenode_bucket {
00279:     freenode bucket[FREENODE_BUCKET_SIZE];
00280:     uint32_t firstfree;
00281:     struct _freenode_bucket *next;
00282: } freenode_bucket;
```



系统模块的主要数据结构和算法介绍

- Mfsmaster核心数据结构，freenode（续）

```
00404: #ifndef METARESTORE
00405: void fsnodes_freeinodes(void) {
00406: #else
00407: uint8_t fs_freeinodes(uint32_t ts,uint32_t freeinodes) {
00408: #endif
00409:     uint32_t fi,now,pos,mask;
00410:     freenode *n,*an;
00411: #ifndef METARESTORE
00412:     now = main_time();
00413: #else
00414:     now = ts;
00415: #endif
00416:     fi = 0;
00417:     n = freelist;
00418:     while (n && n->ftime+86400<now) {
00419:         fi++;
00420:         pos = (n->id >> 5);
00421:         mask = 1<<(n->id&0x1F);
00422:         freebitmask[pos] &= ~mask;
00423:         if (pos<searchpos) {
00424:             searchpos = pos;
00425:         }
00426:         an = n->next;
00427:         freenode_free(n);
00428:         n = an;
00429:     }
00430:     if (n) {
00431:         freelist = n;
00432:     } else {
00433:         freelist = NULL;
00434:         freetail = &(freelist);
00435:     }
00436: #ifndef METARESTORE
00437:     changelog(version++,"%"PRIu32"|FREEINODES():%"PRIu32,(uint32_t)main_time(),fi);
00438: #else
00439:     version++;
00440:     if (freeinodes!=fi) {
00441:         return 1;
00442:     }
00443:     return 0;
00444: #endif
00445: } ? end fsnodes_freeinodes ?
```

真正释放文件系统fsnode节点资源
重置位图掩码

系统模块的主要数据结构和算法介绍

- Mfsmaster核心数据结构，fsedge（续）
  - 建立fsnode的关联关系

```
00098: typedef struct _fsedge {
00099:     struct _fsnode *child,*parent;
00100:     struct _fsedge *nextchild,*nextparent;
00101:     struct _fsedge **prevchild,**prevparent;
00102: #ifdef EDGEHASH
00103:     struct _fsedge *next,**prev;
00104: #endif
00105:     uint16_t nleng;
00106:     uint8_t *name;
00107: } fsedge;
```

Child指针，指向该边关联的子节点

Parent指针，指向该边关联的父节点

Nextchild/Prevchild指针，将该边链入parent节点的和子节点关联的fsedge双向链表中

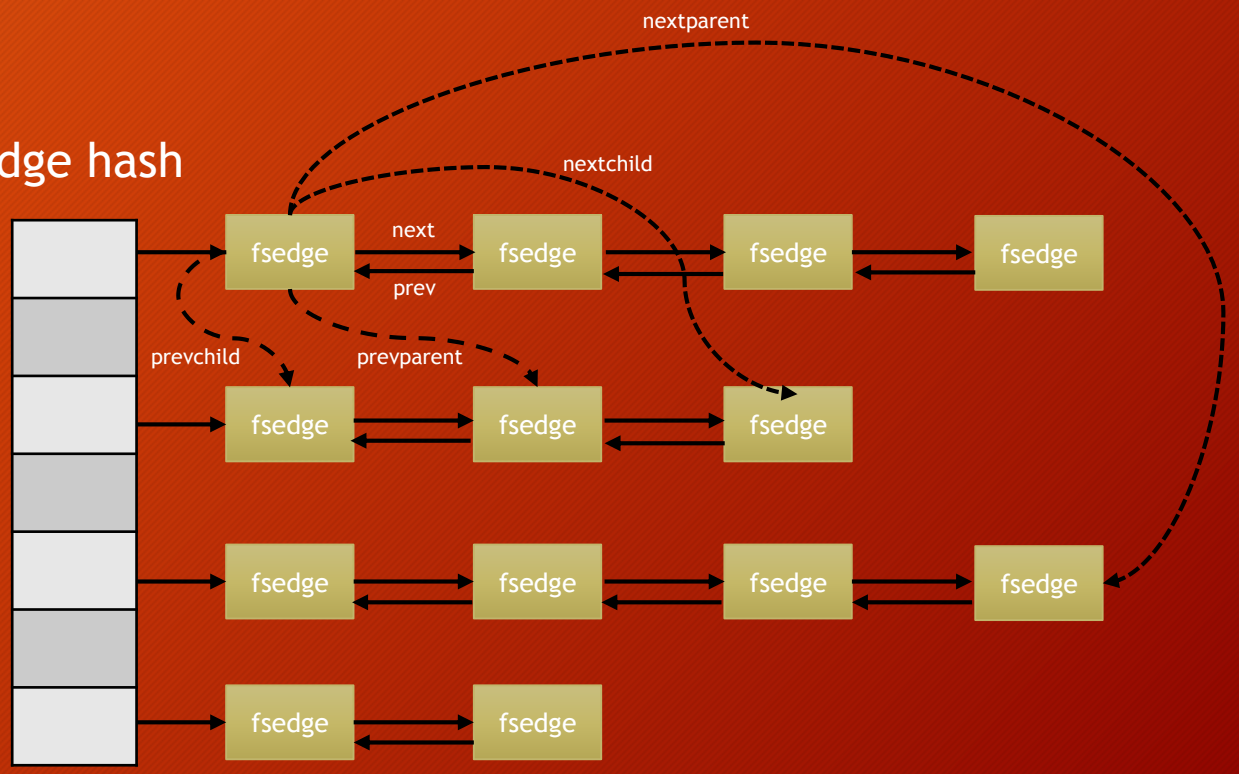
Nextparent/Prevparent指针，将该边链入child节点的和父节点关联的fsedge双向链表中

系统模块的主要数据结构和算法介绍

- Mfsmaster核心数据结构，fsedge（续）
  - 建立fsnode的关联关系

```
00062: #define EDGEHASHBITS (22)
00063: #define EDGEHASHSIZE (1<<EDGEHASHBITS)
00064: #define EDGEHASHPOS(hash) ((hash)&(EDGEHASHSIZE-1))
00065: #define LOOKUPNOHASHLIMIT 10
```

```
00521: static inline uint32_t fsnodes_hash(uint32_t parentid,uint16_t nleng,const uint8_t *name) {
00522:     uint32_t hash,i;
00523:     hash = ((parentid * 0x5F2318BD) + nleng);
00524:     for (i=0 ; i<nleng ; i++) {
00525:         hash = hash*33+name[i];
00526:     }
00527:     return hash;
00528: }
```



系统模块的主要数据结构和算法介绍

- Mfsmaster创建fsnode的过程

```
static inline fsnode* fsnodes_create_node(uint32_t ts,fsnode* node,uint16_t nleng,const uint8_t *name,uint8_t type,uint16_t mode,uint32_t uid,uint32_t gid) {
    fsnode *p;
#ifndef METARESTORE
    statsrecord *sr;
#endif
    uint32_t nodepos;
    p = malloc(sizeof(fsnode));
    nodes++;
    if (type==TYPE_DIRECTORY) {
        dirnodes++;
    }
    if (type==TYPE_FILE) {
        filenodes++;
    }
/* create node */
    p->id = fsnodes_get_next_id();
    p->type = type;
    p->ctime = p->mtime = p->atime = ts;
    if (type==TYPE_DIRECTORY || type==TYPE_FILE) {
        p->goal = node->goal;
        p->trashtime = node->trashtime;
    } else {
        p->goal = DEFAULT_GOAL;
        p->trashtime = DEFAULT_TRASHTIME;
    }
    if (type==TYPE_DIRECTORY) {
        p->mode = (mode&07777) | (node->mode&0xF000);
    } else {
        p->mode = (mode&07777) | (node->mode&(0xF000&(~(EATTR_NOECACHE<<12))));
    }
    p->uid = uid;
    p->gid = gid;
    switch (type) {
    case TYPE_DIRECTORY:
#ifndef METARESTORE
        sr = malloc(sizeof(statsrecord));
        memset(sr,0,sizeof(statsrecord));
        p->data.ddata.stats = sr;
        p->data.ddata.quota = NULL;
#endif
        p->data.ddata.children = NULL;
        p->data.ddata.nlink = 2;
        p->data.ddata.elements = 0;
        break;
    case TYPE_FILE:
        p->data.fdata.length = 0;
        p->data.fdata.chunks = 0;
        p->data.fdata.chunktab = NULL;
        p->data.fdata.sessionids = NULL;
        break;
    case TYPE_SYMLINK:
        p->data.sdata.pleng = 0;
        p->data.sdata.path = NULL;
        break;
    case TYPE_BLOCKDEV:
    case TYPE_CHARDEV:
        p->data.rdev = 0;
    } /* end switch type */
    p->parents = NULL;

    nodepos = NODEHASHPOS(p->id);
    p->next = nodehash[nodepos];
    nodehash[nodepos] = p;
    fsnodes_link(ts,node,p,nleng,name);
    return p;
} /* end fsnodes_create_node */
```

系统模块的主要数据结构和算法介绍

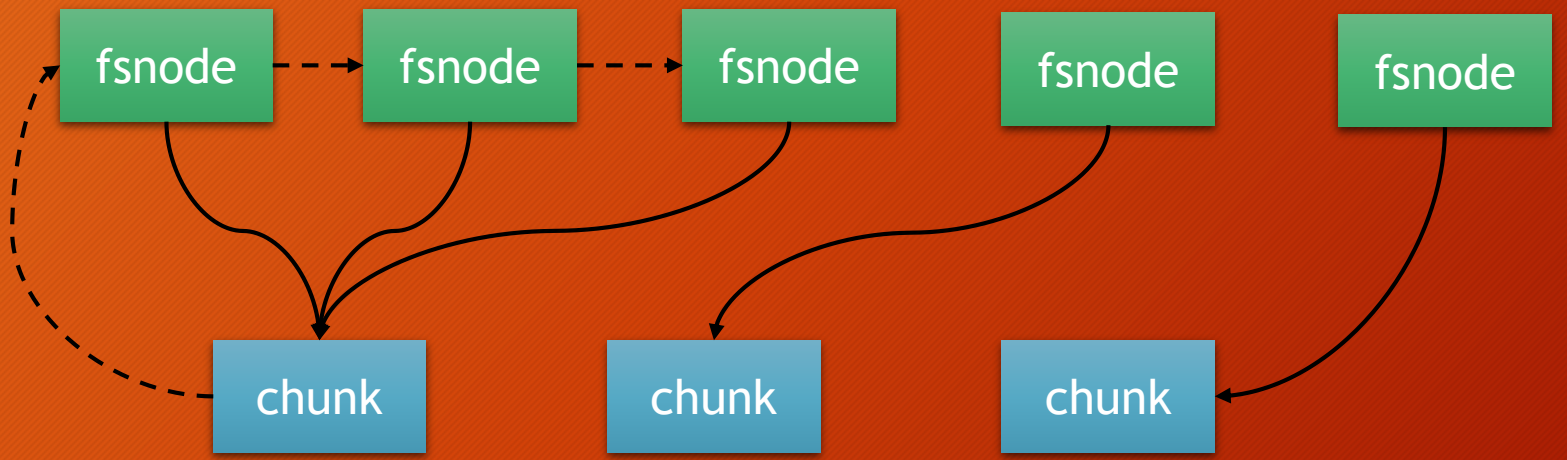
- Mfsmaster创建fsnode的过程（续）

```
00921: static inline void fsnodes_link(uint32_t ts,fsnode *parent,fsnode *child,uint16_t nleng,const uint8_t *name) {
00922:     fsedge *e;
00923: #ifndef METARESTORE
00924:     statsrecord sr;
00925: #endif
00926: #ifdef EDGEHASH
00927:     uint32_t hpos;
00928: #endif
00929:
00930:     e = malloc(sizeof(fsedge));
00931:     e->nleng = nleng;
00932:     e->name = malloc(nleng);
00933:     memcpy(e->name,name,nleng);
00934:     e->child = child;
00935:     e->parent = parent;
00936:     e->nextchild = parent->data.ddata.children;
00937:     if (e->nextchild) {
00938:         e->nextchild->prevchild = &(e->nextchild);
00939:     }
00940:     parent->data.ddata.children = e;
00941:     e->prevchild = &(parent->data.ddata.children);
00942:     e->nextparent = child->parents;
00943:     if (e->nextparent) {
00944:         e->nextparent->prevparent = &(e->nextparent);
00945:     }
00946:     child->parents = e;
00947:     e->prevparent = &(child->parents);
00948: #ifdef EDGEHASH
00949:     hpos = EDGEHASHPOS(fsnodes_hash(parent->id,nleng,name));
00950:     e->next = edgehash[hpos];
00951:     if (e->next) {
00952:         e->next->prev = &(e->next);
00953:     }
00954:     edgehash[hpos] = e;
00955:     e->prev = &(edgehash[hpos]);
00956: #endif
00957:
00958:     parent->data.ddata.elements++;
00959:     if (child->type==TYPE_DIRECTORY) {
00960:         parent->data.ddata.nlink++;
00961:     }
00962: #ifndef METARESTORE
00963:     fsnodes_get_stats(child,&sr);
00964:     fsnodes_add_stats(parent,&sr);
00965: #endif
00966:     if (ts>0) {
00967:         parent->mtime = parent->ctime = ts;
00968:     }
00969: } ? end fsnodes_link ?
```

建立fsnode和fsedge之间指针关系

系统模块的主要数据结构和算法介绍

- Mfsmaster的chunk结构



系统模块的主要数据结构和算法介绍

- Mfsmaster的chunk结构（续）

```
00117: typedef struct chunk {
00118:     uint64_t chunkid;
00119:     uint32_t version;
00120:     uint8_t goal;
00121: #ifndef METARESTORE
00122:     uint8_t allvalidcopies;
00123:     uint8_t regularvalidcopies;
00124:     uint8_t needverincrease:1;
00125:     uint8_t interrupted:1;
00126:     uint8_t operation:4;
00127: #endif
00128:     uint32_t lockedto;
00129: #ifndef METARESTORE
00130: //  uint32_t lockedby;
00131:     slist *slisthead;
00132: //  bcdata *bestchunk;
00133: #endif
00134:     flist *flisthead;
00135:     struct chunk *next;
00136: } ? end chunk ?  chunk;
```

Chunk server list which is aligned with goal!

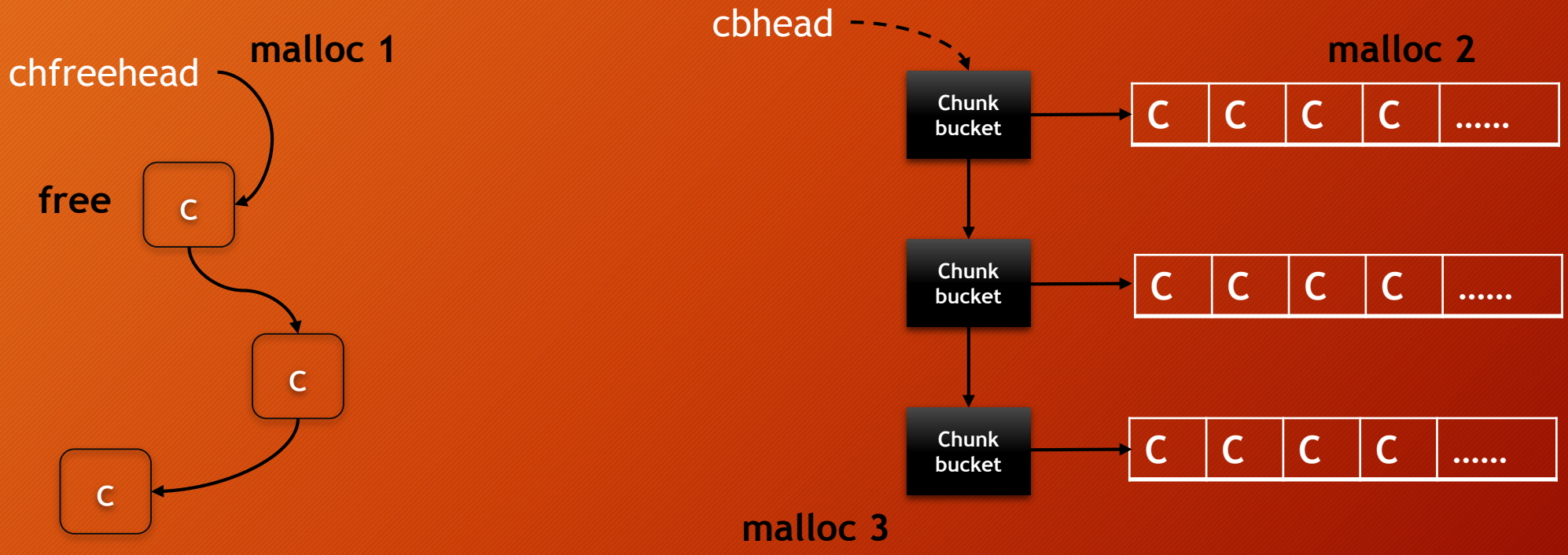
Create chunk

```
01009:         if (servcount<goal) {
01010:             c->allvalidcopies = servcount;
01011:             c->regularvalidcopies = servcount;
01012:         } else {
01013:             c->allvalidcopies = goal;
01014:             c->regularvalidcopies = goal;
01015:         }
01016:         for (i=0 ; i<c->allvalidcopies ; i++) {
01017:             s = slist_malloc();
01018:             s->ptr = ptrs[i];
01019:             s->valid = BUSY;
01020:             s->version = c->version;
01021:             s->next = c->slisthead;
01022:             c->slisthead = s;
01023:             matocsserv_send_createchunk(s->ptr,c->chunkid,c->version);
01024:         }
```

node list

系统模块的主要数据结构和算法介绍

- Mfsmaster的chunk结构（续）
  - 内存管理-预分配技术



系统模块的主要数据结构和算法介绍

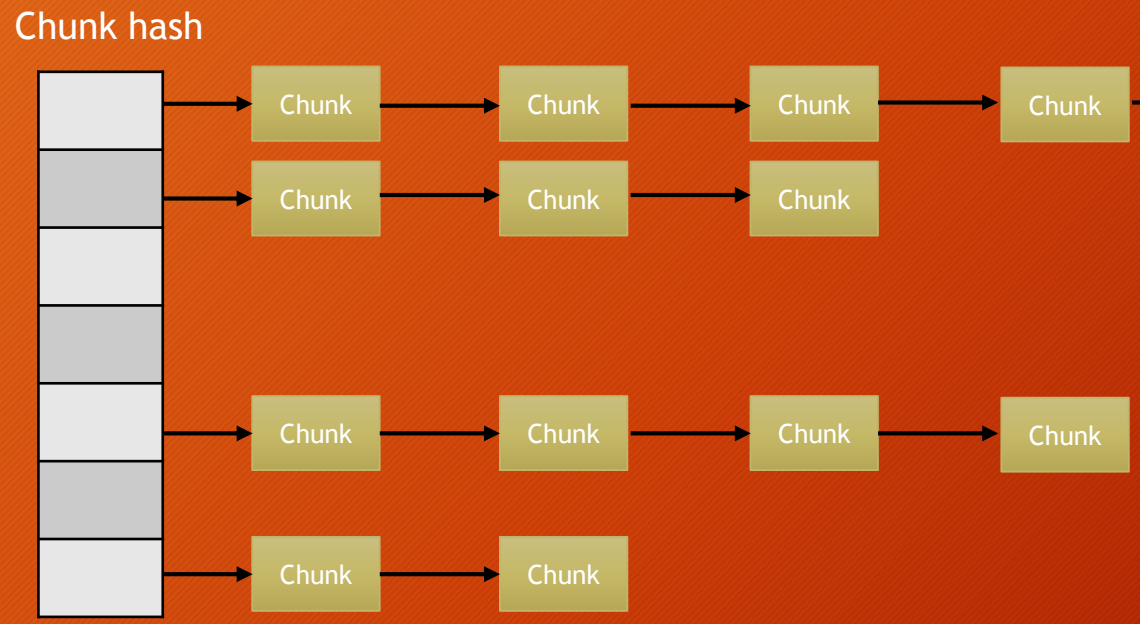
- 内存管理-预分配技术

```
00138: #ifdef USE_CHUNK_BUCKETS
00139: #define CHUNK_BUCKET_SIZE 20000
00140: typedef struct _chunk_bucket {
00141:     chunk bucket[CHUNK_BUCKET_SIZE];
00142:     uint32_t firstfree;
00143:     struct _chunk_bucket *next;
00144: } chunk_bucket;
00145:
00146: static chunk_bucket *cbhead = NULL;
00147: static chunk *chfreehead = NULL;
00148: #endif /* USE_CHUNK_BUCKETS */
00149:
00150: static chunk *chunkhash[HASHSIZE];
```

```
00308: static inline chunk* chunk_malloc() {
00309:     chunk_bucket *cb;
00310:     chunk *ret;
00311:     if (chfreehead) {
00312:         ret = chfreehead;
00313:         chfreehead = ret->next;
00314:         return ret;
00315:     }
00316:     if (cbhead==NULL || cbhead->firstfree==CHUNK_BUCKET_SIZE) {
00317:         cb = (chunk_bucket*)malloc(sizeof(chunk_bucket));
00318:         cb->next = cbhead;
00319:         cb->firstfree = 0;
00320:         cbhead = cb;
00321:     }
00322:     ret = (cbhead->bucket)+(cbhead->firstfree);
00323:     cbhead->firstfree++;
00324:     return ret;
00325: }
00326:
00327: static inline void chunk_free(chunk *p) {
00328:     p->next = chfreehead;
00329:     chfreehead = p;
00330: }
```

系统模块的主要数据结构和算法介绍

- Mfsmaster的chunk结构（续）
  - Chunk管理（快速定位）



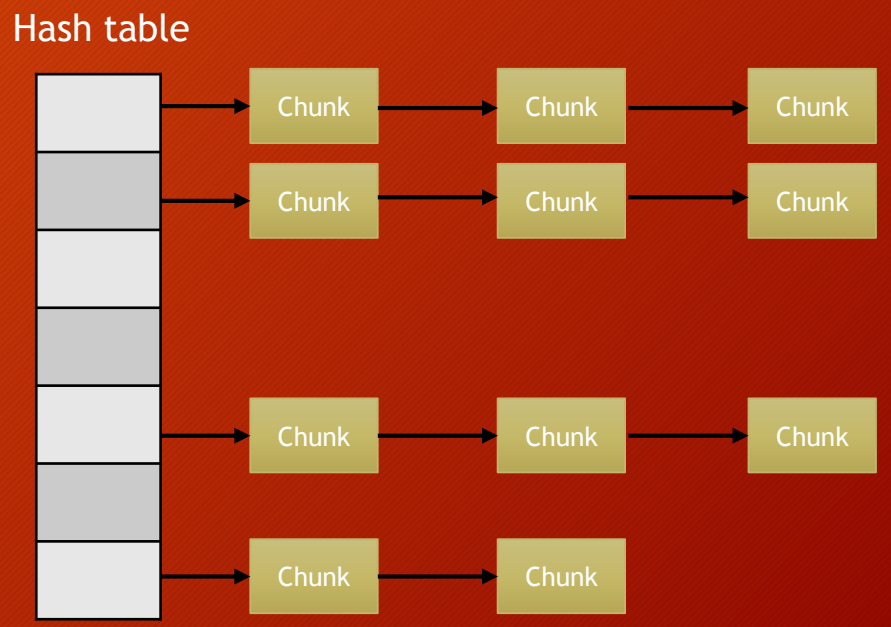

```
00052: #define HASHSIZE 65536
00053: #define HASHPOS(chunkid) (((uint32_t)chunkid)&0xFFFF)
```

Chunkid（uint64_t）是一个从1开始的自增id

系统模块的主要数据结构和算法介绍

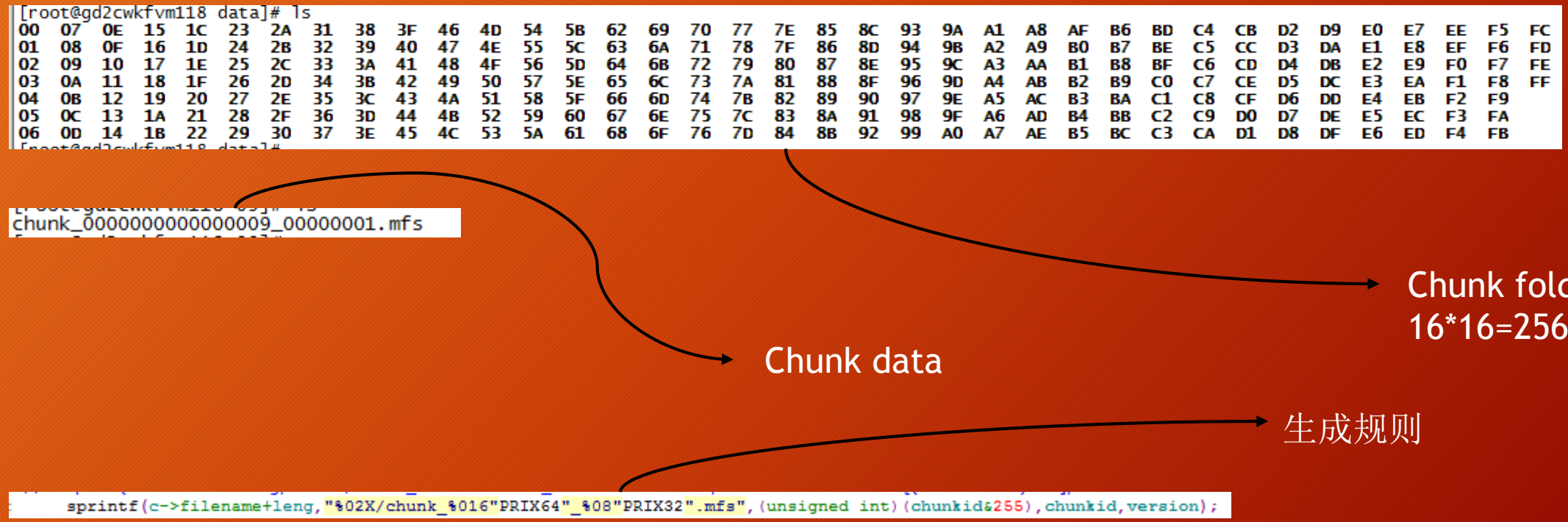
- Mfschunkserver的chunk结构

```
00121: typedef struct chunk {
00122:     char *filename;
00123:     uint64_t chunkid;
00124:     struct folder *owner;
00125:     uint32_t version;
00126:     uint16_t blocks;
00127:     uint16_t crcrefcount;
00128:     uint8_t opensteps;
00129:     uint8_t crcsteps;
00130:     uint8_t crcchanged;
00131: #ifdef _THREAD_SAFE
00132: #define CH_AVAIL 0
00133: #define CH_LOCKED 1
00134: #define CH_DELETED 2
00135: #define CH_TOBEDELETED 3
00136:     uint8_t state;   // CH_AVAIL,CH_LOCKED,CH_DELETED
00137:     cntcond *ccond;
00138: #endif
00139:     uint8_t *crc;
00140:     int fd;
00141:
00142: #ifdef PRESERVE_BLOCK
00143:     uint8_t *block;
00144:     uint16_t blockno;    // 0xFFFF == invalid
00145:     uint8_t blocksteps;
00146: #endif
00147: #ifdef _THREAD_SAFE
00148:     uint32_t testtime;   // at start use max(atime,mtime) then every operation set it to current time
00149:     struct chunk *testnext,**testprev;
00150: #endif
00151:     struct chunk *next;
00152: } ? end chunk ?   chunk;
```



系统模块的主要数据结构和算法介绍

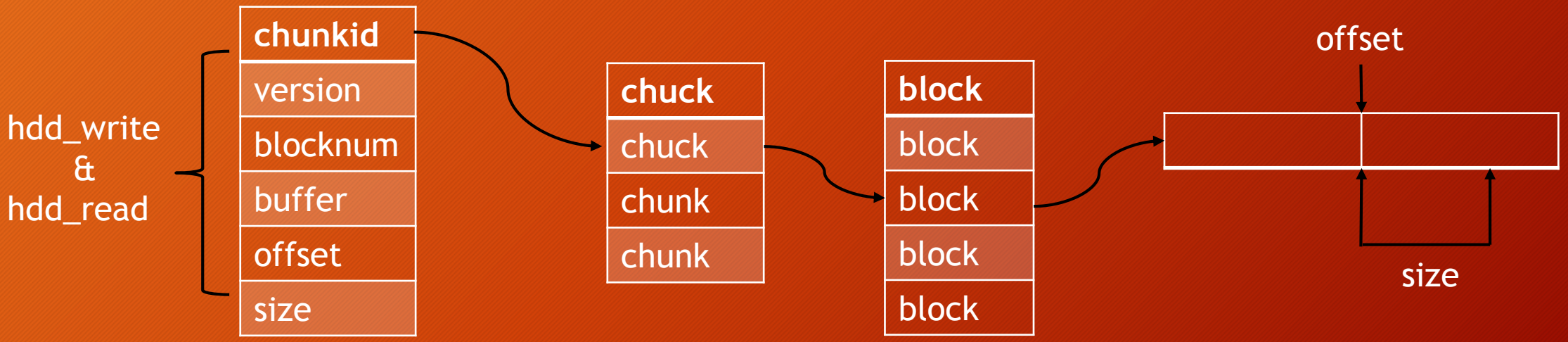
- Mfschunkserver的chunk结构（续）



系统模块的主要数据结构和算法介绍

- Mfschunkserver的block
  - 一个block的大小为0x10000，Blocknum为block的编号。

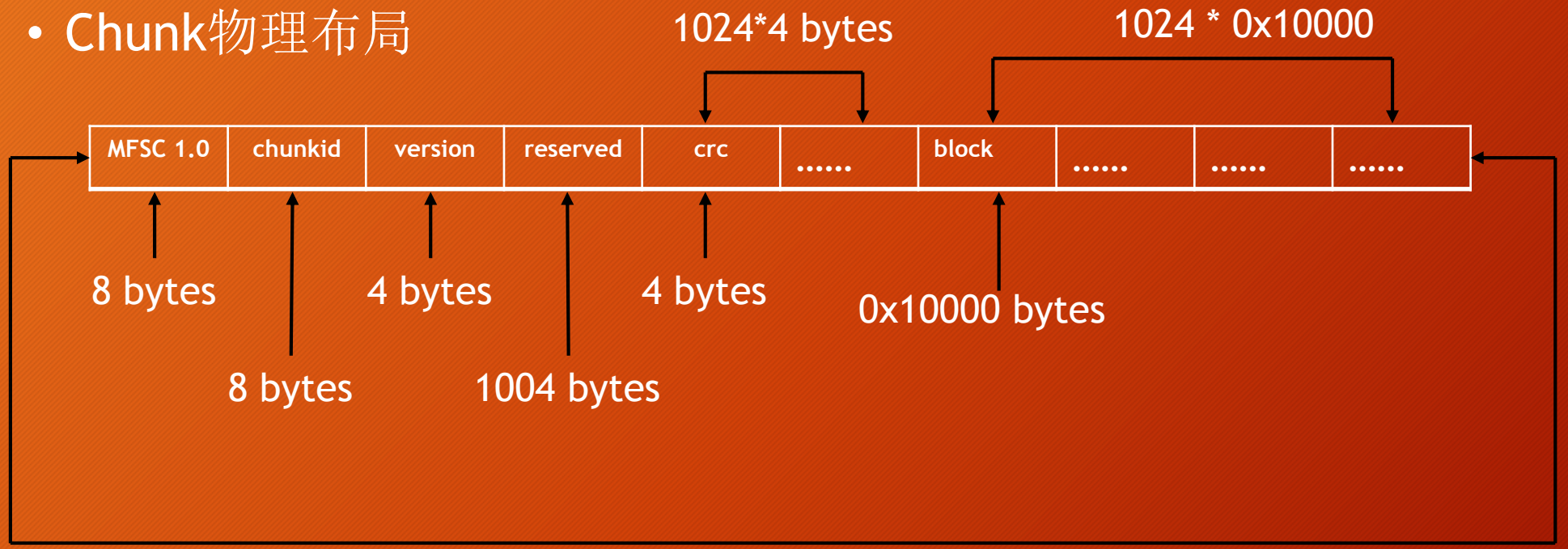
```
lseek(c->fd,CHUNKHDRSIZE+(((uint32_t)blocknum)<<16),SEEK_SET);
ret = write(c->fd,buffer,0x10000);
```



Max size：0x400=1024个block

系统模块的主要数据结构和算法介绍

- Chunk物理布局



(1024 + 1024*4)+ 1024 * 0x10000

Header + Data

系统模块的主要数据结构和算法介绍

- 读和写都是以block为单位进行
  - 举例

```
blocknum = (eptr->offset)>>16;
blockoffset = (eptr->offset)&0xFFFF;
if (((eptr->offset+eptr->size-1)>>16) == blocknum) {     // last block
    size = eptr->size;
} else {
    size = 0x10000-blockoffset;
}
```

read_block函数对读取size进行调整

系统模块的主要数据结构和算法介绍

- Mfs确保data copy的数据一致性，进程后台timer，做data copy的一致性校验，定时向chunk server发送删除无效chunk的消息，确保data copy是一致的。
  - calculate number of valid and invalid copies & verify
  - check number of copies
  - delete invalid copies
  - return if chunk is during some operation
  - check busy count
  - delete unused chunk
  - if chunk has too many copies then delete some of them
  - if chunk has one copy on each server and some of them have status TODEL then delete one of it
  - if chunk has number of copies less than goal then make another copy of this chunk
  - if there is too big difference between chunk servers then make copy of chunk from server with biggest disk usage on server with lowest disk usage

```
void chunk_do_jobs(chunk *c,uint16_t scount,double minusage,double maxusage) {
```

系统模块的主要数据结构和算法介绍

- Mfs确保data copy的数据一致性（续）

```
    if (c->flisthead==NULL) {
//      syslog(LOG_WARNING,"unused - delete");
        if (delcount<TmpMaxDel) {
            for (s=c->slisthead ; s ; s=s->next) {
                if (s->valid==VALID || s->valid==TDVALID) {
                    if (s->valid==TDVALID) {
                        chunk_state_change(c->goal,c->goal,c->allvalidcopies,c->allvalidcopies-1,c->regularvalidcopies,c->regularvalidcopies);
                        c->allvalidcopies--;
                    } else {
                        chunk_state_change(c->goal,c->goal,c->allvalidcopies,c->allvalidcopies-1,c->regularvalidcopies,c->regularvalidcopies-1);
                        c->allvalidcopies--;
                        c->regularvalidcopies--;
                    }
                    c->needverincrease=1;
                    s->valid = DEL;
                    stats_deletions++;
                    matocsserv_send_deletechunk(s->ptr,c->chunkid,c->version);
                    delcount++;
                    inforec.done.del_unused++;
                }
            }
        } ? end if delcount<TmpMaxDel ?  else {
            for (s=c->slisthead ; s ; s=s->next) {
                if (s->valid==VALID || s->valid==TDVALID) {
                    inforec.notdone.del_unused++;
                }
            }
        }
        return ;
    } ? end if c->flisthead==NULL ?
```

Master

```
static void hdd_chunk_delete(chunk *c) {
    folder *f;
    pthread_mutex_lock(&hashlock);
    f = c->owner;
    if (c->ccond) {
        c->state = CH_DELETED;
//      printf("wake up one thread waiting for DELETED chunk: %"PR
//      printbacktrace();
        pthread_cond_signal(&(c->ccond->cond));
    } else {
        hdd_chunk_remove(c);
    }
    pthread_mutex_unlock(&hashlock);
    pthread_mutex_lock(&folderlock);
    f->chunkcount--;
    f->needrefresh = 1;
    pthread_mutex_unlock(&folderlock);
}
#else
static void hdd_chunk_delete(chunk *c) {
    c->owner->chunkcount--;
    c->owner->needrefresh = 1;
    hdd_chunk_remove(c);
}
#endif
```

Chunk server

系统模块的主要数据结构和算法介绍

- Mfschunkserver进程后台起了一个timer，定时对chunk文件进行有效性验证，步骤如下：
  - 根据chunk id查找内存中是否有分配相应的chunk数据结构。
  - Chunk的版本
  - 是否能够成功的打开chunk文件
  - 对每个block的数据进行CRC（32位）校验。
  - 是否能够关闭chunk文件
  - 将damaged的chunk缓存到全局链表damagedchunks，上报给master。

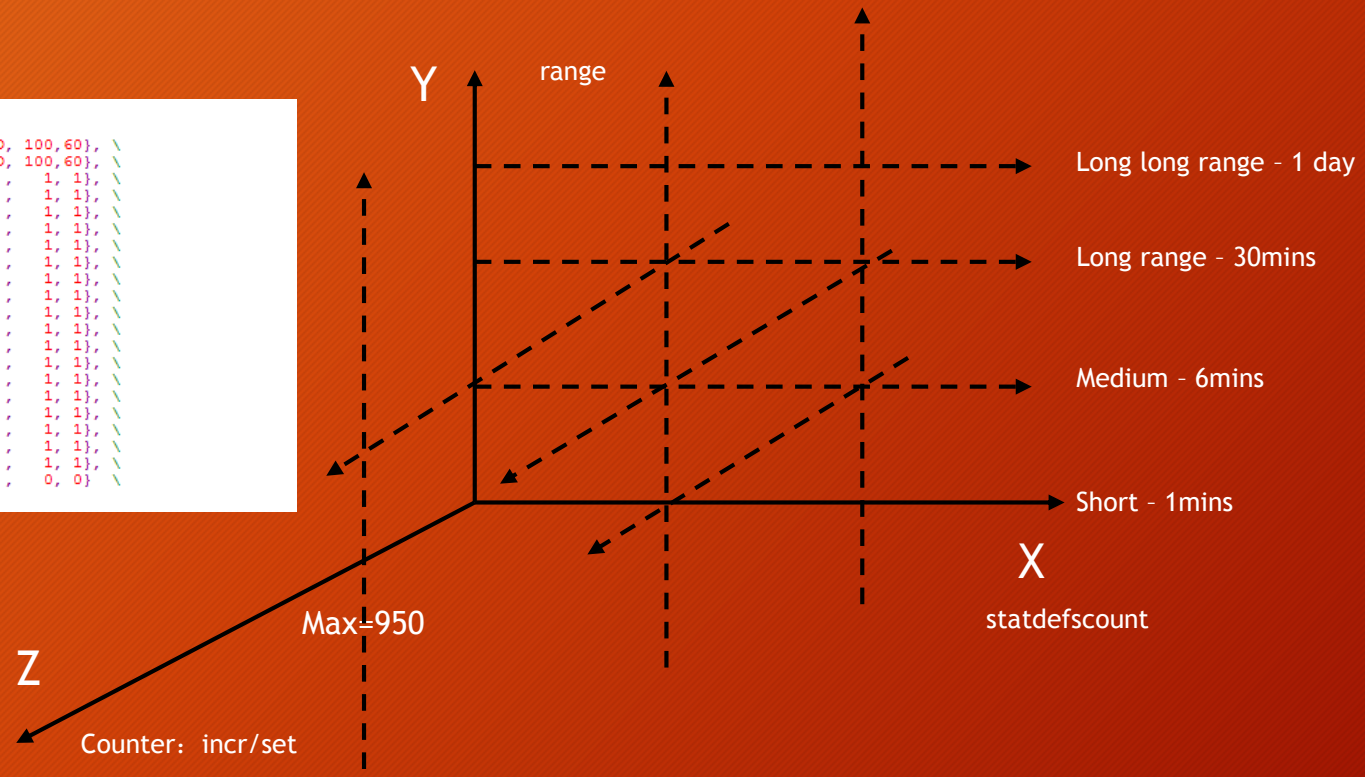
```
00168: typedef struct folder {
00169:     char *path;
00170:     unsigned int needrefresh:1;
00171:     unsigned int todel:1;
00172:     unsigned int damaged:1;
00173:     uint64_t leavefree;
00174:     uint64_t avail;
00175:     uint64_t total;
00176:     hddstats cstat;
00177:     hddstats stats[STATSHISTORY];
00178:     uint32_t statspos;
00179:     ioerror lasterrtab[LASTERRSIZE];
00180:     uint32_t chunkcount;
00181:     uint32_t lasterrindx;
00182:     uint32_t lastrefresh;
00183:     dev_t devid;
00184:     ino_t lockinode;
00185:     double carry;
00186: #ifdef _THREAD_SAFE
00187:     pthread_t scanthread;
00188:     struct chunk *testhead,**testtail;
00189: #endif
00190:     struct folder *next;
00191: } ? end folder ?  folder;
```

系统模块的主要数据结构和算法介绍

- Mfsmaster的Chart data

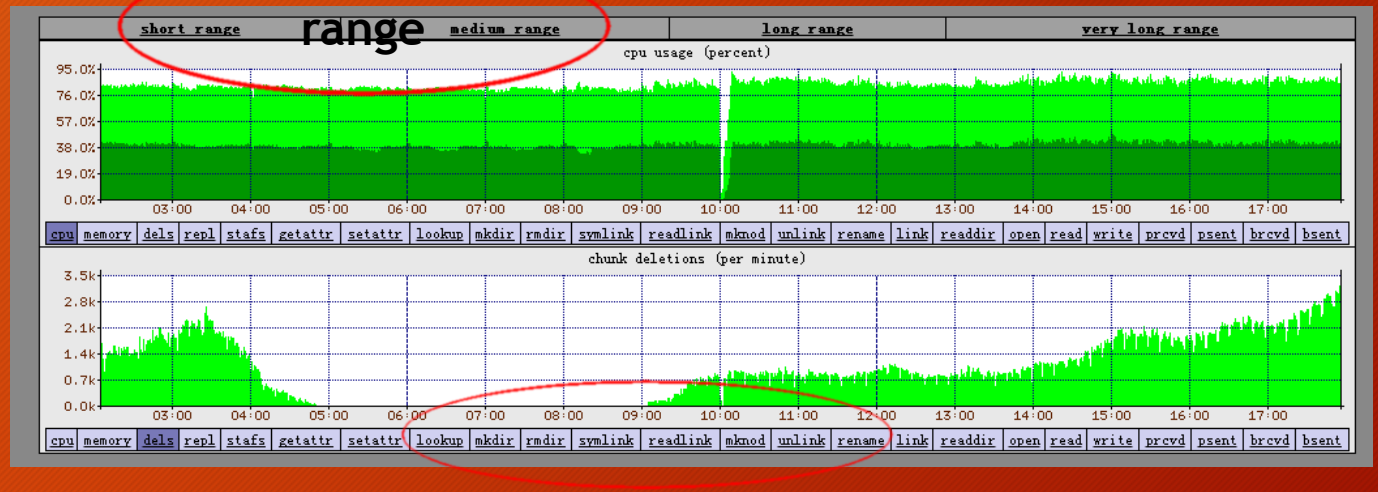
```
00062: /* name , join mode , percent , scale , multiplier , divisor */
00063: #define STATDEFS { \
00064:     {"ucpu"          ,CHARTS_MODE_ADD,1,CHARTS_SCALE_MICRO, 100,60}, \
00065:     {"scpu"          ,CHARTS_MODE_ADD,1,CHARTS_SCALE_MICRO, 100,60}, \
00066:     {"delete"        ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00067:     {"replicate"     ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00068:     {"statfs"        ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00069:     {"getattr"       ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00070:     {"setattr"       ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00071:     {"lookup"        ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00072:     {"mkdir"         ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00073:     {"rmdir"         ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00074:     {"symlink"       ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00075:     {"readlink"      ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00076:     {"mknod"         ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00077:     {"unlink"        ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00078:     {"rename"        ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00079:     {"link"          ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00080:     {"readdir"       ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00081:     {"open"          ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00082:     {"read"          ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00083:     {"write"         ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00084:     {NULL            ,0              ,0,0                 ,   0, 0}  \
00085: };
```

```
00081:
00082: typedef uint64_t stat_record[RANGES][LENG];
00083:
00084: static stat_record *series;
```

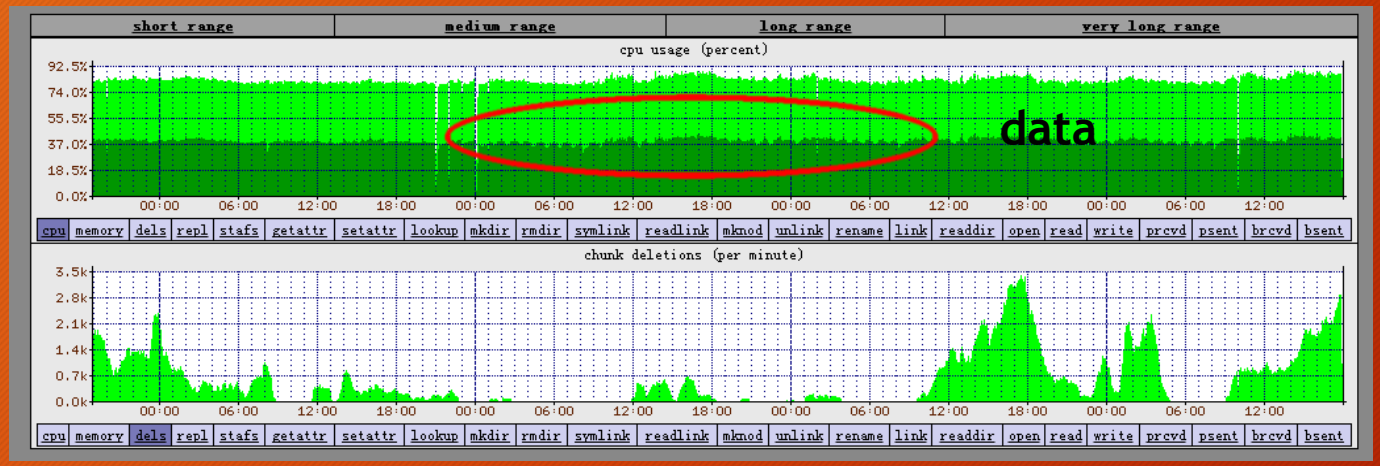


每分钟flush一次-> stats.mfs、csstats.mfs

系统模块的主要数据结构和算法介绍



operation



系统模块的主要数据结构和算法介绍

- Mfschunkserver的Chart data

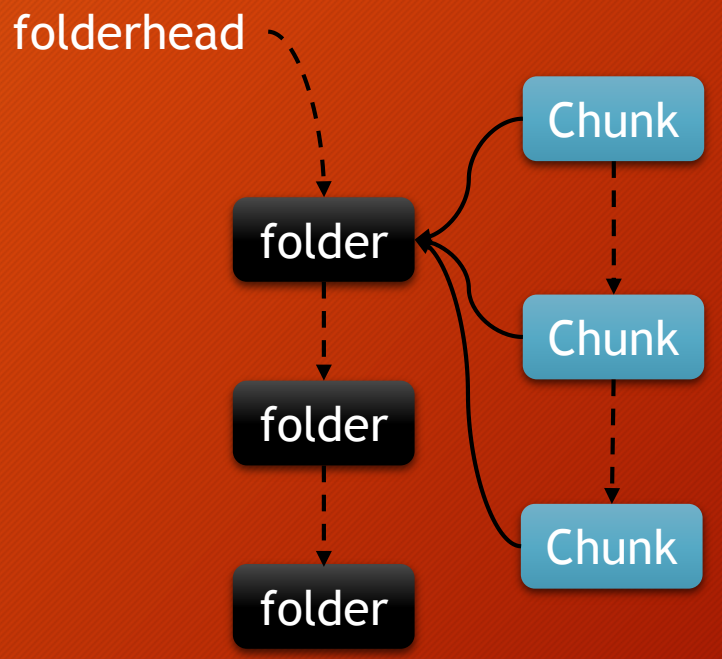
```
00075: /* name , join mode , percent , scale , multiplier , divisor */
00076: #define STATDEFS { \
00077:     {"ucpu"          ,CHARTS_MODE_ADD,1,CHARTS_SCALE_MICRO, 100,60}, \
00078:     {"scpu"          ,CHARTS_MODE_ADD,1,CHARTS_SCALE_MICRO, 100,60}, \
00079:     {"masterin"      ,CHARTS_MODE_ADD,0,CHARTS_SCALE_MILI ,8000,60}, \
00080:     {"masterout"     ,CHARTS_MODE_ADD,0,CHARTS_SCALE_MILI ,8000,60}, \
00081:     {"csconnin"      ,CHARTS_MODE_ADD,0,CHARTS_SCALE_MILI ,8000,60}, \
00082:     {"csconnout"     ,CHARTS_MODE_ADD,0,CHARTS_SCALE_MILI ,8000,60}, \
00083:     {"csservin"      ,CHARTS_MODE_ADD,0,CHARTS_SCALE_MILI ,8000,60}, \
00084:     {"csservout"     ,CHARTS_MODE_ADD,0,CHARTS_SCALE_MILI ,8000,60}, \
00085:     {"bytesr"        ,CHARTS_MODE_ADD,0,CHARTS_SCALE_MILI ,1000,60}, \
00086:     {"bytesw"        ,CHARTS_MODE_ADD,0,CHARTS_SCALE_MILI ,1000,60}, \
00087:     {"llopr"         ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00088:     {"llopw"         ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00089:     {"databytesr"    ,CHARTS_MODE_ADD,0,CHARTS_SCALE_MILI ,1000,60}, \
00090:     {"databytesw"    ,CHARTS_MODE_ADD,0,CHARTS_SCALE_MILI ,1000,60}, \
00091:     {"datallopr"     ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00092:     {"datallopw"     ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00093:     {"hlopr"         ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00094:     {"hlopw"         ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00095:     {"rtime"         ,CHARTS_MODE_ADD,0,CHARTS_SCALE_MICRO,   1,60}, \
00096:     {"wtime"         ,CHARTS_MODE_ADD,0,CHARTS_SCALE_MICRO,   1,60}, \
00097:     {"repl"          ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00098:     {"create"        ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00099:     {"delete"        ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00100:     {"version"       ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00101:     {"duplicate"     ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00102:     {"truncate"      ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00103:     {"duptrunc"      ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00104:     {"test"          ,CHARTS_MODE_ADD,0,CHARTS_SCALE_NONE ,   1, 1}, \
00105:     {"chunkiojobs"   ,CHARTS_MODE_MAX,0,CHARTS_SCALE_NONE ,   1, 1}, \
00106:     {"chunkopjobs"   ,CHARTS_MODE_MAX,0,CHARTS_SCALE_NONE ,   1, 1}, \
00107:     {NULL            ,0               ,0,0                 ,   0, 0}  \
00108: };
```

数据存储结构，同mfsmaster一样

系统模块的主要数据结构和算法介绍

- Mfschunkserver的folder数据结构

```
00168: typedef struct folder {
00169:     char *path;
00170:     unsigned int needrefresh:1;
00171:     unsigned int todel:1;
00172:     unsigned int damaged:1;
00173:     uint64_t leavefree;
00174:     uint64_t avail;
00175:     uint64_t total;
00176:     hddstats cstat;
00177:     hddstats stats[STATSHISTORY];
00178:     uint32_t statspos;
00179:     ioerror lasterrtab[LASTERRSIZE];
00180:     uint32_t chunkcount;
00181:     uint32_t lasterrindx;
00182:     uint32_t lastrefresh;
00183:     dev_t devid;
00184:     ino_t lockinode;
00185:     double carry;
00186: #ifdef _THREAD_SAFE
00187:     pthread_t scanthread;
00188:     struct chunk *testhead,**testtail;
00189: #endif
00190:     struct folder *next;
00191: } ? end folder ?   folder;
```



系统模块的主要数据结构和算法介绍

- Mfschunkserver在create_chunk的时候，如何选择合适的分区？

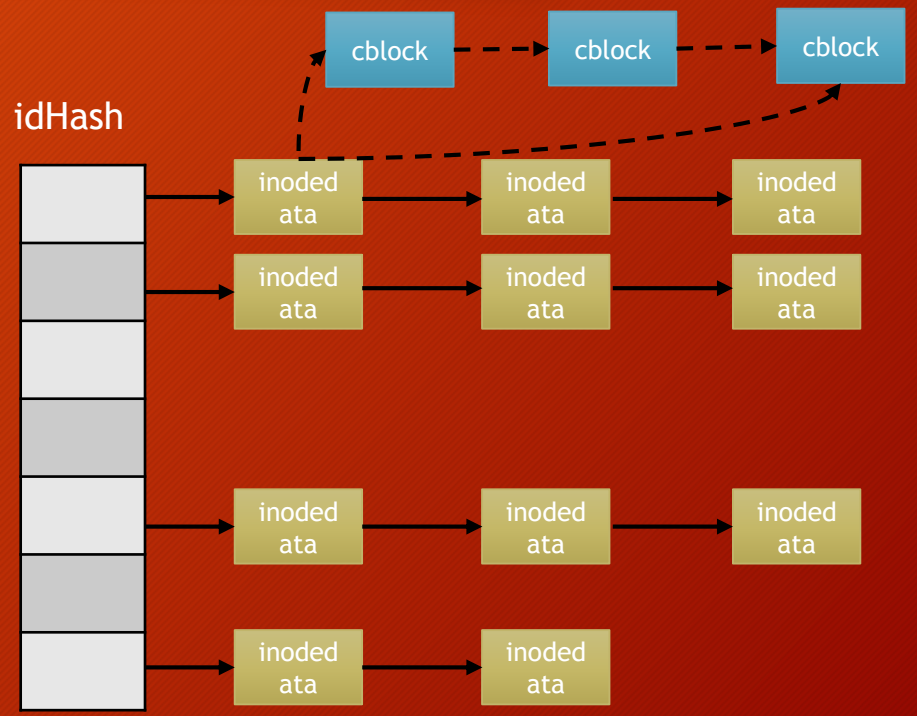
```
01045: static inline folder* hdd_getfolder() {
01046:     folder *f,*bf;
01047:     double maxcarry;
01048:     double minavail,maxavail;
01049:     double s,d;
01050:     double pavail;
01051:     int ok;
01052: //  uint64_t minavail;
01053:
01054:     minavail=0.0;
01055:     maxavail=0.0;
01056:     maxcarry=1.0;
01057:     bf=NULL;
01058:     ok=0;
01059:     for (f=folderhead ; f ; f=f->next) {
01060:         if (f->damaged || f->todel || f->total==0 || f->avail==0) {
01061:             continue;
01062:         }
01063:         if (f->carry >= maxcarry) {
01064:             maxcarry = f->carry;
01065:             bf=f;
01066:         }
01067:         pavail = (double)(f->avail)/(double)(f->total);
01068:         if (ok==0 || minavail>pavail) {
01069:             minavail=pavail;
01070:             ok=1;
01071:         }
01072:         if (pavail>maxavail) {
01073:             maxavail=pavail;
01074:         }
01075:     }
01076:     if (bf) {
01077:         bf->carry-=1.0;
01078:         return bf;
01079:     }
01080:     if (maxavail==0.0) {     // no space
01081:         return NULL;
01082:     }
```

```
01083:     if (maxavail<0.01) {
01084:         s=0.0;
01085:     } else {
01086:         s=minavail*0.8;
01087:         if (s<0.01) {
01088:             s=0.01;
01089:         }
01090:     }
01091:     d = maxavail-s;
01092:     maxcarry=1.0;
01093:     for (f=folderhead ; f ; f=f->next) {
01094:         if (f->damaged || f->todel || f->total==0 || f->avail==0) {
01095:             continue;
01096:         }
01097:         pavail = (double)(f->avail)/(double)(f->total);
01098:         if (pavail>s) {
01099:             f->carry += ((pavail-s)/d);
01100:         }
01101:         if (f->carry >= maxcarry) {
01102:             maxcarry = f->carry;
01103:             bf=f;
01104:         }
01105:     }
01106:     if (bf) {    // should be always true
01107:         bf->carry-=1.0;
01108:     }
01109:     return bf;
01110: } ? end hdd_getfolder ?
```

系统模块的主要数据结构和算法介绍

- Mfsmount的inode

```
00043: typedef struct cblock_s {
00044:     uint8_t data[65536];      // modified only when writeid==0
00045:     uint16_t chindx;          // chunk number
00046:     uint16_t pos;             // block in chunk (0...1023) - never modified
00047:     uint32_t writeid;         // 0 = not sent, >0 = block was sent (modified and accessed only when wchunk is locked)
00048:     uint32_t from;            // first filled byte in data (modified only when writeid==0)
00049:     uint32_t to;              // first not used byte in data (modified only when writeid==0)
00050:     struct cblock_s *next,*prev;
00051: } cblock;
00052:
00053: typedef struct inodedata_s {
00054:     uint32_t inode;
00055:     uint64_t maxfleng;
00056:     uint32_t cacheblocks;
00057:     int status;
00058:     uint16_t flushwaiting;
00059:     uint16_t writewaiting;
00060:     uint16_t cachewaiting;
00061:     uint16_t lcnt;
00062:     uint32_t trycnt;
00063:     uint8_t waitingworker;
00064:     uint8_t inqueue;
00065:     int pipe[2];
00066:     cblock *datachainhead,*datachaintail;
00067:     pthread_cond_t flushcond;     // wait for inqueue==0 (flush)
00068:     pthread_cond_t writecond;     // wait for flushwaiting==0 (write)
00069:     pthread_cond_t cachecond;     // wait for cache blocks
00070:     struct inodedata_s *next;
00071: } inodedata;
```



1. 1024 BLOCKS IN CHUNK
2. THE SIZE OF BLOCK IS 65532
3. IN EACH HDD_WRITE, THE SIZE IS 16 BYTES

系统模块的主要数据结构和算法介绍

- 写文件系统，mfsmount进程将从mfsmaster进程获取mfschunkserver的最佳路由表。将要写入文件系统的数据根据路由表进行数据路由，mfschunkserver执行写操作。

```
01521:      for (s=c->slisthead ;s ; s=s->next) {
01522:          if (s->valid!=INVALID && s->valid!=DEL) {
01523:              if (cnt<100 && matocsserv_getlocation(s->ptr,&(lstab[cnt].ip),&(lstab[cnt].port))==0) {
01524:                  lstab[cnt].dist = (lstab[cnt].ip==cuip)?0:1;      // in the future prepare more sofisticated distance function
01525:                  lstab[cnt].rnd = rndu32();
01526:                  cnt++;
01527:              }
01528: //           sptr[cnt++]=s->ptr;
01529:          }
01530:      }
01531:      qsort(lstab,cnt,sizeof(locsort),chunk_locsort_cmp);
01532:      wptr = log;
```

系统模块的主要数据结构和算法介绍

- Mfsmaster访问控制数据结构

```
00019: typedef struct _acl {
00020:     uint32_t pleng;
00021:     const uint8_t *path;     // without '/' at the begin and at the end
00022:     uint32_t fromip,toip;
00023:     uint32_t minversion;
00024:     uint8_t passworddigest[16];
00025:     unsigned alldirs:1;
00026:     unsigned needpassword:1;
00027:     unsigned meta:1;
00028:     unsigned rootredefined:1;
00029: //   unsigned old:1;
00030:     uint8_t sesflags;
00031:     uint32_t rootuid;
00032:     uint32_t rootgid;
00033:     uint32_t mapalluid;
00034:     uint32_t mapallgid;
00035:     struct _acl *next;
00036: } acl;
```

- 进程刚启动的时候，会初始化访问控制链表

```
00789: int acl_init(FILE *msgfd) {
00790:     ExportsFileName = cfg_getstr("EXPORTS_FILENAME",ETC_PATH "/mfsexports.cfg");
00791:     acl_records = NULL;
00792:     acl_loadexports(msgfd);
00793:     main_reloadregister(acl_reloadexports);
00794:     return 0;
00795: }
```

- Mfsmount向mfsmaster发送注册消息，会进行访问权限的校验
  - IP地址范围校验
  - 目录校验
  - 密码校验
  - 访问权限校验read/write/gid/uid

系统模块的主要数据结构和算法介绍

- Mfsmaster会话数据结构
  - 当有新的mfsmount向master注册的时候，会创建一个新的会话
  - 将会话信息存储在本地，用于master进程恢复

```
00079: typedef struct session {
00080:     uint32_t sessionid;
00081:     char *info;
00082:     uint32_t peerip;
00083:     uint8_t newsession;
00084:     uint8_t sesflags;
00085:     uint32_t rootuid;
00086:     uint32_t rootgid;
00087:     uint32_t mapalluid;
00088:     uint32_t mapallgid;
00089:     uint32_t rootinode;
00090:     uint32_t disconnected;   // 0 = connected ; other = disconnection timestamp
00091:     uint32_t nsocks;     // >0 - connected (number of active connections) ; 0 - not connected
00092:     uint32_t currentopstats[16];
00093:     uint32_t lasthouropstats[16];
00094:     filelist *openedfiles;
00095:     struct session *next;
00096: } session;
```

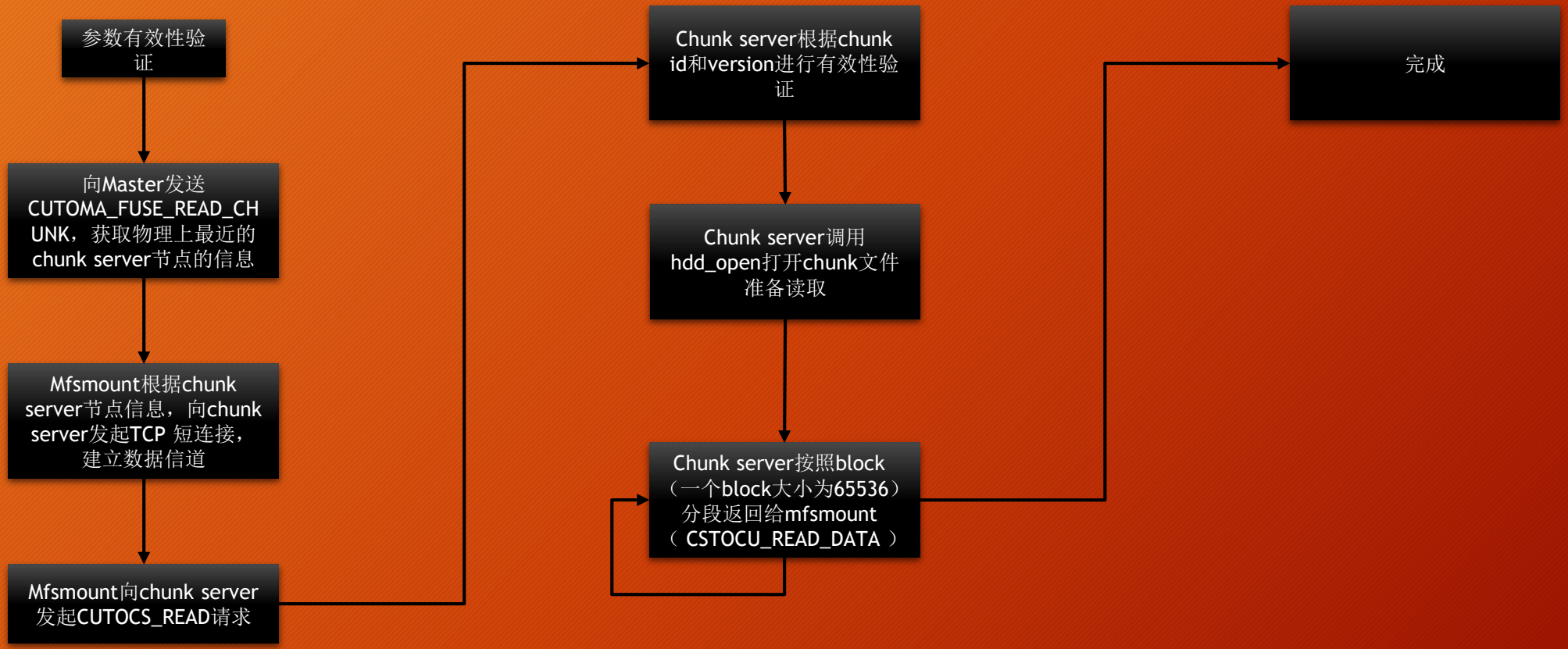
系统模块的主要数据结构和算法介绍

- Mfsmetalogger
  - Mfsmetalogger进程和mfsmaster建立TCP长连接
  - 从mfsmaster下载metadata数据，存于metadata_ml.mfs
  - 从mfsmaster下载session数据，存于session_ml.mfs

```
00729:      main_timeregister(TIMEMODE_RUNONCE,MetaDLFreq*3600,630,masterconn_metadownloadinit);
00730:      main_timeregister(TIMEMODE_RUNONCE,60,0,masterconn_sessionsdownloadinit);
```

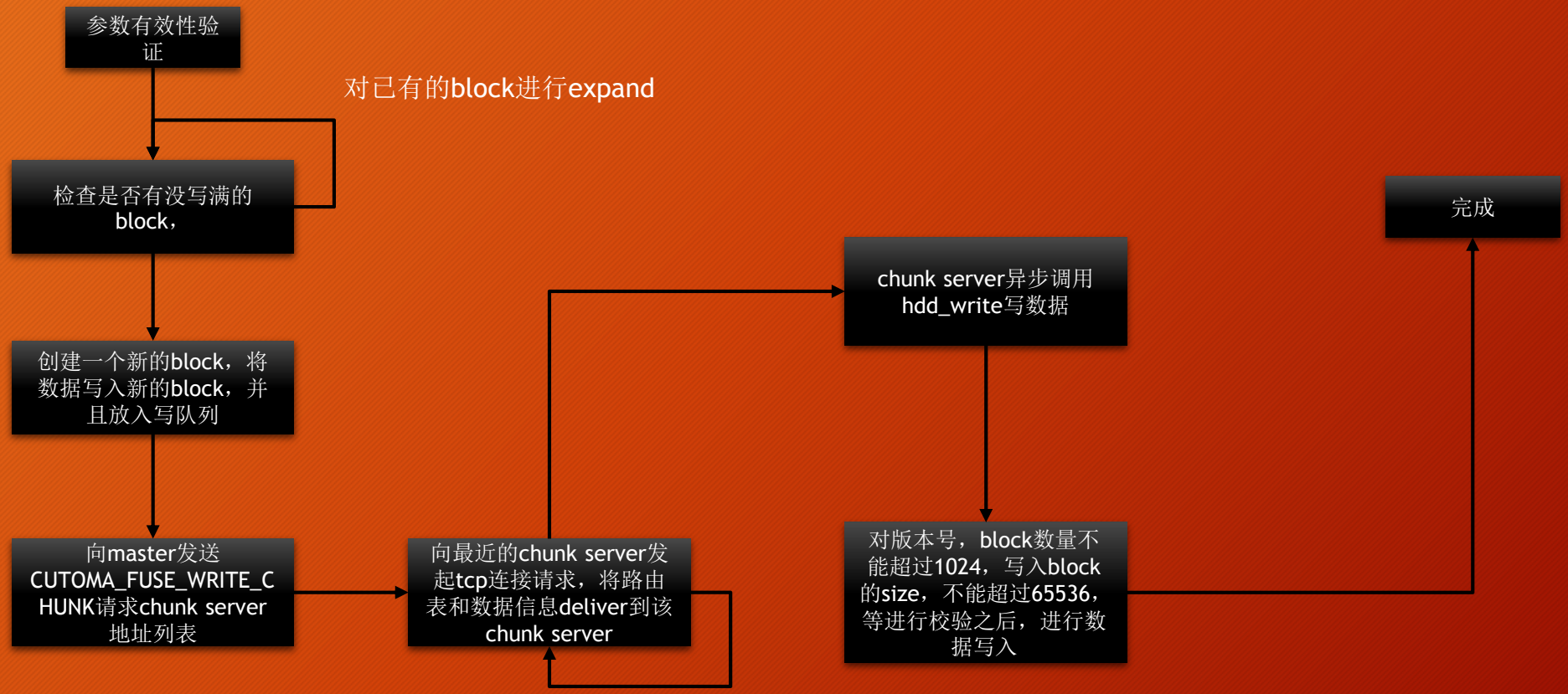
系统主要的调用流程

```
void mfs_read(fuse_req_t req, fuse_ino_t ino, size_t size, off_t off, struct fuse_file_info *fi)
```



系统主要的调用流程

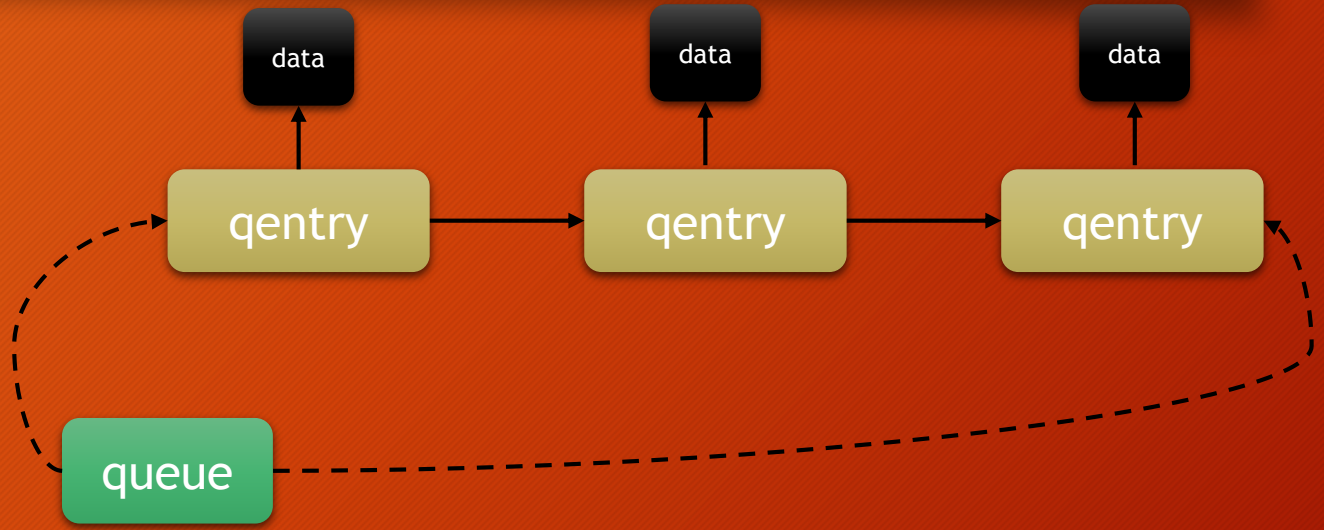
```
void mfs_write(fuse_req_t req, fuse_ino_t ino, const char *buf, size_t size, off_t off, struct fuse_file_info *fi)
```



设计技巧的介绍

- 进程内队列通信

```
00027: typedef struct _qentry {
00028:     uint32_t id;
00029:     uint32_t op;
00030:     uint8_t *data;
00031:     uint32_t leng;
00032:     struct _qentry *next;
00033: } qentry;
00034:
00035: typedef struct _queue {
00036:     qentry *head,**tail;
00037:     void *semfree,*semfull;
00038:     pthread_mutex_t lock;
00039: } queue;
```



线程安全，互斥锁
线程同步，信号量

```
00025: typedef struct _semaphore {
00026:     uint32_t count;
00027:     pthread_mutex_t lock;
00028:     pthread_cond_t cond;
00029: } semaphore;
00030:
```

信号量，条件变量，线程同步

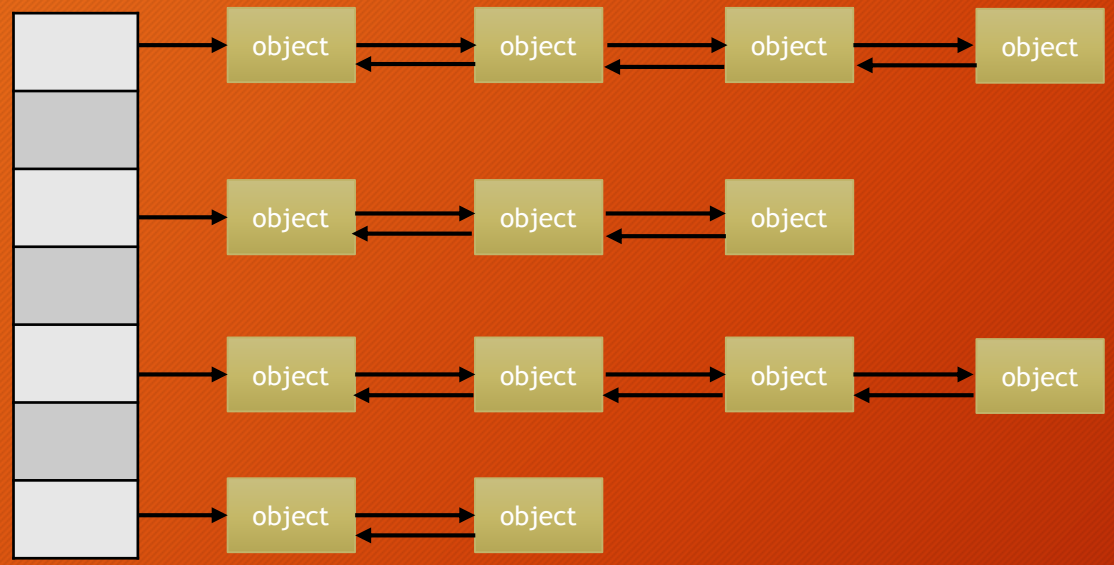
应用：

1. Mfsmount进程写block。
2. Mfschunkserver进程后台模式

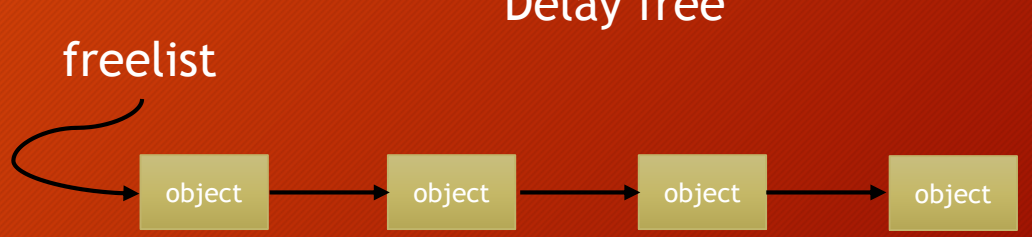
设计技巧的介绍

- 内存预分配技术

Object Pool



Delay free



Advanced

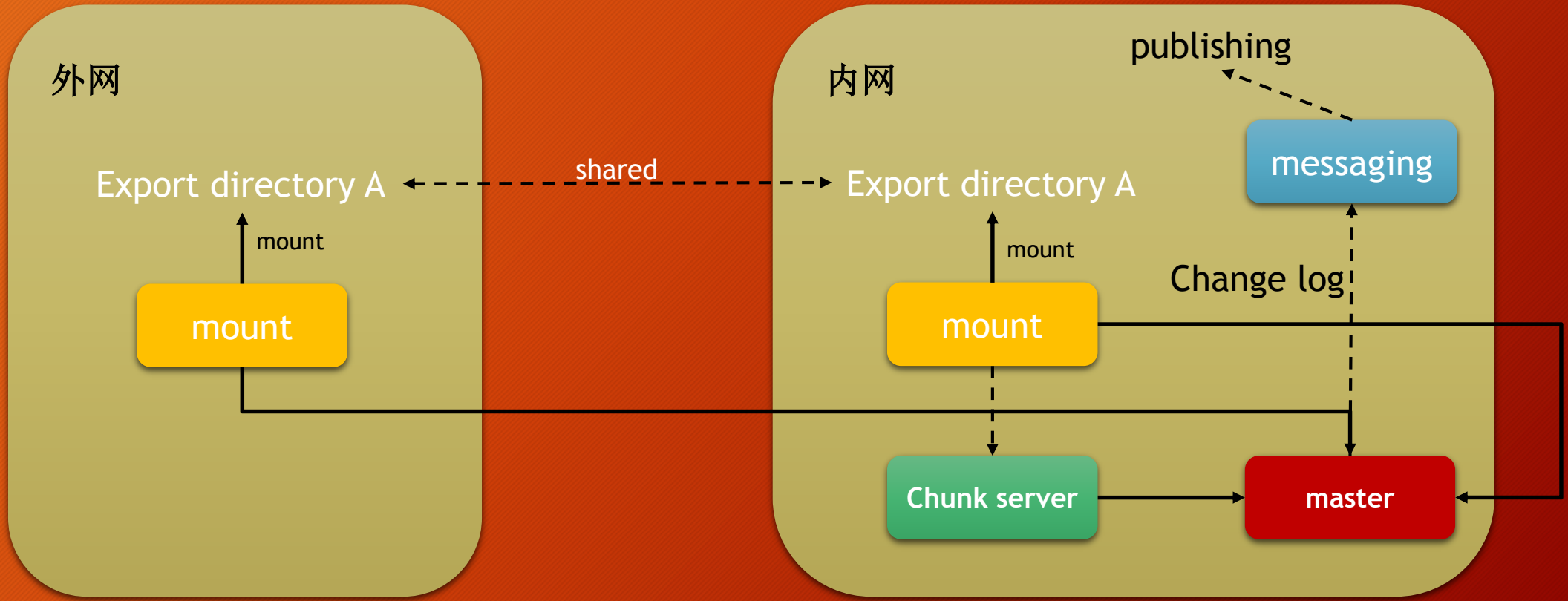
Global MM by Buddy system

基于我们的应用，可以做的一些改进

- 问题
  - 大量的账单文件，每个月增长量为3万个，保留18个月，每个文件大小平均为8M左右（账单明细），几十K（账单详情）。
  - 需要内网和外网共享，提供给用户在线下载账单文件。
  - 考虑到信息安全，外网的账单只能部分和零时共享到外网，提供用户下载。
- 目前的做法
  - 内外网共享文件系统，通过MFS。
  - 用户需要下载的时候，才将内网的账单copy到外网的共享目录，待用户下载完毕在删除。

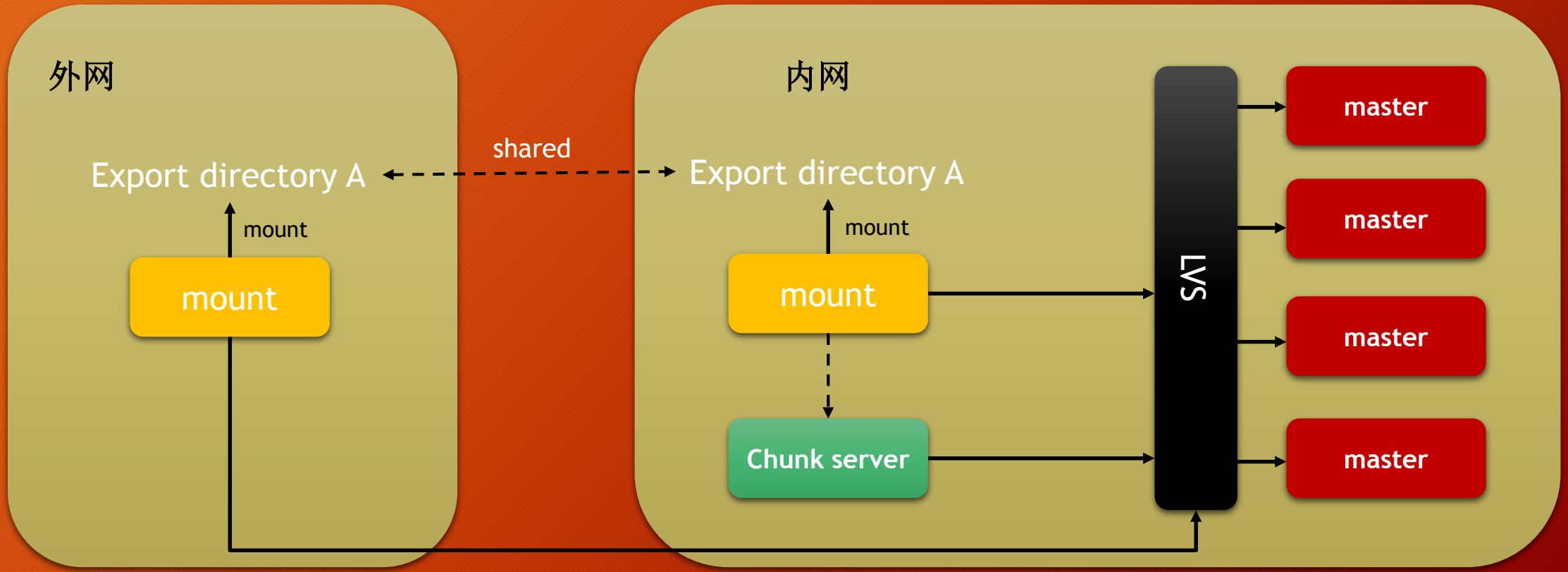
基于我们的应用，可以做的一些改进

- 监控文件系统的变化



基于我们的应用，可以做的一些改进

- 多master实例，负载均衡



QA环节

Thanks