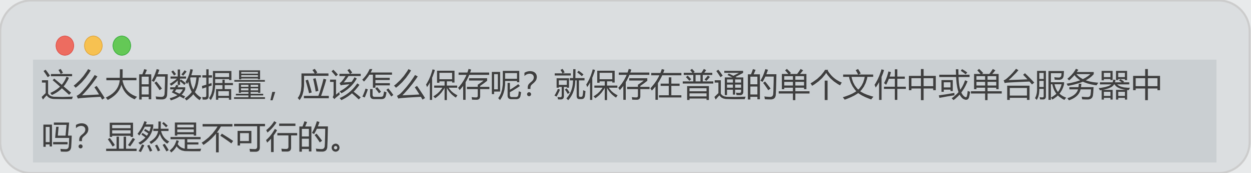
TFS（淘宝分布式存储引擎）

什么是TFS?

根据淘宝2016年的数据分析，淘宝卖家已经达到900多万，有上十亿的商品。每一个商品有包括大量的图片和文字(平均：15k)，粗略估计下，数据所占的存储空间在1PB 以上，如果使用单块容量为1T容量的磁盘来保存数据，那么也需要1024 x 1024块磁盘来保存.

思考?



这么大的数据量，应该怎么保存呢？就保存在普通的单个文件中或单台服务器中吗？显然是不可行的。

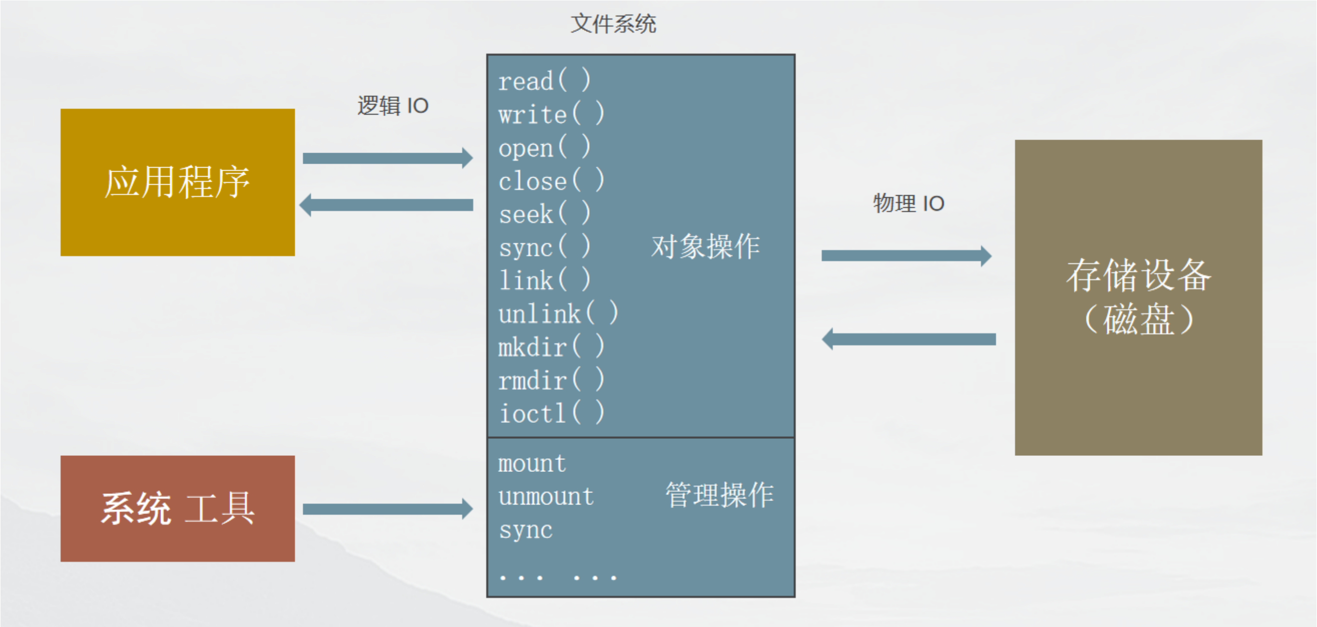
淘宝针对海量非结构化数据存储设计出了的一款分布式系统，叫TFS，它构筑在普通的Linux机器集群上，可为外部提供高可靠和高并发的存储访问。

文件系统的基本概念

文件系统的接口

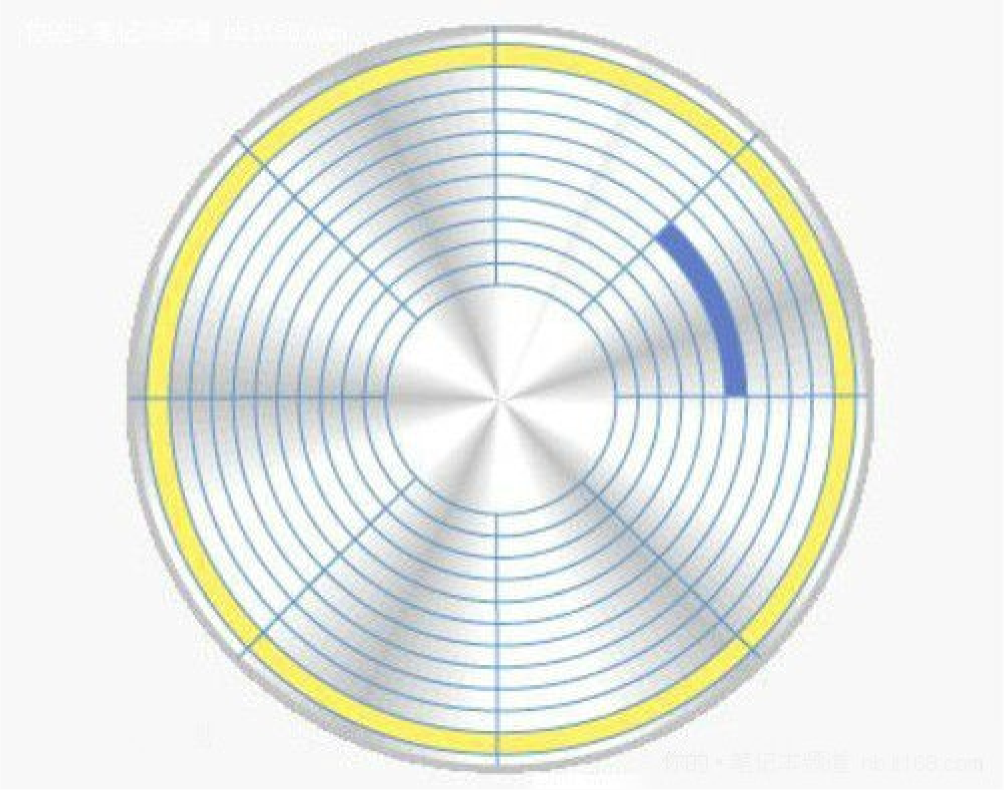
文件系统：

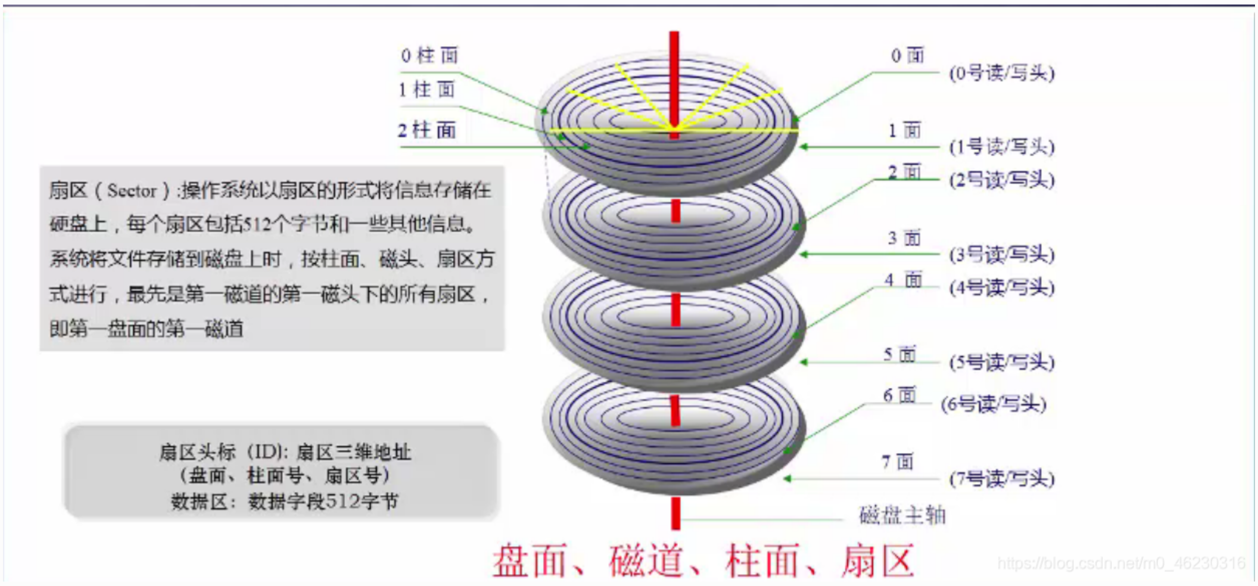
一种把数据组织成文件和目录的存储方式，提供了基于文件的存取接口，并通过文件权限控制访问。



存储的基本单位

扇区：





扇区（Sector）:操作系统以扇区的形式将信息存储在硬盘上，每个扇区包括512个字节和一些其他信息。系统将文件存储到磁盘上时，按柱面、磁头、扇区方式进行，最先是第一磁道的第一磁头下的所有扇区，即第一盘面的第一磁道

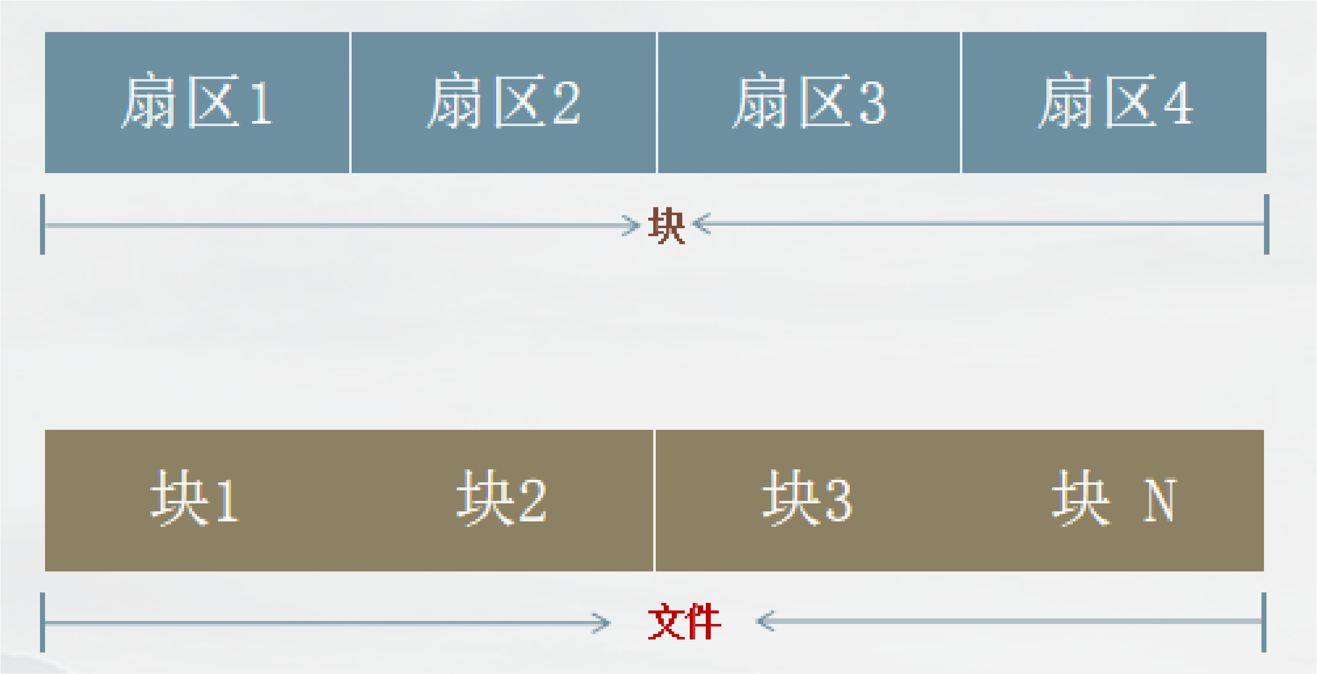
扇区头标（ID）: 扇区三维地址
（盘面、柱面号、扇区号）
数据区：数据字段512字节

磁盘的每一面被分为很多条磁道，即表面上的一些同心圆，越接近中心，圆就越小。而每一个磁道又按512个字节为单位划分为等分，叫做扇区

文件的最小存储单位

块

文件存取的最小单位。“块”的大小，最常见的是4KB，即连续八个 sector组成一个 block。

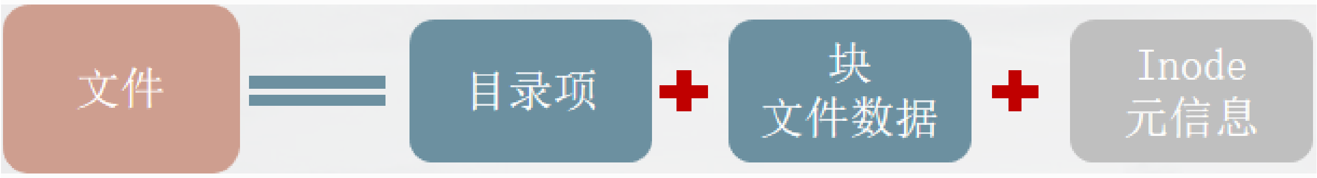


文件结构

Ext*格式化分区 - 操作系统自动将硬盘分成三个区域。

- 目录项区 - 存放目录下文件的列表信息数据区

- 存放文件数据inode区 (inode table)
- 存放inode所包含的信息

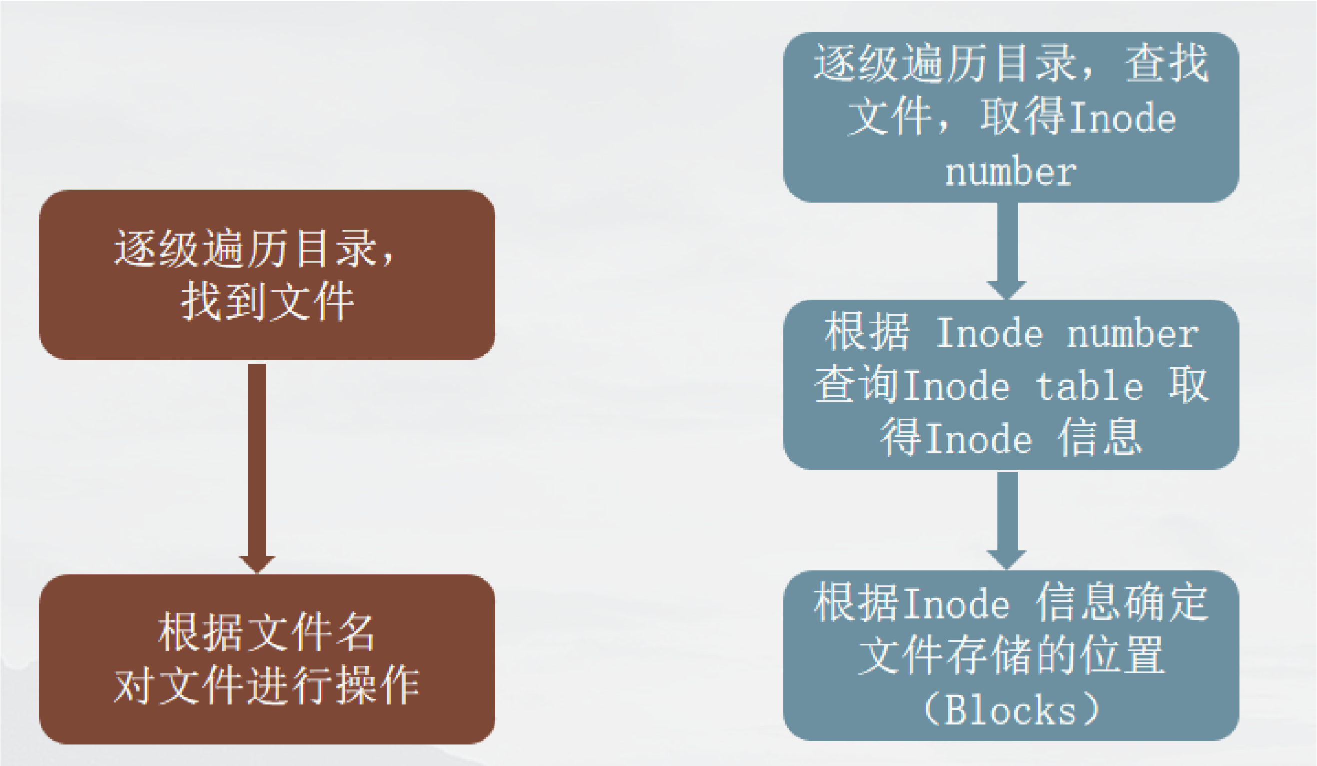


关于Inode

inode - “索引节点”,储存文件的元信息，比如文件的创建者、文件的创建日期、文件的大小等等。每个inode都有一个号码，操作系统用inode号码来识别不同的文件。 `ls -i` 查看inode 号

inode节点大小 - 一般是128字节或256字节。inode节点的总数，格式化时就给定，一般是每1KB或每2KB就设置一个inode。一块1GB的硬盘中，每1KB就设置一个inode，那么inode table的大小就会达到128MB，占整块硬盘的12.8%。

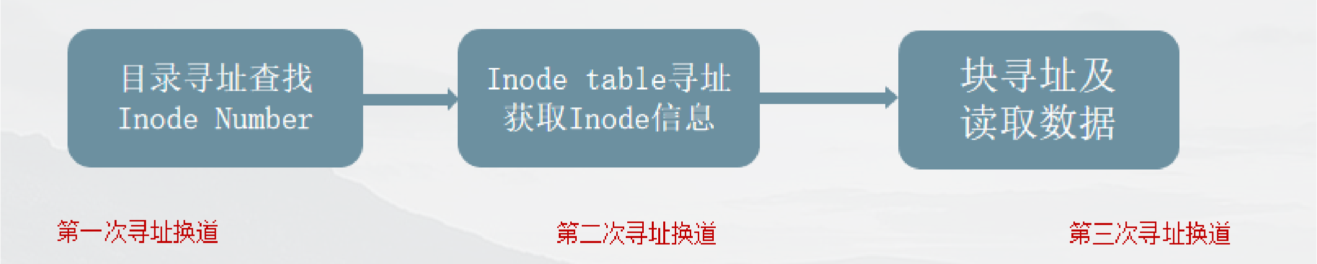
读取文件的三个步骤


逐级遍历目录，
找到文件
根据文件名
对文件进行操作
逐级遍历目录，查找文件，取得Inode number
根据 Inode number 查询Inode table 取得Inode 信息
根据Inode 信息确定文件存储的位置（Blocks）

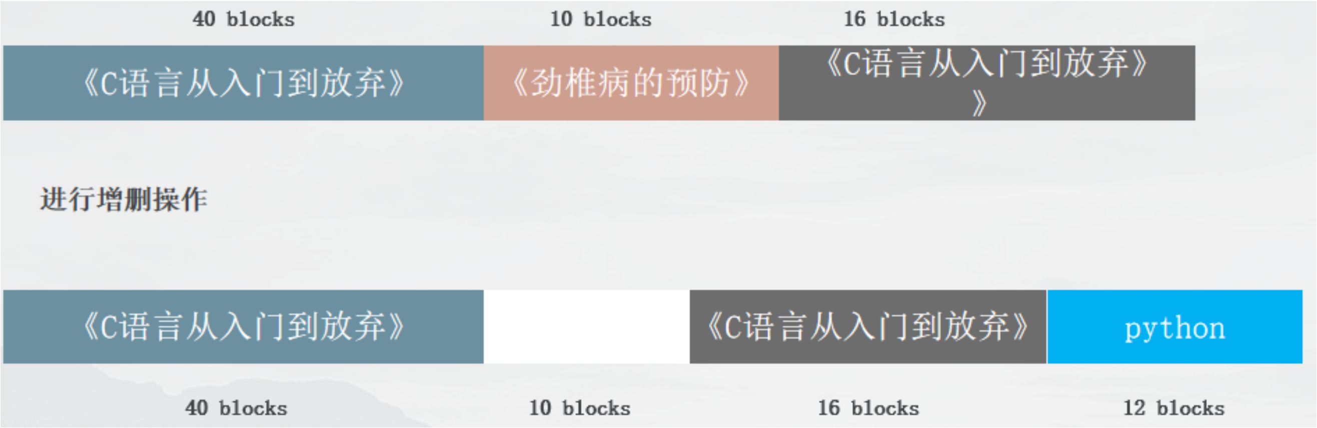
为什么海量存储使用大文件结构

1.大规模的小文件存取，磁头需要频繁的寻道和换道，因此在读取上容易带来较长的延时。

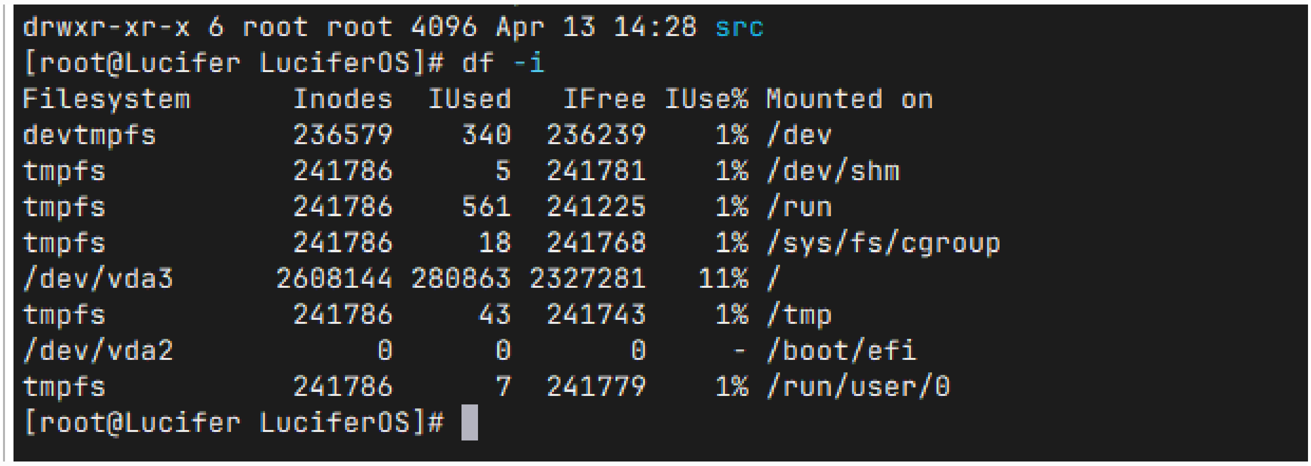
千兆网络发送 1MB 数据	10ms
机房内网络来回	0.5ms
SATA 磁盘寻道	10ms
从SATA磁盘顺序读取 1MB 数据	20ms



2.频繁的新增删除操作导致磁盘碎片，降低磁盘利用率和IO读写效率



3.Inode 占用大量磁盘空间，降低了缓存的效果



```
drwxr-xr-x 6 root root 4096 Apr 13 14:28 src
[root@Lucifer LuciferOS]# df -i
Filesystem       Inodes  IUsed   IFree IUse% Mounted on
devtmpfs         236579    340  236239    1% /dev
tmpfs            241786      5  241781    1% /dev/shm
tmpfs            241786    561  241225    1% /run
tmpfs            241786     18  241768    1% /sys/fs/cgroup
/dev/vda3       2608144 280863 2327281   11% /
tmpfs            241786     43  241743    1% /tmp
/dev/vda2             0      0       0     - /boot/efi
tmpfs            241786      7  241779    1% /run/user/0
[root@Lucifer LuciferOS]# 
```

TFS文件系统的大文件结构

设计思路

- 以block文件的形式存放数据文件（一般为64M为一个block），以下简称块，每一个块都有唯一的一个整数编号，块在使用之前所用到的存储空间都会预先分配和初始化
- 每一个块由一个索引文件、一个主块文件和若干个扩展块组成“小文件”主要存放在主块文件中，扩展块主要用来存放溢出的数据。

- 每个索引文件存放对应的块信息和“小文件”索引信息，索引文件会在服务启动是映射（mmap）到内存，以便极大的提高文件检索速度。“小文件”索引信息采用在索引文件中的数据结构哈希链表来实现。
- 每个文件有对应的文件编号，文件编号从1开始编号，依次递增，同时作为哈希查找算法的Key 来定位“小文件”在主块和扩展块中的偏移量。文件编号+块编号按某种算法可得到“小文件”对应的文件名。

哈希链表

哈希表 - 散列表，它是基于快速存取的角度设计的，也是一种典型的“空间换时间”的做法

关键点:

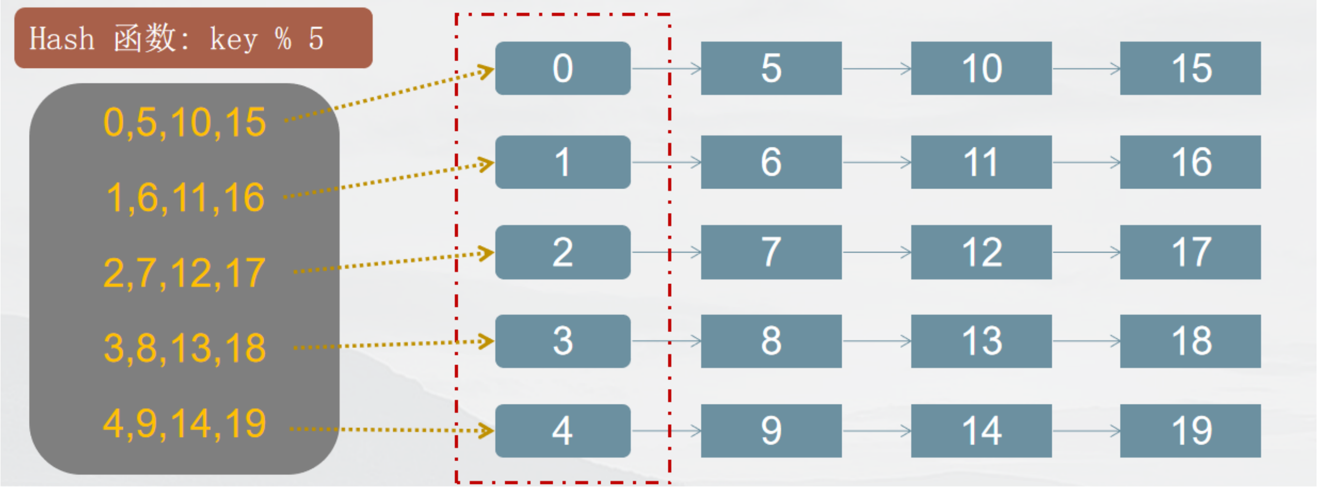
键(key): 文件的编号 如，1 、5 、19 。 。 。

值(value): 文件的索引信息（包含 文件大小、位置）

索引: 数组的下标(0,1,2,3,4) ，用以快速定位和检索数据

哈希桶：保存索引的数组，数组成员为每一个索引值相同的多个元素（以链表的形式链接）的首节点

哈希函数：将文件编号映射到索引上，采用求余法 ，如： 文件编号 19



Hash 函数：key % 5

0,5,10,15

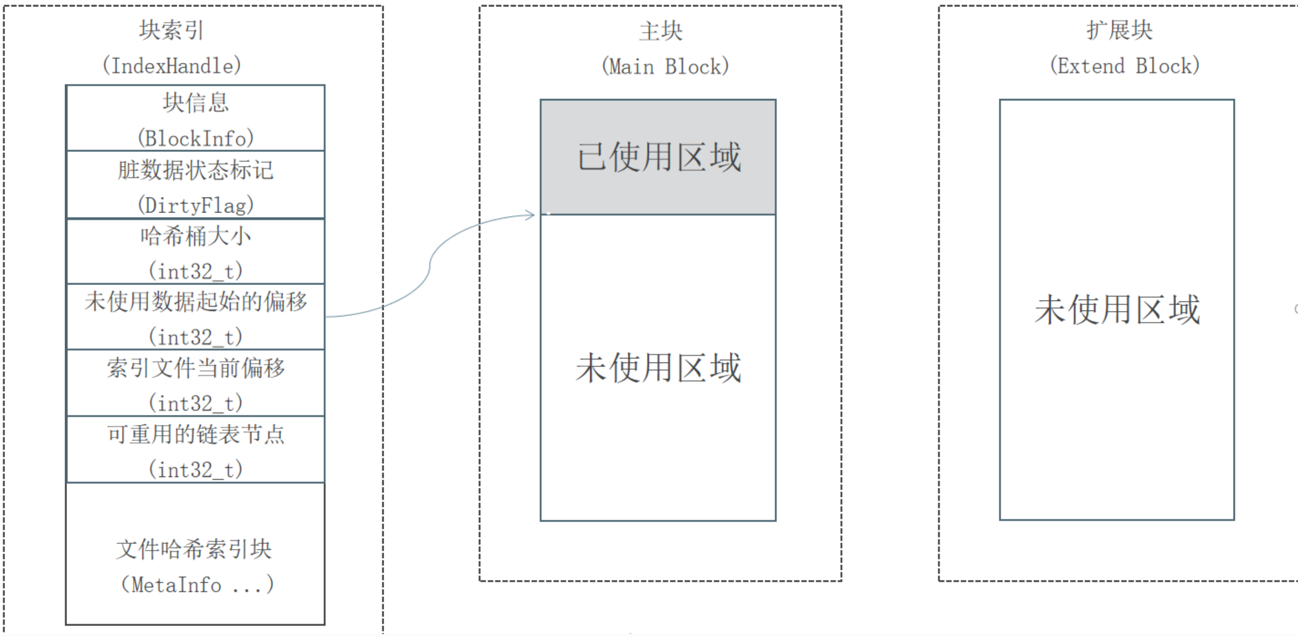
1,6,11,16

2,7,12,17

3,8,13,18

4,9,14,19

大文件存储结构



块索引
(IndexHandle)

块信息
(BlockInfo)

脏数据状态标记
(DirtyFlag)

哈希桶大小
(int32_t)

未使用数据起始的偏移
(int32_t)

索引文件当前偏移
(int32_t)

可重用的链表节点
(int32_t)

文件哈希索引块
(MetaInfo ...)

主块
(Main Block)

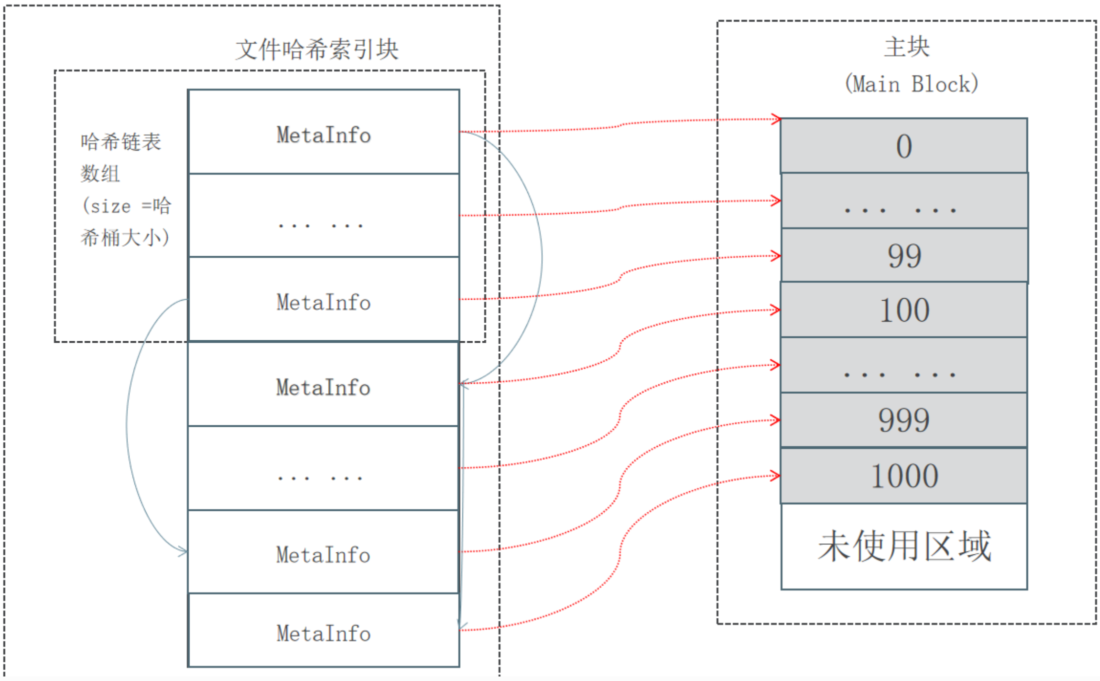
已使用区域

未使用区域

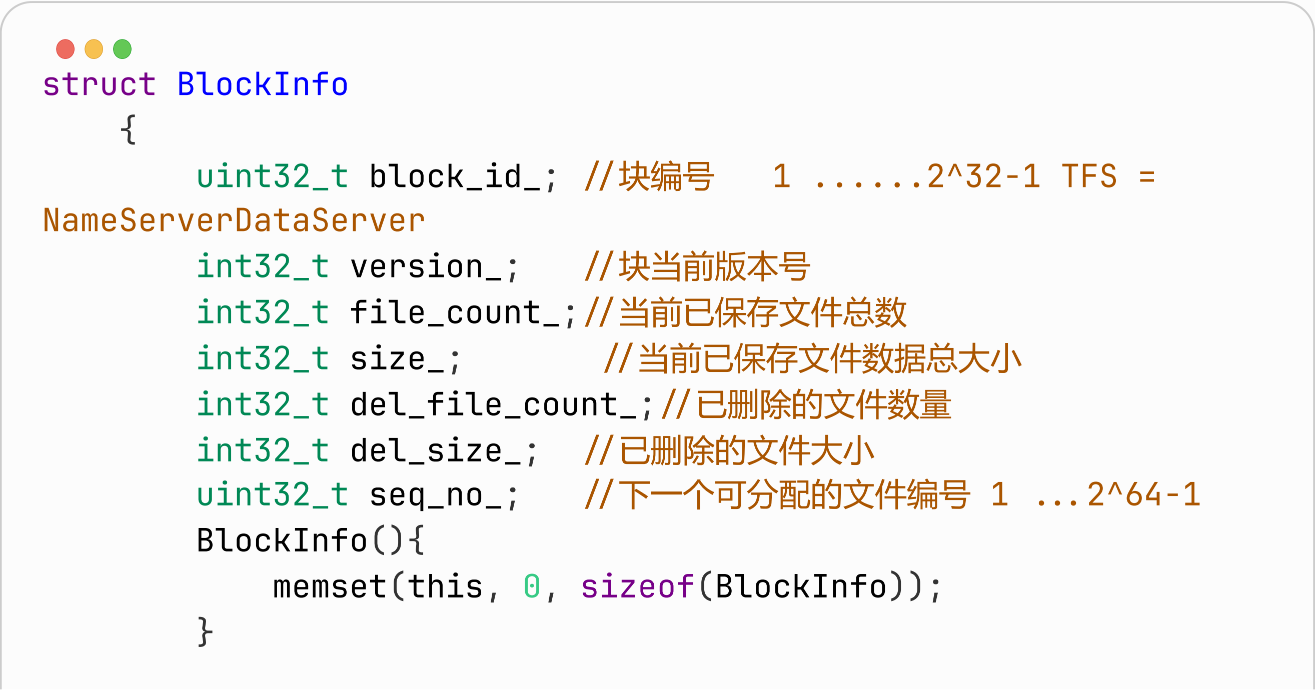
扩展块
(Extend Block)

未使用区域

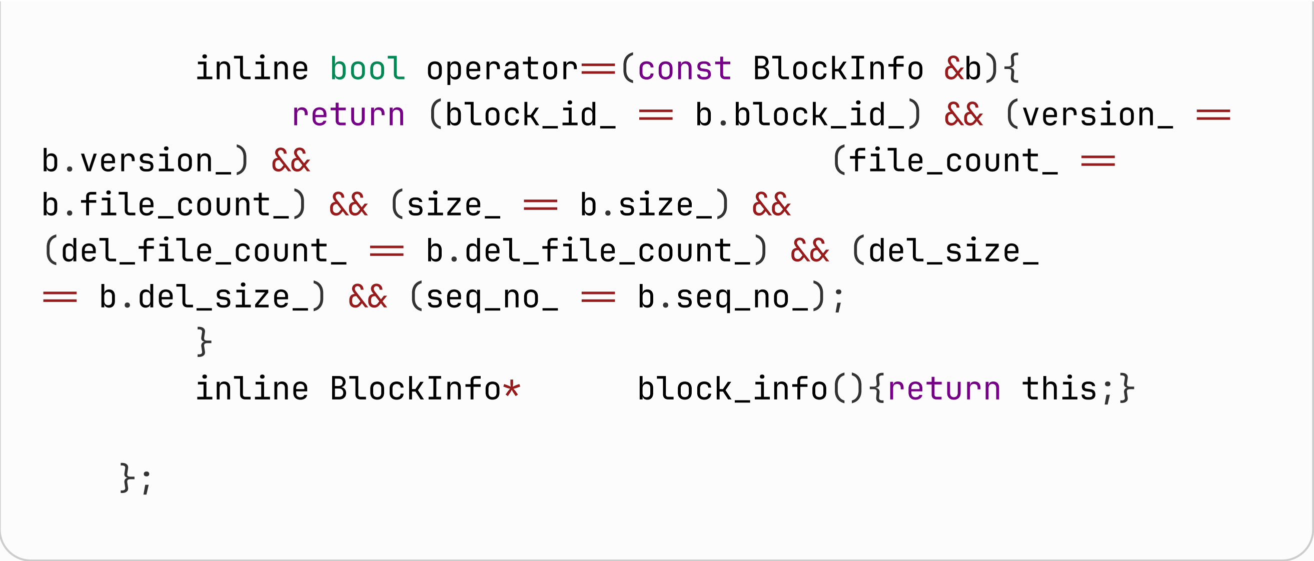
文件哈希链表的实现图



关键数据结构

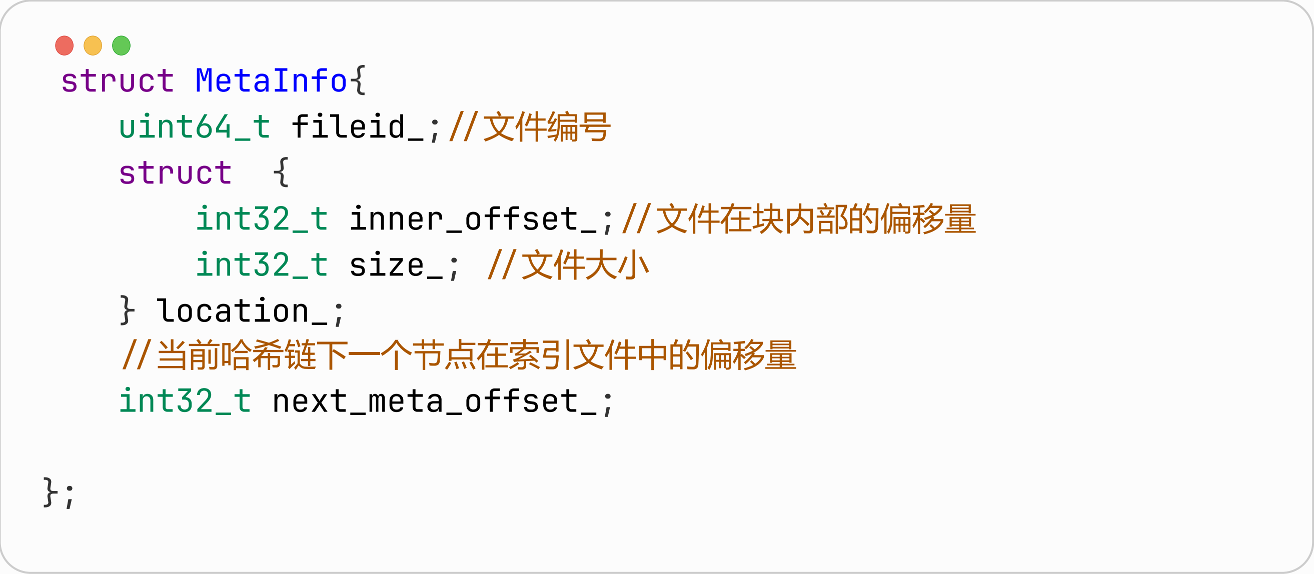


```
struct BlockInfo
    {
        uint32_t block_id_; //块编号   1 ......2^32-1 TFS = NameServerDataServer
        int32_t version_;    //块当前版本号
        int32_t file_count_;//当前已保存文件总数
        int32_t size_;         //当前已保存文件数据总大小
        int32_t del_file_count_;//已删除的文件数量
        int32_t del_size_;   //已删除的文件大小
        uint32_t seq_no_;    //下一个可分配的文件编号 1 ...2^64-1
        BlockInfo(){
            memset(this, 0, sizeof(BlockInfo));
        }
```



```
        inline bool operator==(const BlockInfo &b){
             return (block_id_ == b.block_id_) && (version_ ==
b.version_) &&                           (file_count_ ==
b.file_count_) && (size_ == b.size_) &&
(del_file_count_ == b.del_file_count_) && (del_size_
== b.del_size_) && (seq_no_ == b.seq_no_);
        }
        inline BlockInfo*      block_info(){return this;}

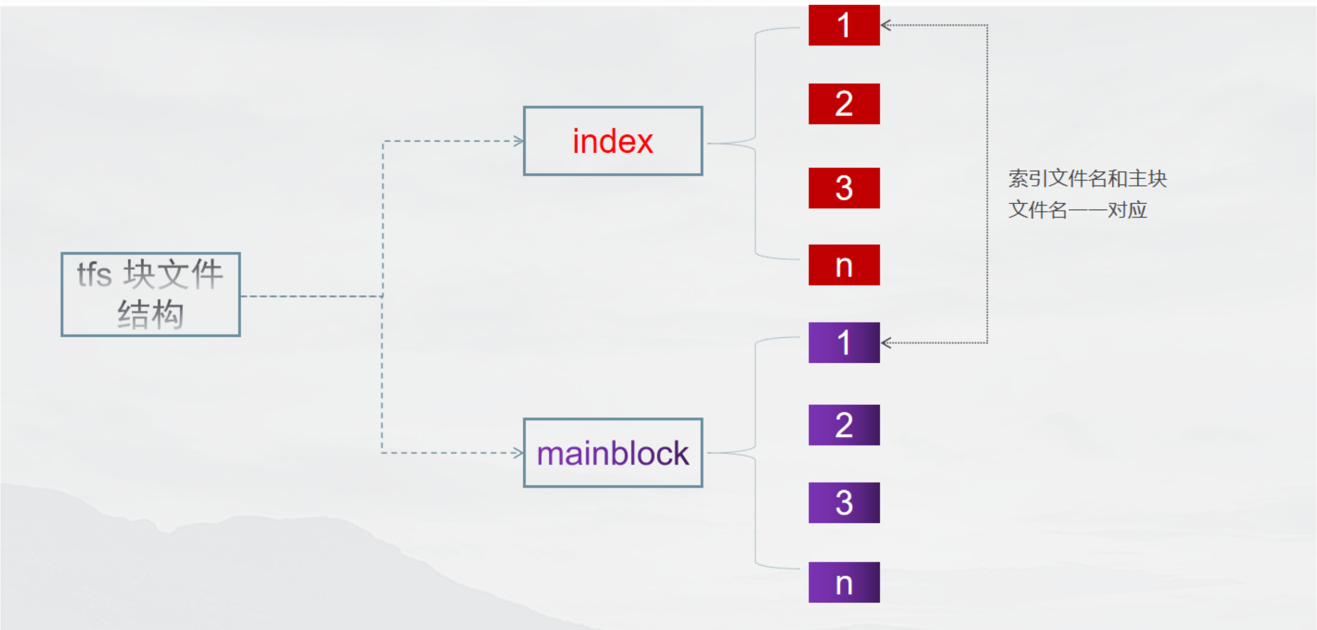
    };
```



```
 struct MetaInfo{
    uint64_t fileid_;//文件编号
    struct  {
        int32_t inner_offset_;//文件在块内部的偏移量
        int32_t size_; //文件大小
    } location_;
    //当前哈希链下一个节点在索引文件中的偏移量
    int32_t next_meta_offset_;

};
```

目录结构



索引文件名和主块文件名一一对应

块的相关操作

块的初始化

1. 生成主块文件
   - 根据block_id创建文件
   - 预分配空间
2. 生成索引文件
   - 根据id创建文件
   - 头部初始化

        - 块信息的初始化
        - 索引信息的初始化
    - 同步写入磁盘
    - 映射至内存访问

块中写入文件

1. 加载索引文件
    - 映射文件索引至内存
2. 文件写入至主块
    - 从索引文件中读取块数据的偏移
    - 从文件写入主块的对应偏移位置中
3. 文件索引信息写入索引文件
    1. 生成MetaInfo信息（包括文件在块中的fd
    2. 将MetaInfo写入索引文件
    3. 更新块信息（同步写入磁盘

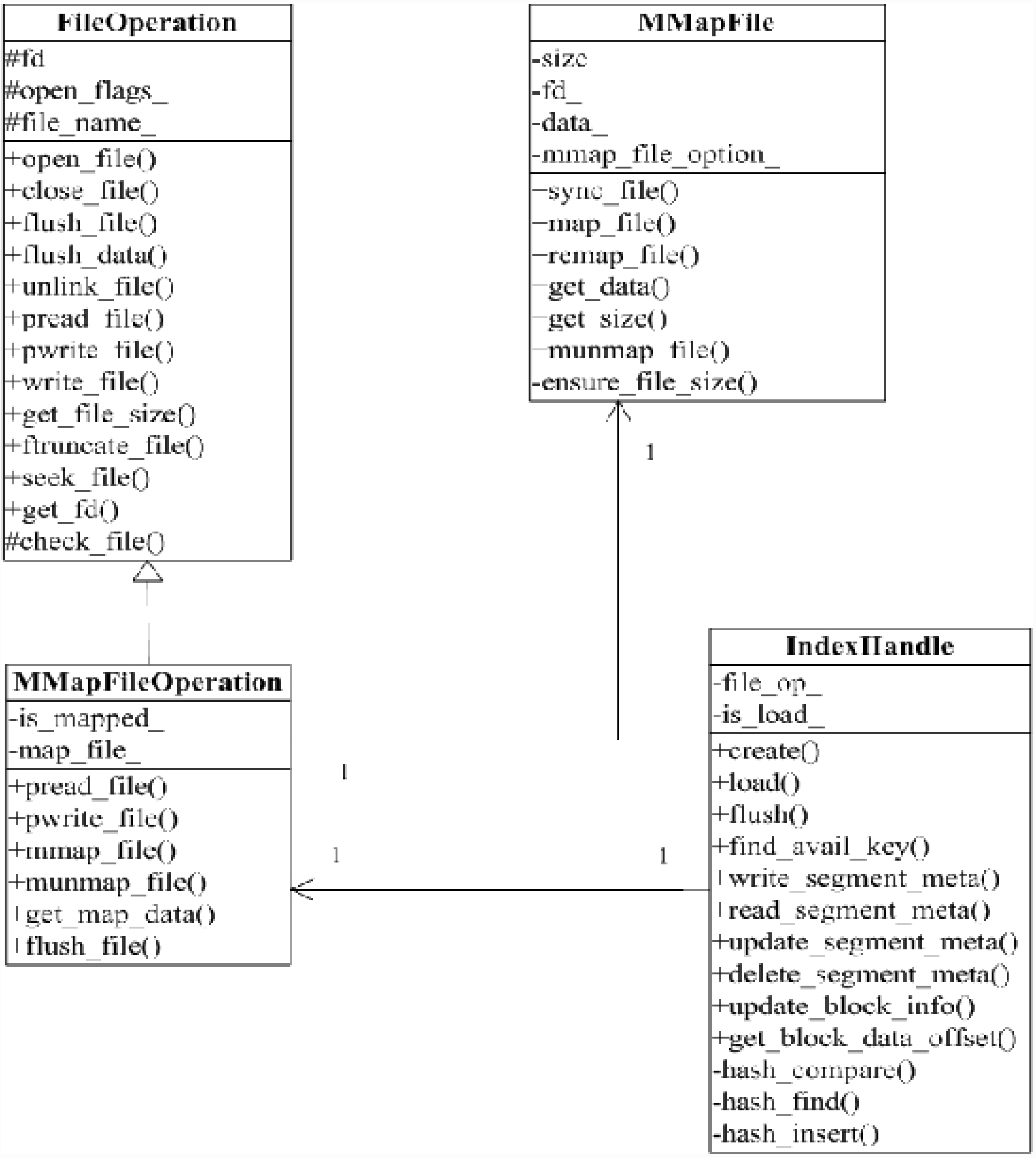
块中读取文件

1. 加载索引文件
    - 映射文件至内存
2. 从索引文件中获取MetaInfo
    1. 根据文件id从块索引内存映射的Hash文件链表中查找文件的MetaInfo
3. 根据MetaInfo从块文件中读取文件

块中删除文件

1. 加载索引文件
   - 映射索引文件至内存
2. 从索引文件中获取文件MetaInfo
   - 根据文件id从块索引的Hash文件链表中查找文件的MetaInfo
3. 索引文件中删除MetaInfo
   - 将当前文件在对应MetaInfo在哈希链表中的上一个节点指向其后一个节点
   - 当前MetaInfo加入可重用空闲链表中
   - 更新快信息
4. （可选）
   1. 把已删除的多个小文件进行彻底删除，同时让所有有效的小文件连续的存储在一起，防止大量碎片化的块空间堆积，

设计图


FileOperation
#fd
#open_flags_
#file_name_
+open_file()
+close_file()
+flush_file()
+flush_data()
+unlink_file()
+pread_file()
+pwrite_file()
+write_file()
+get_file_size()
+ftruncate_file()
+seek_file()
+get_fd()
#check_file()
MMapFile
-size
-fd_
-data_
-mmap_file_option_
-sync_file()
-map_file()
-remap_file()
-get_data()
-get_size()
-munmap_file()
-ensure_file_size()
1
MMapFileOperation
-is_mapped_
-map_file_
+pread_file()
+pwrite_file()
+mmap_file()
+munmap_file()
+get_map_data()
+flush_file()
1
1
1
IndexHandle
-file_op_
-is_load_
+create()
+load()
+flush()
+find_avail_key()
+write_segment_meta()
+read_segment_meta()
+update_segment_meta()
+delete_segment_meta()
+update_block_info()
+get_block_data_offset()
-hash_compare()
-hash_find()
-hash_insert()

文件映射

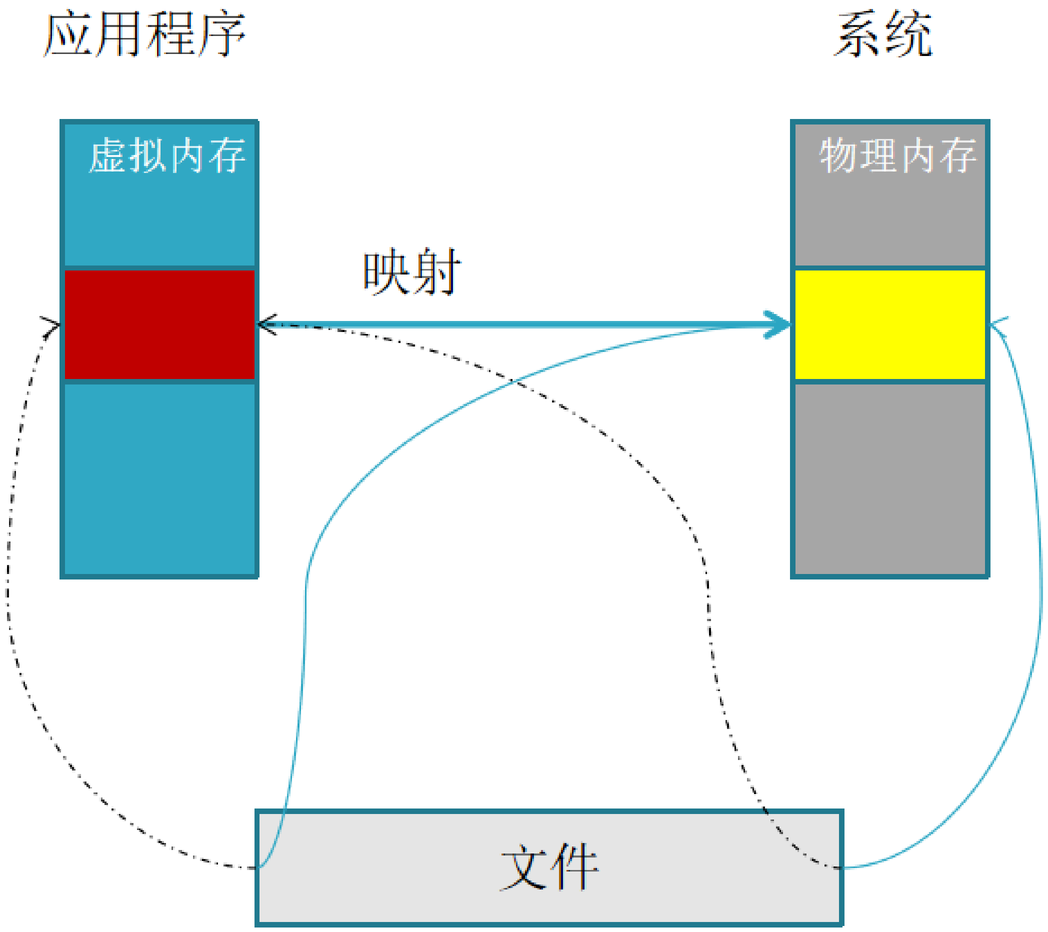
应用场景

1. 进程间共享信息

2. 实现文件数据从磁盘到内存的映射，极大的提升应用程序访问文件的速度

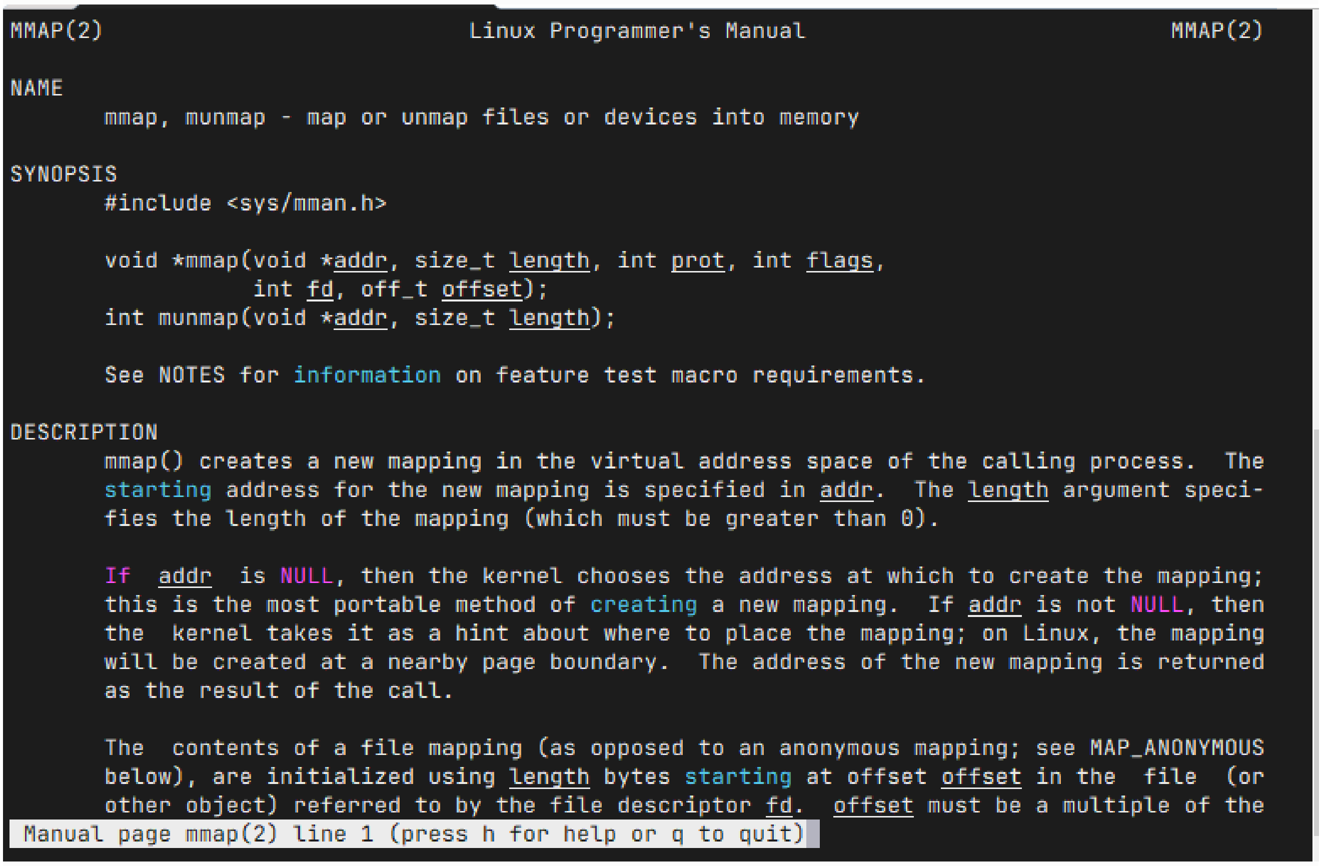
进程间的通信-文件映射的原理

```
原理:   将一个文件或者其它对象映射进内存。
        1.使用普通文件提供的内存映射
        2.使用特殊文件提供匿名内存映射
```



应用程序
系统
虚拟内存
物理内存
映射
文件

mmap的实现



```
MMAP(2)                    Linux Programmer's Manual                   MMAP(2)

NAME
       mmap, munmap - map or unmap files or devices into memory

SYNOPSIS
       #include <sys/mman.h>

       void *mmap(void *addr, size_t length, int prot, int flags,
                  int fd, off_t offset);
       int munmap(void *addr, size_t length);

       See NOTES for information on feature test macro requirements.

DESCRIPTION
       mmap() creates a new mapping in the virtual address space of the calling process.  The
       starting address for the new mapping is specified in addr.  The length argument speci-
       fies the length of the mapping (which must be greater than 0).

       If  addr  is NULL, then the kernel chooses the address at which to create the mapping;
       this is the most portable method of creating a new mapping.  If addr is not NULL, then
       the  kernel takes it as a hint about where to place the mapping; on Linux, the mapping
       will be created at a nearby page boundary.  The address of the new mapping is returned
       as the result of the call.

       The  contents of a file mapping (as opposed to an anonymous mapping; see MAP_ANONYMOUS
       below), are initialized using length bytes starting at offset offset in the  file  (or
       other object) referred to by the file descriptor fd.  offset must be a multiple of the
 Manual page mmap(2) line 1 (press h for help or q to quit)
```

```
#include <sys/mman.h>
```

```


void *mmap(void *addr, size_t length, int prot, int flags,int
fd, off_t offset);

int munmap(void *addr, size_t length)
```

参数addr:

指向欲映射的内存起始地址，通常设为NULL，代表让系统自动选定地址，映射成功后返回该地址。

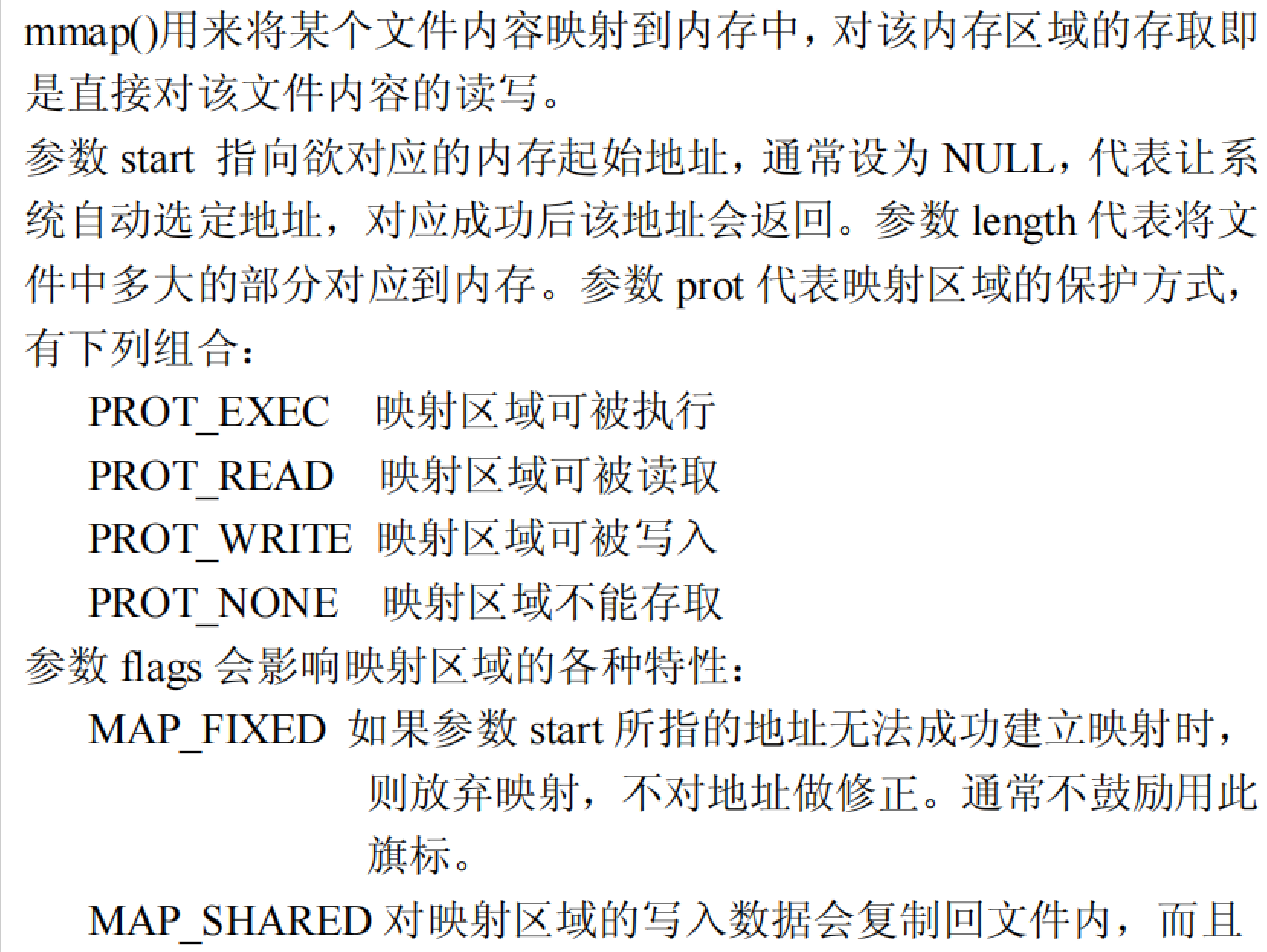
参数length:

代表将文件中多大的部分映射到内存,分页大小的整数倍(4096)

参数port:

映射区域的保护方式。可以为以下几种方式的组合:

PROT_EXEC	执行
PROT_READ	读取
PROT_WRITE	写入
PROT_NONE	不能存取



mmap()用来将某个文件内容映射到内存中，对该内存区域的存取即是直接对该文件内容的读写。

参数 start 指向欲对应的内存起始地址，通常设为 NULL，代表让系统自动选定地址，对应成功后该地址会返回。参数 length 代表将文件中多大的部分对应到内存。参数 prot 代表映射区域的保护方式，有下列组合：

PROT_EXEC	映射区域可被执行
PROT_READ	映射区域可被读取
PROT_WRITE	映射区域可被写入
PROT_NONE	映射区域不能存取

参数 flags 会影响映射区域的各种特性：

MAP_FIXED 如果参数 start 所指的地址无法成功建立映射时，则放弃映射，不对地址做修正。通常不鼓励用此旗标。

MAP_SHARED 对映射区域的写入数据会复制回文件内，而且

允许其他映射该文件的进程共享。

MAP_PRIVATE 对映射区域的写入操作会产生一个映射文件的复制，即私人的“写入时复制”（copy on write）对此区域作的任何修改都不会写回原来的文件内容。

MAP_ANONYMOUS 建立匿名映射。此时会忽略参数 fd，不涉及文件，而且映射区域无法和其他进程共享。

MAP_DENYWRITE 只允许对映射区域的写入操作，其他对文件直接写入的操作将会被拒绝。

MAP_LOCKED 将映射区域锁定住，这表示该区域不会被置换（swap）。

在调用 mmap()时必须要指定 MAP_SHARED 或 MAP_PRIVATE。参数 fd 为 open()返回的文件描述词，代表欲映射到内存的文件。参数 offset 为文件映射的偏移量，通常设置为 0，代表从文件最前方开始对应，offset 必须是分页大小的整数倍。

若映射成功则返回映射区的内存起始地址，否则返回 MAP_FAILED（－1），错误原因存于 errno 中。

错误代码	EBADF 参数 fd 不是有效的文件描述词 EACCES 存取权限有误。如果是 MAP_PRIVATE 情况下文件必须可读，使用 MAP_SHARED 则要有 PROT_WRITE 以及该文件要能写入。 EINVAL 参数 start、length 或 offset 有一个不合法。 EAGAIN 文件被锁住，或是有太多内存被锁住。 ENOMEM 内存不足。

mysnc

> 实现磁盘文件内容于共享内存区中的内容一致，即同步操作。

函数原型

`int msync ( void * addr, size_t len, int flags)`

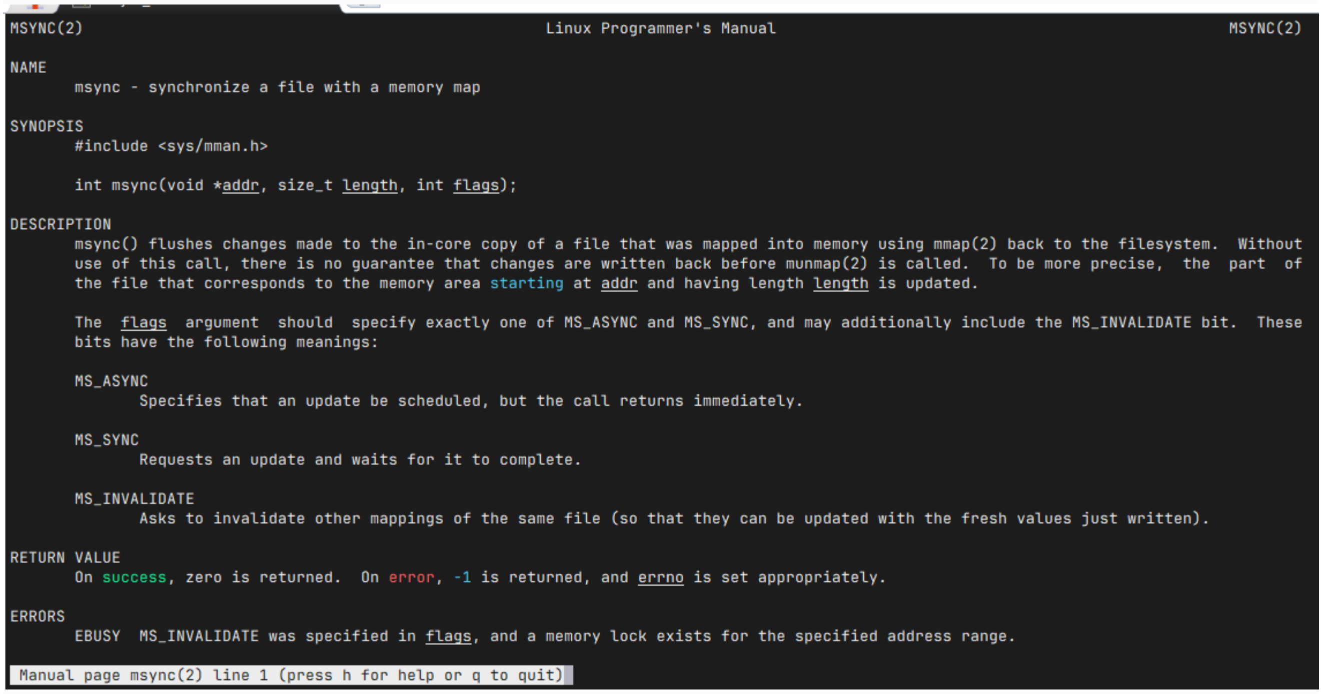
头文件　#include<sys/mman.h>

addr：文件映射到进程空间的地址；

len：映射空间的大小；

flags：刷新的参数设置，可以取值MS_ASYNC/ MS_SYNC

其中：取值为MS_ASYNC（异步）时，调用会立即返回，不等到更新的完成；取值为MS_SYNC（同步）时，调用会等到更新完成之后返回；返回值成功则返回0；失败则返回-1；



```
MSYNC(2)                          Linux Programmer's Manual                          MSYNC(2)

NAME
       msync - synchronize a file with a memory map

SYNOPSIS
       #include <sys/mman.h>

       int msync(void *addr, size_t length, int flags);

DESCRIPTION
       msync() flushes changes made to the in-core copy of a file that was mapped into memory using mmap(2) back to the filesystem.  Without
       use of this call, there is no guarantee that changes are written back before munmap(2) is called.  To be more precise,  the  part  of
       the file that corresponds to the memory area starting at addr and having length length is updated.

       The  flags  argument  should  specify exactly one of MS_ASYNC and MS_SYNC, and may additionally include the MS_INVALIDATE bit.  These
       bits have the following meanings:

       MS_ASYNC
              Specifies that an update be scheduled, but the call returns immediately.

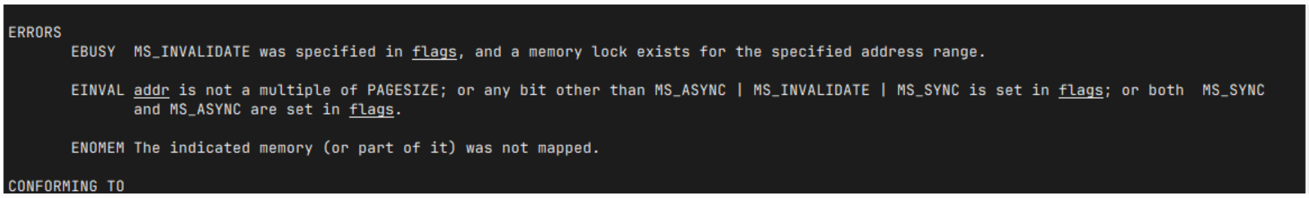
       MS_SYNC
              Requests an update and waits for it to complete.

       MS_INVALIDATE
              Asks to invalidate other mappings of the same file (so that they can be updated with the fresh values just written).

RETURN VALUE
       On success, zero is returned.  On error, -1 is returned, and errno is set appropriately.

ERRORS
       EBUSY  MS_INVALIDATE was specified in flags, and a memory lock exists for the specified address range.

 Manual page msync(2) line 1 (press h for help or q to quit)
```



```
ERRORS
       EBUSY  MS_INVALIDATE was specified in flags, and a memory lock exists for the specified address range.

       EINVAL addr is not a multiple of PAGESIZE; or any bit other than MS_ASYNC | MS_INVALIDATE | MS_SYNC is set in flags; or both  MS_SYNC
              and MS_ASYNC are set in flags.

       ENOMEM The indicated memory (or part of it) was not mapped.

CONFORMING TO
```

mremap

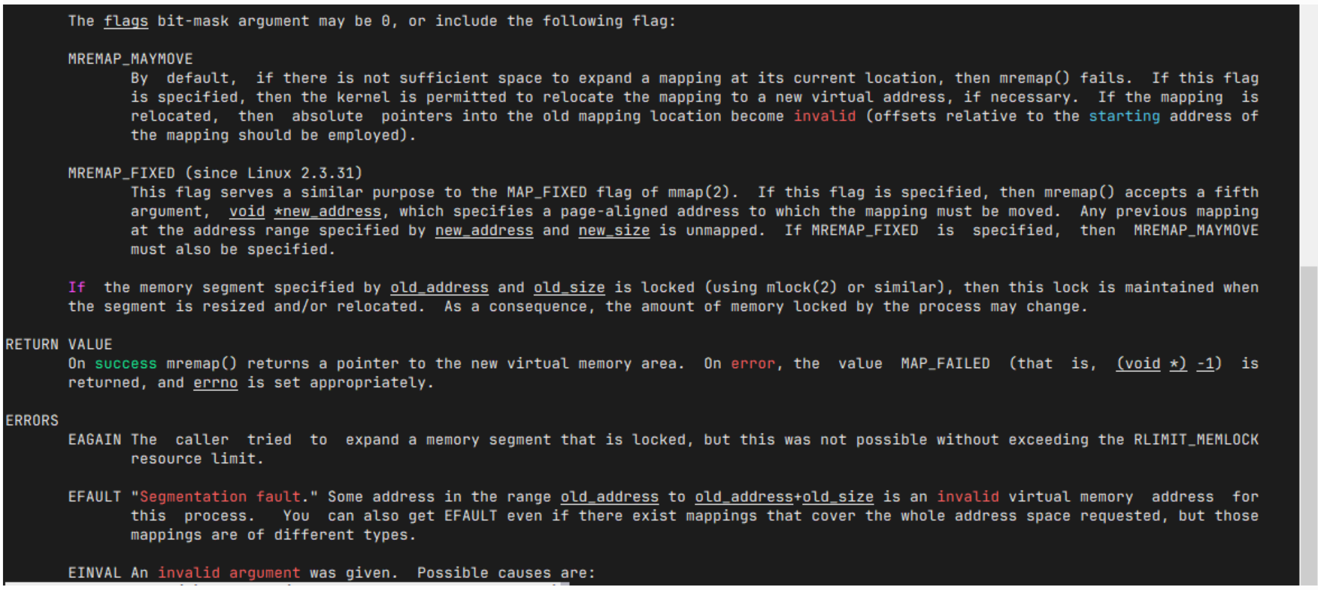
扩大（或缩小）现有的内存映射

函数原型
void * mremap(void *old_address, size_t old_size , size_t new_size, int flags);

头文件
#include <unistd.h>
#include <sys/mman.h>

addr:　　上一次已映射到进程空间的地址;
old_size:　旧空间的大小;
new_size:　重新映射指定的新空间大小;
flags:　　取值可以是0或者MREMAP_MAYMOVE，0代表不允许内核移动映射区域，MREMAP_MAYMOVE则表示内核可以根据实际情况移动映射区域以找到一个符合new_size大小要求的内存区域

返回值
成功则返回0；失败则返回-1;



```
       The flags bit-mask argument may be 0, or include the following flag:

       MREMAP_MAYMOVE
              By  default,  if there is not sufficient space to expand a mapping at its current location, then mremap() fails.  If this flag
              is specified, then the kernel is permitted to relocate the mapping to a new virtual address, if necessary.  If the mapping  is
              relocated,  then  absolute  pointers into the old mapping location become invalid (offsets relative to the starting address of
              the mapping should be employed).

       MREMAP_FIXED (since Linux 2.3.31)
              This flag serves a similar purpose to the MAP_FIXED flag of mmap(2).  If this flag is specified, then mremap() accepts a fifth
              argument,  void *new_address, which specifies a page-aligned address to which the mapping must be moved.  Any previous mapping
              at the address range specified by new_address and new_size is unmapped.  If MREMAP_FIXED  is  specified,  then  MREMAP_MAYMOVE
              must also be specified.

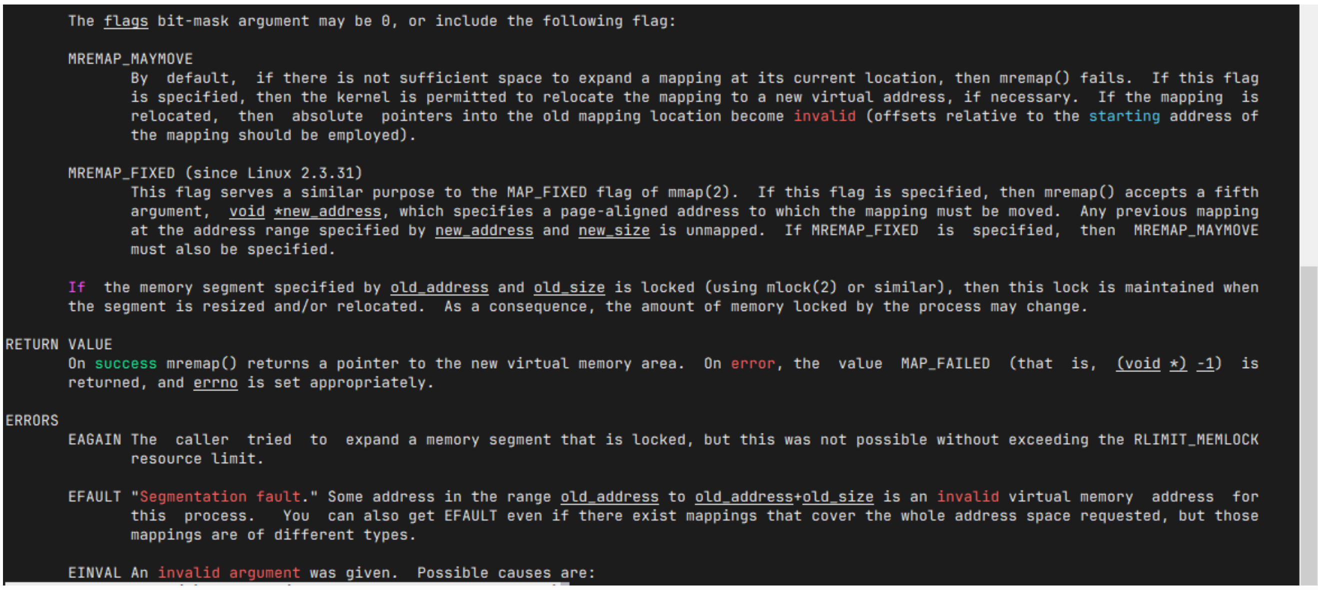
       If  the memory segment specified by old_address and old_size is locked (using mlock(2) or similar), then this lock is maintained when
       the segment is resized and/or relocated.  As a consequence, the amount of memory locked by the process may change.

RETURN VALUE
       On success mremap() returns a pointer to the new virtual memory area.  On error, the  value  MAP_FAILED  (that  is,  (void *) -1)  is
       returned, and errno is set appropriately.

ERRORS
       EAGAIN The  caller  tried  to  expand a memory segment that is locked, but this was not possible without exceeding the RLIMIT_MEMLOCK
              resource limit.

       EFAULT "Segmentation fault." Some address in the range old_address to old_address+old_size is an invalid virtual memory  address  for
              this  process.   You  can also get EFAULT even if there exist mappings that cover the whole address space requested, but those
              mappings are of different types.

       EINVAL An invalid argument was given.  Possible causes are:
```



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              mappings are of different types.

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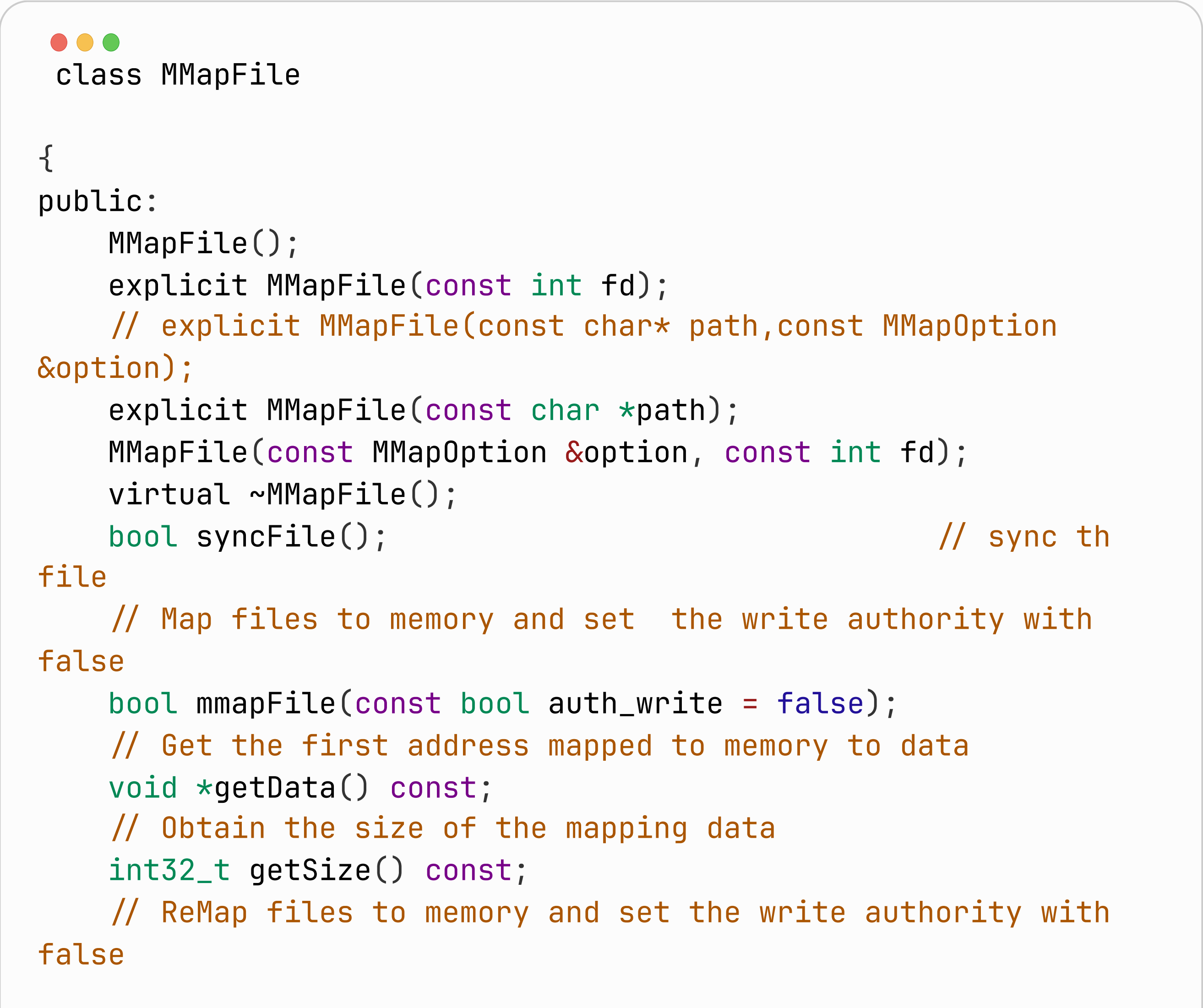
```

映射文件类

mmap_file.h



```
 class MMapFile

{
public:
    MMapFile();
    explicit MMapFile(const int fd);
    // explicit MMapFile(const char* path,const MMapOption
&option);
    explicit MMapFile(const char *path);
    MMapFile(const MMapOption &option, const int fd);
    virtual ~MMapFile();
    bool syncFile();                              // sync th
file
    // Map files to memory and set  the write authority with
false
    bool mmapFile(const bool auth_write = false);
    // Get the first address mapped to memory to data
    void *getData() const;
    // Obtain the size of the mapping data
    int32_t getSize() const;
    // ReMap files to memory and set the write authority with
false
```

```
    bool remapFile(const bool auth_write = false);
    bool mumapFile();                           // unmap the
file

protected:
    bool ensureFileSize(const int32_t size);

protected:

    void *data_ = nullptr;
    int32_t size_;
    int32_t fd_;
    struct MMapOption mmap_file_option_;

};
```

mmap_file.cpp

```
#include "mmap_file.h"

static bool debug = true;

namespace lucifer
{

    namespace tfs
    {

        MMapFile::MMapFile() : size_(0), data_(nullptr), fd_(-1)
{}

        MMapFile::MMapFile(const int fd) : size_(0),
data_(nullptr), fd_(fd) {}

        MMapFile::MMapFile(const MMapOption &mmap_option, const
int fd) : size_(0), data_(nullptr), fd_(fd)
        {

            this->mmap_file_option_.max_mmap_size_ =
mmap_option.max_mmap_size_;
            this->mmap_file_option_.per_mmap_size_ =
mmap_option.per_mmap_size_;
```

```
      this->mmap_file_option_.first_mmap_size_ = mmap_option.first_mmap_size_;
    }

    MMapFile::~MMapFile()
    {
      if (this->data_)
      {
        if (debug)
        {
          printf("mmap file destruct,fd:%d,maped size:%d,data%p\n", this->fd_, this->size_, this->data_);
        }

        msync(this->data_, this->size_, MS_SYNC);

        munmap(this->data_, this->size_);

        this->size_ = 0;
        this->data_ = nullptr;
        this->fd_ = -1;

        this->mmap_file_option_.first_mmap_size_ = 0;
        this->mmap_file_option_.max_mmap_size_ = 0;
        this->mmap_file_option_.per_mmap_size_ = 0;

        // delete this->data_;
      }
    }

    bool MMapFile::syncFile()
    {
      if (this->data_ != nullptr && this->size_ > 0)
      {
        return msync(this->data_, this->size_, MS_ASYNC) == 0;
      }
      return true;
    }

    bool MMapFile::mmapFile(const bool auth_write)
    {
      int flags = PROT_READ;
      if (auth_write)
      {
        flags |= PROT_WRITE;
      }
      if (this->fd_ < 0)
        return false;

      if (mmap_file_option_.max_mmap_size_ == 0)
        return false;
      if (this->size_ < this-
>mmap_file_option_.first_mmap_size_)
        this->size_ = this-
>mmap_file_option_.first_mmap_size_;
      else
        this->size_ = this-
>mmap_file_option_.max_mmap_size_;
      if (!this->ensureFileSize(size_))
      {
        fprintf(stderr, "ensureFileSize failed in
mmapFile ,reason%s\n", strerror(errno));
        return false;
      }

      this->data_ = mmap(0, this->size_, flags,
MAP_SHARED, this->fd_, 0);

      if (this->data_ == MAP_FAILED)
      {

        fprintf(stderr, "mmap file failed, resason%s
fd:%d,maped size:%d,data%p\n", strerror(errno), this->fd_, this-
>size_, this->data_);
        this->size_ = 0;
        this->data_ = nullptr;
        this->fd_ = -1;

        return false;

        if (debug)
          printf("mmap file success,fd:%d,maped
size:%d,data%p\n", this->fd_, this->size_, this->data_);

        return true;
      }
      return true;
    }
    void *MMapFile::getData() const { return this->data_; }
    int32_t MMapFile::getSize() const { return this->size_;
}

    bool MMapFile::mumapFile()
    {
      if (munmap(this->data_, this->size_) == 0)
        return true;
      else
        return false;
    }

    bool MMapFile::ensureFileSize(const int32_t size)
    {
      struct stat st;
      if (fstat(this->fd_, &st) < 0)
      {
        fprintf(stderr, "fstat erro  ,reason%s\n",
strerror(errno));
        return false;
      }
      if (st.st_size < size)
      {
        if (ftruncate(this->fd_, size) < 0)
        {
          fprintf(stderr, "ensureFileSize
failed,reason%s\n", strerror(errno));
          return false;
        }
        return true;
      }
      // 添加一个默认的返回值，或者修改函数返回类型为void
      return true;
    }

    bool MMapFile::remapFile(const bool auth_write)
    {

      if (this->fd_ < 0 || this->size_ == 0 || this->data_
== nullptr)
      {
        fprintf(stderr, "mremap not mapped yet\n");
        return false;
      }
```

```
            if (this->size_ == this->mmap_file_option_.max_mmap_size_)
            {
                if (debug)
                    printf("remap file failed,fd:%d,maped size:%d,data%p\n", this->fd_, this->size_, this->data_);
                fprintf(stderr, "already mapped max size,now size:%d,max size :%d\n", this->size_, this->mmap_file_option_.max_mmap_size_);
                return false;
            }
            int32_t new_size = this->size_ + this->mmap_file_option_.per_mmap_size_;
            // if(new_size > this->mmap_file_option_.max_mmap_size_) new_size= this->mmap_file_option_.max_mmap_size_;
            new_size = (new_size > this->mmap_file_option_.max_mmap_size_) ? this->mmap_file_option_.max_mmap_size_ : new_size;

            if (!this->ensureFileSize(new_size))
            {
                fprintf(stderr, "ensureFileSize failed in remapFile ,reason%s\n", strerror(errno));
                return false;
            }

            void *new_map_data = mremap(this->data_, this->size_, new_size, MREMAP_MAYMOVE, auth_write ? PROT_WRITE : PROT_READ);

            if (DEBUG)
                printf("remap file,fd:%d,maped size:%d,new size:%d old data :%p new data %p\n", this->fd_, this->size_, new_size, this->data_, new_map_data);

            if (MAP_FAILED == new_map_data)
            {
                fprintf(stderr, "mremap failed new_map_data is MAP_FAILD,reason%s new size :%d fd:%d \n", strerror(errno), new_size, this->fd_);
                return false;
            }
            else
            {
                if (DEBUG)
                    printf("mremap success new_map_data:%p,new
size:%d\n", new_map_data, new_size);
            }
            this->data_ = new_map_data;
            this->size_ = new_size;
            return true;
        }

    }
}
```

映射文件操作类

mmap_file_op.h

```
#ifndef TFS_MMAP_FILE_OPERATION_H
#define TFS_MMAP_FILE_OPERATION_H

#include "head.h"
#include "file_op.h"
#include "mmap_file.h"

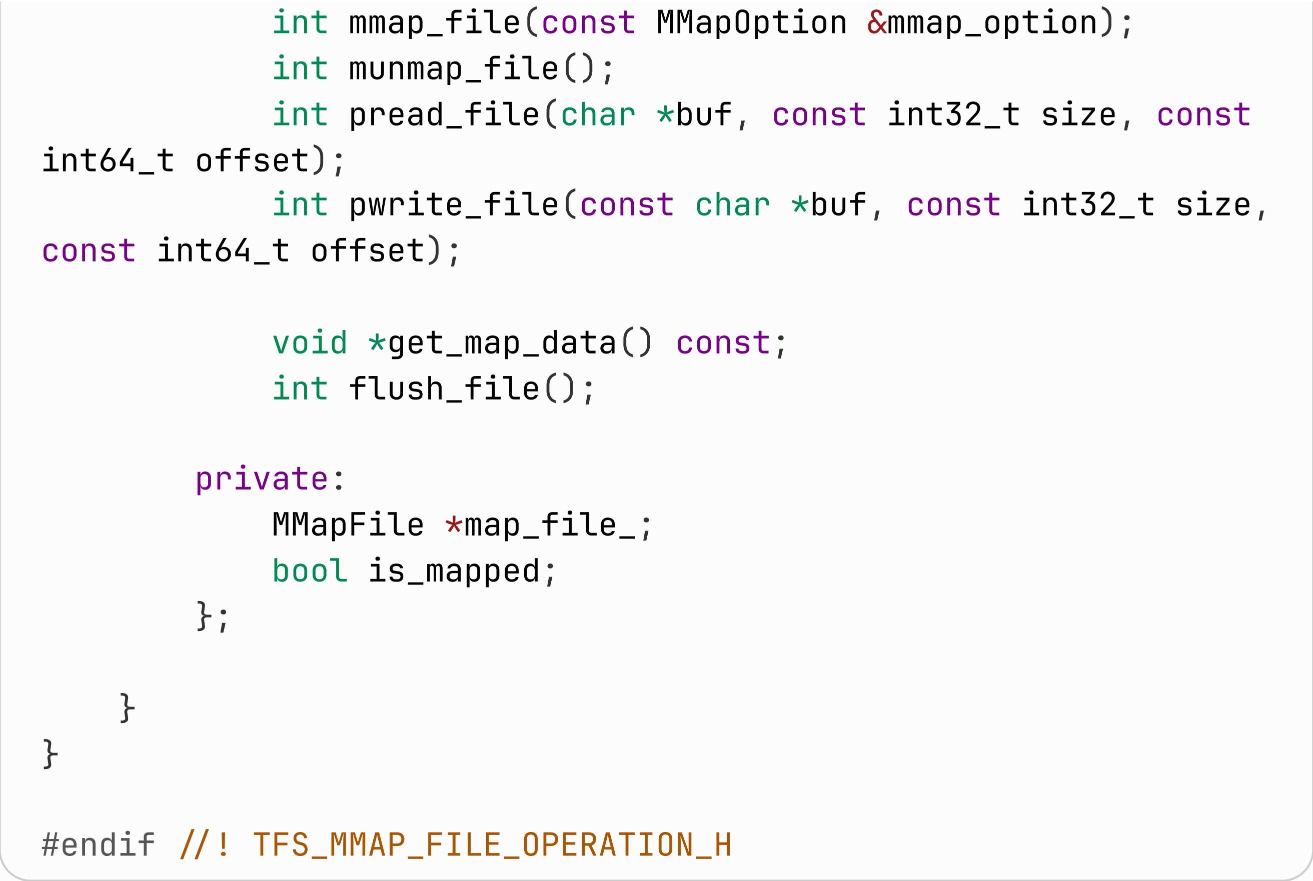
namespace lucifer
{
    namespace tfs
    {

        class MMapFileOperation : public FileOperation
        {
        public:

            MMapFileOperation(const std::string& file_name, int
open_flags = O_RDWR|O_LARGEFILE)
                : FileOperation(file_name, open_flags),
map_file_(nullptr), is_mapped(false) {}

            ~MMapFileOperation();

```



```
            int mmap_file(const MMapOption &mmap_option);
            int munmap_file();
            int pread_file(char *buf, const int32_t size, const int64_t offset);
            int pwrite_file(const char *buf, const int32_t size, const int64_t offset);

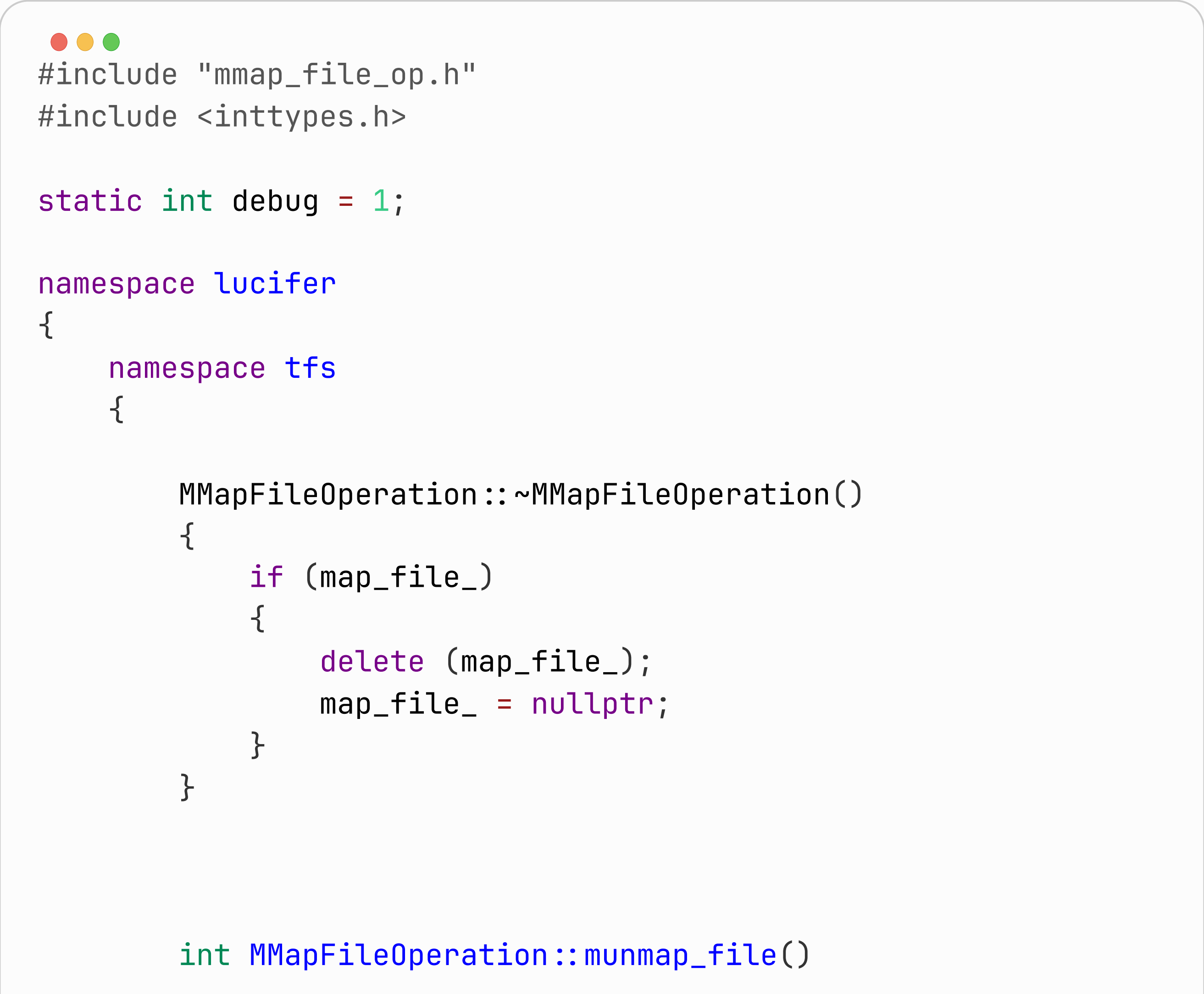
            void *get_map_data() const;
            int flush_file();

        private:
            MMapFile *map_file_;
            bool is_mapped;
        };

    }
}

#endif //! TFS_MMAP_FILE_OPERATION_H
```

mmap_file_op.cpp



```
#include "mmap_file_op.h"
#include <inttypes.h>

static int debug = 1;

namespace lucifer
{
    namespace tfs
    {

        MMapFileOperation::~MMapFileOperation()
        {
            if (map_file_)
            {
                delete (map_file_);
                map_file_ = nullptr;
            }
        }



        int MMapFileOperation::munmap_file()
        {
            if (this->is_mapped && this->map_file_ != nullptr)
            {
                delete (this->map_file_);
                this->is_mapped = false;
            }
            return TFS_SUCCESS;
        }

        int MMapFileOperation::mmap_file(const MMapOption &mmap_option)
        {
            if (mmap_option.max_mmap_size_ <= 0)
            {
                return TFS_ERROR;
            }
            if (mmap_option.max_mmap_size_ < mmap_option.first_mmap_size_)
                return TFS_ERROR;
            int fd = this->check_file();
            if (fd < 0)
            {
                fprintf(stderr, "MMapFileOpation::mmap_file checking faild ");
                return TFS_ERROR;
            }
            if (!is_mapped)
            {
                if (nullptr == this->map_file_)
                {
                    delete map_file_;
                }
                map_file_ = new MMapFile(mmap_option, fd);
                this->is_mapped = this->map_file_->mmapFile(true);
            }

            if (this->is_mapped)
            {
                return TFS_SUCCESS;
            }
            else
            {
                return TFS_ERROR;
            }
        }

        void *MMapFileOperation::get_map_data() const
        {

            if (this->is_mapped)
            {
                return this->map_file_->getData();
            }
            return nullptr;
        }

        int MMapFileOperation::pread_file(char *buf, const int32_t size, const int64_t offset)
        {
            // 如果读取不全可以考虑使用while
            // 内存已经映射
            if (this->is_mapped && (offset + size) > map_file_->getSize())
            {
                if (DEBUG)
                {
                    fprintf(stdout, "mmapFileOperation pread file, size: %d, offset: %" PRId64 ", map file size: %d. need remap\n", size, offset, map_file_->getSize());
                }
                this->map_file_->remapFile(); // 追加内存
            }
            if (is_mapped && (offset + size) <= this->map_file_->getSize())
            {
                memcpy(buf, (char *)map_file_->getData() + offset, size);

                return TFS_SUCCESS;
            }
            // 映射不全 内存没有映射或者是要读取的数据不全
            return FileOperation::pread_file(buf, size, offset);
        }

        int MMapFileOperation::pwrite_file(const char *buf, const int32_t size, const int64_t offset)
        {
            if (is_mapped && (offset + size) > this->map_file_->getSize())
            {
                if (DEBUG)
                {
                    fprintf(stdout, "mmapFileOperation pwrite file, size: %d, offset: %" PRId64 ", map file size: %d. need remap\n", size, offset, map_file_->getSize());
                }
                this->map_file_->remapFile(); // 追加内存
            }

            if (is_mapped && (offset + size) <= this->map_file_->getSize())
            {
               // memccpy((char*)map_file_->getData()+offset,buf,size);
                memcpy((char*)map_file_->getData()+offset,buf,size);
                return TFS_SUCCESS;
            }


            //内存没有映射or写入映射数据补全
            return FileOperation::pwrite_file(buf,size,offset);//or write
        }

        int MMapFileOperation::flush_file(){
            if(is_mapped){
                if(map_file_->syncFile())
                {
                    return TFS_SUCCESS;
                }else{
                    return TFS_ERROR;
                }
            }

          return int();
        }

    }

}
```

文件操作类

```
#ifndef TFS_FILE_OP_H_
#define TFS_FILE_OP_H_

#include "head.h"

namespace lucifer
{

    namespace tfs
    {

        class FileOperation
        {
        public:
            FileOperation();
            FileOperation(const std::string &file_name, const
int open_flags = O_RDWR | O_LARGEFILE);
            virtual ~FileOperation();

            void close_file();
            int open_file();
            int flush_file(); // write thre file to the disk
            int unlink_file();
            virtual int pread_file(char *buf, const int32_t
nbytes, const int64_t offset);
            virtual int pwrite_file(const char *buf, const
int32_t nbytes, const int64_t offset);

            virtual int write_file(const char *buf, const
int32_t nbytes);
            virtual int read_file( char *buf, const int32_t
nbytes);
            int64_t get_file_size();

            int ftruncate_file(const int64_t length);
            int seek_file(const int64_t offset);

            int get_fd()const;
        protected:
            int fd_;
            int open_flags_;
            char* file_name_;
            int64_t file_size_;
            int disk_times_;
        protected:
            static constexpr mode_t OPEN_MODE = 0644;
            static constexpr int MAX_DISK_TIMES = 5;
        protected:
            int check_file();
        };

    }
}

#endif // TFS_FILE_OP_H_
```

```
#include "file_op.h"
#include "head.h"

namespace lucifer
{

    namespace tfs
    {

        FileOperation::FileOperation() {}
        FileOperation::FileOperation(const std::string
&file_name, const int open_flags)
            : fd_(-1), open_flags_(open_flags)
        {
            this->file_name_ = strdup(file_name.c_str());
        }
        FileOperation::~FileOperation()
        {
            if (this->fd_ > 0)
                ::close(this->fd_);
            if (nullptr != file_name_)
            {
                free(file_name_);
                file_name_ = nullptr;
            }
        }

        int FileOperation::open_file()
        {
            if (this->fd_ > 0)
            {
                close(fd_);
            }

            this->fd_ = ::open(this->file_name_, this-
>open_flags_, OPEN_MODE);

            if (this->fd_ < 0)
            {
                return -errno;
            }
            return fd_;
        }

        void FileOperation::close_file()
        {
            if (this->fd_ > 0)
            {
                ::close(this->fd_);
                this->fd_ = -1;
            }
            return;
        }

        int64_t FileOperation::get_file_size()
        {
            int fd = this->check_file();
            if (fd < 0)
                return -1;
            struct stat st;
            if (fstat(fd, &st) < 0)
                return -1;
            return st.st_size;
        }

        int FileOperation::check_file()
        {
            if (this->fd_ < 0)
            {
                this->fd_ = this->open_file();
```

```
    }

    return this->fd_;
}

int FileOperation::ftruncate_file(const int64_t length)
{
    int fd = this->check_file();
    if (fd < 0)
        return -1;
    return ftruncate(fd, length);
}
// move
int FileOperation::seek_file(const int64_t offset)
{
    int fd = this->check_file();
    if (fd < 0)
        return -1;
    return lseek(fd, offset, SEEK_SET);
}
int FileOperation::flush_file()
{
    if (this->open_flags_ & O_SYNC)
    {
        return 0;
    }
    int fd = this->check_file();
    if (fd < 0)
        return -1;
    return fsync(fd);
}

int FileOperation::unlink_file()
{
    if (this->fd_ > 0)
    {
        this->close_file();
        this->fd_ = -1;
    }
    return ::unlink(this->file_name_);
}

int FileOperation::get_fd() const
{
    return this->fd_;
```

```
        }

        int FileOperation::pread_file(char *buf, const int32_t nbytes, const int64_t offset)
        {
            int fd = this->check_file();
            if (fd < 0)
                return -1;

            int32_t left = nbytes; // 剩余字节
            int64_t read_offset = offset;
            int32_t read_len = 0;
            char *p_tmp = buf;
            int i = 0;
            while (left > 0)
            {
                ++i;
                if (i >= MAX_DISK_TIMES)
                    return -1;
                if (this->check_file() < 0)
                    return -errno;
                read_len = ::pread64(fd, p_tmp, left, read_offset);
                if (read_len < 0)
                {
                    read_len = -errno;
                    if (read_len == -EINTR || -EAGAIN == read_len)
                        continue;
                    else if (-EBADF == read_len)
                    {
                        // fd_ = -1;
                        return read_len;
                    }
                    else
                    {

                        return read_len;
                    }
                }
                else if (0 == read_len)
                {
                    break;
                }
                left -= read_len;
                p_tmp += read_len;
                read_offset += read_len;
            }
            if (0 != left)
            {
                return EXIT_DISK_OPER_INCOMPLETE;
            }
            return TFS_SUCCESS;
        }

        int FileOperation::pwrite_file(const char *buf, const
int32_t nbytes, const int64_t offset)
        {
            int fd = this->check_file();
            if (fd < 0)
            {
                return -1;
            }

            int32_t left = nbytes; // 剩余字节
            int64_t write_offset = offset;
            int32_t write_len = 0;
            const char *p_tmp = buf;
            int i = 0;
            while (left > 0)
            {
                ++i;
                if (i >= MAX_DISK_TIMES)
                    return -1;
                write_len = ::pwrite64(fd, p_tmp, left,
write_offset);
                if (write_len < 0)
                {
                    write_len = -errno;
                    if (-write_len == EINTR || EAGAIN == -
write_len)
                        continue;
                    else if (EBADF == -write_len)
                    {
                        // fd_ = -1;
                        continue;
                    }
                    else
                    {
                        return write_len;
                    }
                }

                left -= write_len;
                p_tmp += write_len;
                write_offset += write_len;
            }
            if (0 == left)
                return TFS_SUCCESS;

            return EXIT_DISK_OPER_INCOMPLETE;
        }

        int FileOperation::write_file(const char *buf, const int32_t nbytes)
        {
            int fd = this->check_file();
            if (fd < 0)
                return -1;
            int32_t left = nbytes; // 剩余字节
            const char *p_tmp = buf;
            int i = 0;
            while (left > 0)
            {
                ++i;
                if (i >= MAX_DISK_TIMES)
                    return -1;
                int32_t write_len = ::write(fd, p_tmp, left);
                if (write_len < 0)
                {
                    write_len = -errno;
                    if (-write_len == EINTR || EAGAIN == -write_len)
                        continue;
                    else if (EBADF == -write_len)
                    {
                        // this->fd_ = -1; // 使用 fd 替换 fd_
                        continue;
                    }
                    else
                    {
                        return write_len;
                    }
                }
                left -= write_len;
                p_tmp += write_len;
            }
            if (0 == left)
            {
                return TFS_SUCCESS;
            }
            return EXIT_DISK_OPER_INCOMPLETE;
        }

        int FileOperation::read_file(char *buf, const int32_t nbytes)
        {
            int fd = this->check_file();
            if (fd < 0)
            {
                if (DEBUG)
                {
                    std::cout << "fd < 0" << std::endl;
                }
                return -1;
            }

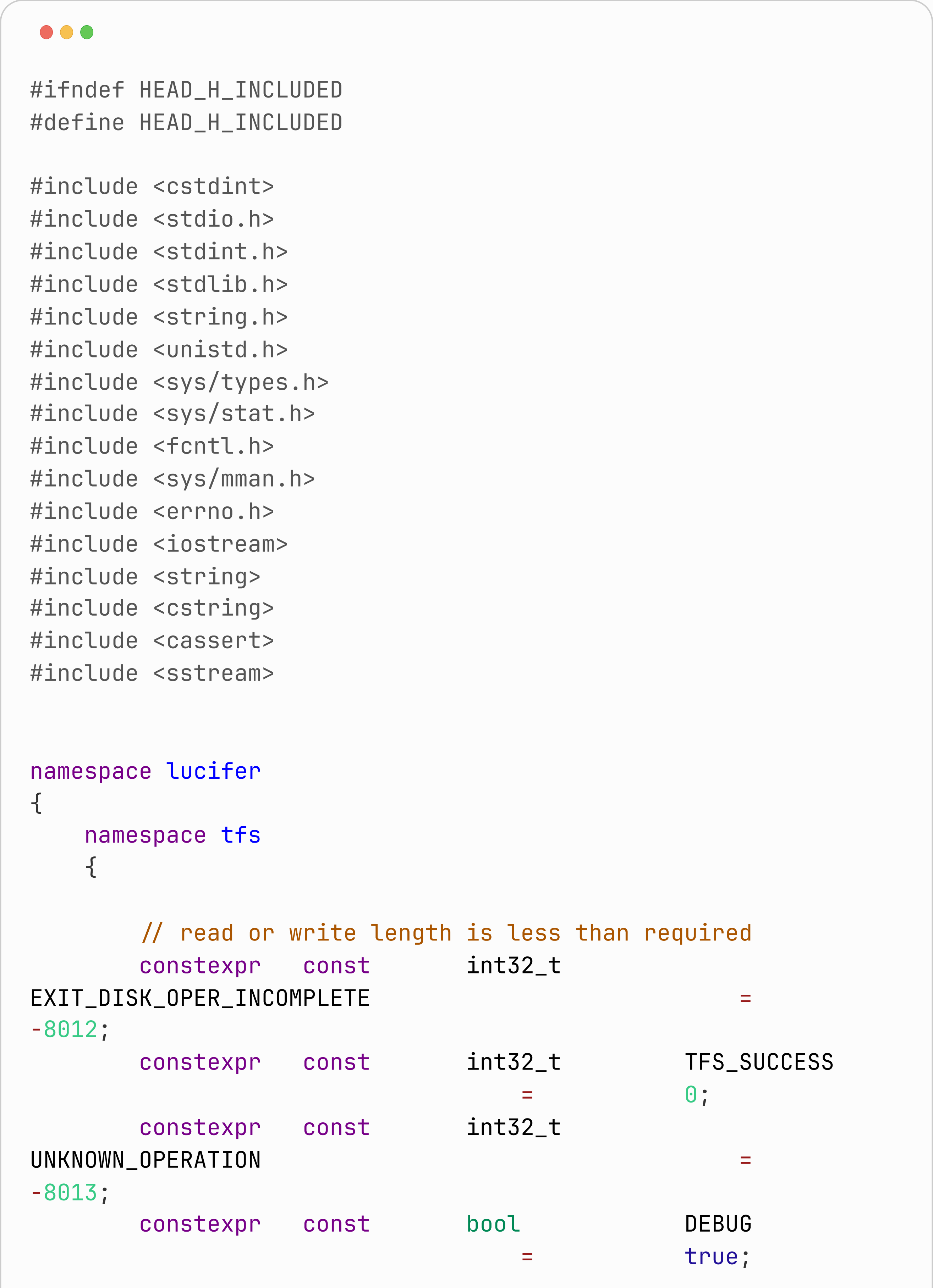
            char *p_tmp = buf;
            int32_t left = nbytes;
            int i = 0;
            while (left > 0)
            {
                ++i;
                if (i >= MAX_DISK_TIMES)
                    return -1;
                int32_t read_len = ::read(fd, p_tmp, left);
                std::cout << "read_len: " << read_len << std::endl;
                if (read_len < 0)
                {
                    read_len = -errno;
                    if (-read_len == EINTR || EAGAIN == -read_len)
                        continue;
                    else if (EBADF == -read_len)
                    {
                        if (DEBUG)
                        {
                            std::cout << "is EBADF" <<
std::endl;
                        }
                        return -1; // 直接返回错误码
                    }
                    else
                    {
                        if (DEBUG)
                        {
                            std::cout << "is else" << std::endl;
                        }
                        return read_len;
                    }
                }
                else if (read_len == 0)
                {
                    // 文件读取结束
                    break;
                }
                left -= read_len;
                p_tmp += read_len;
            }
            std::cout<<"The left is "<<left<<std::endl;
            // 检查剩余字节数
            if (left != 0)
            {
                if (DEBUG)
                {
                    std::cout << "left != 0" << std::endl;
                }
                return EXIT_DISK_OPER_INCOMPLETE;
            }

            return TFS_SUCCESS;
        }

    }

}
```

公用头文件



```
#ifndef HEAD_H_INCLUDED
#define HEAD_H_INCLUDED

#include <cstdint>
#include <stdio.h>
#include <stdint.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>
#include <sys/mman.h>
#include <errno.h>
#include <iostream>
#include <string>
#include <cstring>
#include <cassert>
#include <sstream>


namespace lucifer
{
    namespace tfs
    {

        // read or write length is less than required
        constexpr   const       int32_t
EXIT_DISK_OPER_INCOMPLETE                           =
-8012;
        constexpr   const       int32_t         TFS_SUCCESS
                                    =           0;
        constexpr   const       int32_t
UNKNOWN_OPERATION                                   =
-8013;
        constexpr   const       bool            DEBUG
                                    =           true;
        constexpr    const        int32_t          TFS_ERROR
                                      =            -8014;
        static       const        std::string
MAINLOCK_DIR_PREFIX                                    =
"/mainblock/";
        static       const        std::string      INDEX_DIR_PREFIX
                                   =           "/index/";
        static       const        mode_t           DIR_MODE
                                   =           0755;
        constexpr    const        int32_t
EXIT_INDEX_ALREADY_LOADED_ERROR                        =
-8015;
        constexpr    const        int32_t
EXIT_META_UNEXPECT_FOUND_ERROR                         =
-8016;
        constexpr    const        int32_t
EXIT_INDEX_CORRUPT_ERROR                               =
-8017;
        constexpr    const        int32_t
EXIT_BLOCKID_CONFLICT_ERROR                            =
-8018;
        constexpr    const        int32_t
EXIT_BUCKET_CONFLICT_ERROR                             =
-8019;
        constexpr    const        int32_t
EXIT_MEFA_NOT_FOUND_ERROR                              =
-8020;
        constexpr    const        int32_t
EXIT_BLOCKID_ZERO_ERROR                                =
-8021;
        constexpr    const        int32_t          UNKNOWN_ERROR
                                    =          -8022;
        constexpr    const        int32_t
EXIT_BLOCK_NOT_EXIST                                   =
-8023;
        constexpr    const        int32_t
EXIT_BLOCK_DEL_FILE_COUNT_LESSZERO                     =
-8024;
        constexpr    const        int32_t
EXIT_BLOCK_DEL_SIZE_LESSZEOR                           =
-8025;
        constexpr    const        int32_t
EXIT_META_NOT_FOUND_ERROR                              =
-8026;
```

```
        constexpr   const       int32_t
MAINBLOCK_DIR_PREFIX                                =
-8027;
        enum OperType{
            C_OPER_INSERT = 1,
            C_OPER_DELETE
        };

        struct MMapOption
        {

            int32_t max_mmap_size_;
            int32_t first_mmap_size_;
            int32_t per_mmap_size_;
        };

        struct BlockInfo
        {
            uint32_t block_id_;
            int32_t version_;
            int32_t file_count_;
            int32_t size_;
            int32_t del_file_count_;
            int32_t del_size_;
            uint32_t seq_no_;
            BlockInfo()
            {
                memset(this, 0, sizeof(BlockInfo));
            }
            inline bool operator==(const BlockInfo &b)
            {
                return (block_id_ == b.block_id_) && (version_
== b.version_) && (file_count_ == b.file_count_) && (size_ ==
b.size_) && (del_file_count_ == b.del_file_count_) && (del_size_
== b.del_size_) && (seq_no_ == b.seq_no_);
            }
            inline BlockInfo*      block_info(){return this;}

        };

        struct MetaInfo
        {
        private:
            uint64_t fileid_;
            struct
            {
                int32_t inner_offset_;
                int32_t size_;
            } location_;

            int32_t next_meta_offset_;

        public:
            MetaInfo()
            {
                init();
            }
            MetaInfo(const uint64_t fileid, const int32_t
inner_offset, const int32_t size,
                     const int32_t next_meta_offset)
            {

                fileid_ = fileid;
                location_.inner_offset_ = inner_offset;
                location_.size_ = size;
                this->next_meta_offset_ = next_meta_offset;
            }

            MetaInfo(const MetaInfo &other)
            {
                // 使用内存拷贝赋值
                memcpy(this, &other, sizeof(MetaInfo));
            }

            uint64_t get_key() const { return fileid_; }
            void set_key(const uint64_t key) { fileid_ = key; }
            uint64_t get_file_id() const { return fileid_; }
            void set_file_id(const uint64_t file_id) { fileid_ =
file_id; }

            int32_t get_inner_offset() const { return
location_.inner_offset_; }
            void set_inner_offset(const int32_t inner_offset) {
location_.inner_offset_ = inner_offset; }

            int32_t get_size() const { return location_.size_; }
            void set_size(const int32_t file_size) {
location_.size_ = file_size; }
```

```
            int32_t get_next_meta_offset() const { return
next_meta_offset_; }
            void set_next_meta_offset(const int32_t
next_meta_offset) { next_meta_offset_ = next_meta_offset; }

            MetaInfo &operator=(const MetaInfo &other)
            {
                if (this == &other)
                {
                    return *this;
                }

                fileid_ = other.fileid_;
                location_.inner_offset_ =
other.location_.inner_offset_;
                location_.size_ = other.location_.size_;
                next_meta_offset_ = other.next_meta_offset_;
            }
            MetaInfo &clone(const MetaInfo &other)
            {
                assert(this != &other);

                fileid_ = other.fileid_;
                location_.inner_offset_ =
other.location_.inner_offset_;
                location_.size_ = other.location_.size_;
                next_meta_offset_ = other.next_meta_offset_;
                return *this;
            }

            bool operator==(const MetaInfo &other) const
            {
                return (fileid_ == other.fileid_) &&
(location_.inner_offset_ == other.location_.inner_offset_) &&
(location_.size_ == other.location_.size_) && (next_meta_offset_
== other.next_meta_offset_);
            }

        private:
            void init()
            {
                /* fileid_ = 0;
                 location_.inner_offset_ = 0;
                 location_.size_ = 0;
                 next_meta_offset_ = 0;*/
                memset(this, 0, sizeof(MetaInfo));
            }
        };


    }
}

#endif // HEAD_H_INCLUDED
```

index_handle

```
#include "index_handle.h"

namespace lucifer
{
    namespace tfs
    {
        IndexHandle::IndexHandle() {}

        IndexHandle::IndexHandle(const std::string &base_path, const int32_t &main_block_id)
        {

            // create file_op_ handle object
            std::stringstream tmp_stream;

            tmp_stream << base_path << INDEX_DIR_PREFIX << main_block_id;

            std::string index_path;
            tmp_stream >> index_path;

            file_op_ = new MMapFileOperation(index_path, O_CREAT | O_RDWR | O_LARGEFILE);

            this->is_load_ = false;
        }

        IndexHandle::~IndexHandle()
        {
            if (file_op_)
            {
                delete this->file_op_;
                this->file_op_ = nullptr;
            }
        }

        int IndexHandle::create(const int32_t logic_block_id,
const int32_t bucket_size, const MMapOption map_option)
        {
            int ret;
            if (DEBUG)
            {
                printf("create index\n\tblock id: %u\n\tbucket
size: %d\n\tmax_mmap_Size:%d\n\tper mmap size:%d\n\tfirst mmap
size:%d\n\n",
                       logic_block_id, bucket_size,
map_option.max_mmap_size_, map_option.per_mmap_size_,
map_option.first_mmap_size_);
            }
            if (is_load_)
            {
                return EXIT_INDEX_ALREADY_LOADED_ERROR;
            }
            int64_t file_size = this->file_op_->get_file_size();
            if (file_size < 0)
            {
                return TFS_ERROR;
            }
            else if (file_size == 0)
            {
                IndexHeader i_header;

                i_header.block_info_.block_id_ = logic_block_id;
                i_header.block_info_.seq_no_ = 1;
                i_header.bucket_size_ = bucket_size;

                i_header.index_file_size_ = sizeof(IndexHandle)
+ bucket_size * sizeof(int32_t);
                // index_header + total buckets
                char *init_data = new
char[i_header.index_file_size_];
                memcpy(init_data, &i_header,
sizeof(IndexHeader));
```

```
                memset(init_data + sizeof(IndexHeader), 0,
i_header.index_file_size_ - sizeof(IndexHeader));
                // write index header and buckets into index
file

                ret = file_op_->pwrite_file(init_data,
i_header.index_file_size_, 0);
                delete[] init_data;
                init_data = nullptr;

                if (ret != TFS_SUCCESS)
                {
                    return ret;
                }
                ret = file_op_->flush_file();
                if (ret != TFS_SUCCESS)
                {
                    return ret;
                }
            }
            else // file_size > 0 ,index already exist
            {
                return EXIT_META_UNEXPECT_FOUND_ERROR;
            }
            ret = this->file_op_->mmap_file(map_option);
            if (TFS_SUCCESS != ret)
            {
                return ret;
            }
            is_load_ = true;
            if (DEBUG)
            {

                printf("index successful\n\tinit blockid:
%d\n\tdata file size: %d\n\tindex file size: %d\n\tbucket_size:
%d\n\tfree head offset: %d\n\tseq no: %d\n\tsize:
%d\n\tfilecount: %d\n\tdel size : %d\n\tdel_file_count:
%d\n\tversion: %d\n\n",
                       logic_block_id, index_header()-
>data_file_offset_, index_header()->index_file_size_,
                       index_header()->bucket_size_,
index_header()->free_head_offset_,
                       index_header()->block_info_.seq_no_,
index_header()->block_info_.size_,
                       index_header()->block_info_.file_count_,
index_header()->block_info_.del_size_,
                       index_header()-
>block_info_.del_file_count_, index_header()-
>block_info_.version_);
            }
            return TFS_SUCCESS;
        }
        IndexHeader *IndexHandle::index_header()
        {
            return reinterpret_cast<IndexHeader *>(this-
>file_op_->get_map_data());
        }

        BlockInfo *IndexHandle::block_info()
        {
            return reinterpret_cast<BlockInfo *>(this->file_op_-
>get_map_data());
        }

        int32_t IndexHandle::bucket_size() const
        {
            return reinterpret_cast<IndexHeader *>(this-
>file_op_->get_map_data())->bucket_size_;
        }

        int IndexHandle::load(const int32_t logic_block_id,
const int32_t bucket_size,
                              const MMapOption map_option)
        {
            int ret = TFS_SUCCESS;

            if (is_load_)
            {
                return EXIT_INDEX_ALREADY_LOADED_ERROR;
            }

            int64_t file_size = this->file_op_->get_file_size();
            if (file_size < 0)
                return file_size;
            else if (file_size == 0)
            {
                printf("----------------file_size: %d\n",
file_size);
                return EXIT_INDEX_CORRUPT_ERROR;
            }

            MMapOption tmp_map_option = map_option;
            if (file_size > tmp_map_option.first_mmap_size_ && file_size <= tmp_map_option.max_mmap_size_)
            {
                tmp_map_option.first_mmap_size_ = file_size;
            }
            ret = this->file_op_->mmap_file(tmp_map_option);
            if (TFS_SUCCESS != ret)
            {
                return ret;
            }


            if (0 == this->bucket_size() || 0 == block_info()->block_id_)
            {
                if (DEBUG)
                    printf("bucket_size is 0 or block id is 0\n");
                fprintf(stderr, "index corrpurt ,block id: %u,bucket size: %d \n",
                        block_info()->block_id_, this->bucket_size());
                return EXIT_INDEX_CORRUPT_ERROR;
            }

            // check file size
            int32_t index_file_size = sizeof(IndexHeader) + this->bucket_size() * sizeof(int32_t);

            if (file_size < index_file_size)
            {
                fprintf(stderr, "index corrupt error,blockid: %u,\
                    this bucket size: %d,file size : %d,index file size : %d\n ",
                        block_info()->block_id_, this->bucket_size(), file_size, index_file_size);
                return EXIT_INDEX_CORRUPT_ERROR;
            }
            // check block id size
            if (logic_block_id != block_info()->block_id_)
            {
                fprintf(stderr, "block id confict : %u,index
blockid : %u\n", logic_block_id, block_info()->block_id_);
                return EXIT_BLOCKID_CONFLICT_ERROR;
            }

            // check bucket size
            if (bucket_size != this->bucket_size())
            {

                fprintf(stderr, "Index configure error,old
bucket size: %d,bew bucket size: %d\n", this->bucket_size(),
bucket_size);
                return EXIT_BUCKET_CONFLICT_ERROR;
            }
            this->is_load_ = true;
            if (DEBUG)
            {

                printf("Load index handle successful \n\tload
blockid:%d\n\tdata file size: %d\n\tindex file size:
%d\n\tbucket_size: %d\n\tfree head offset: %d\n\tseq no:
%d\n\tsize: %d\n\tfilecount: %d\n\tdel size :
%d\n\tdel_file_count: %d\n\tversion: %d\n\n",
                       logic_block_id, index_header()-
>data_file_offset_, index_header()->index_file_size_,
                       index_header()->bucket_size_,
index_header()->free_head_offset_,
                       index_header()->block_info_.seq_no_,
index_header()->block_info_.size_,
                       index_header()->block_info_.file_count_,
index_header()->block_info_.del_size_,
                       index_header()-
>block_info_.del_file_count_, index_header()-
>block_info_.version_);
            }

            return TFS_SUCCESS;
        }

        int IndexHandle::remove(const uint32_t logic_block_id)
        {
            if (is_load_)
            {
                if (logic_block_id != block_info()->block_id_)
                {
                    fprintf(stderr, "block id confict : %u,index
blockid : %u\n", logic_block_id, block_info()->block_id_);
                    return EXIT_BLOCKID_CONFLICT_ERROR;
                }
            }
            auto ret = file_op_->munmap_file();

            if (TFS_SUCCESS != ret)
            {
                return ret;
            }

            ret = file_op_->unlink_file();
            return TFS_SUCCESS;
        }

        int IndexHandle::flush()
        {
            int ret = this->file_op_->flush_file();
            if (TFS_SUCCESS != ret)
            {
                fprintf(stderr, "index flush fail,ret:%d error
desc:%s\n", ret, strerror(ret));
            }
            return ret;
        }

        int32_t IndexHandle::get_block_data_offset()
        {
            return reinterpret_cast<IndexHeader *>(file_op_-
>get_map_data())->data_file_offset_;
        }
           int32_t IndexHandle::free_head_offset() const
        {
            return reinterpret_cast<IndexHeader *>(file_op_-
>get_map_data())->free_head_offset_;
        }


        int32_t IndexHandle::write_segment_meta(const uint64_t
key, MetaInfo &meta)
        {

            int32_t current_offset = 0;   // 查找的偏移
            int32_t previous_offset = 0; // 查找的偏移
            // key exist or not
            // find from file hashTbale is exist  (hash_find
(key,current_offset))

            int ret = hash_find(key, current_offset,
previous_offset);

            if (TFS_SUCCESS == ret)
            {
                return EXIT_META_UNEXPECT_FOUND_ERROR;
            }
            else if (EXIT_MEFA_NOT_FOUND_ERROR != ret)
            {
                return ret;
            }

            // if not exist ,then write the meta to file (hash
insert(meta,slot))
            ret = hash_insert(key, previous_offset, meta);
            return ret;
        }

        int32_t *IndexHandle::bucket_slot()
        {
            return reinterpret_cast<int32_t *>
(reinterpret_cast<char *>(file_op_->get_map_data()) +
sizeof(IndexHeader));
        }

        int32_t IndexHandle::hash_find(const uint64_t key,
int32_t &current_offset, int32_t &previous_offset)
        {
            int ret = TFS_SUCCESS;

            // ensure the key slot
            previous_offset = 0;
            current_offset = 0;

            MetaInfo meta_info;
            // 1. 确定key存放的桶（slot）的位置
            int32_t slot = static_cast<uint32_t>(key) % this-
>bucket_size();
            // 2. 读取桶的首节点存储的第一个节点的偏移量  如果偏移为0 :
EXIT_MEFA_NOT_FOUND_ERROR
            // 3. 根据偏移量读取存储的meta info
            // 4. 与key进行比较，相等就设置喷设置 (—curoffset
pre_offset 并且返回TFS_SUCCESS,否则执行5
            // 5. 从mefainfo取得下一个节点在文件中间的偏移量 如果偏移为
0 : EXIT_MEFA_NOT_FOUND_ERROR

            int32_t pos = this->bucket_slot()[slot];
            for (; pos != 0;)
            {
                ret = file_op_->pread_file(reinterpret_cast<char
*>(&meta_info),
                                           sizeof(MetaInfo),
pos);
                if (TFS_SUCCESS != ret)
                {
                    return ret;
                }

                if (hash_compatre(key, meta_info.get_key()))
                {
                    current_offset = pos;
                    return TFS_SUCCESS;
                }
                previous_offset = pos;
                pos = meta_info.get_next_meta_offset();
            }
            return EXIT_MEFA_NOT_FOUND_ERROR;
        }

        int32_t IndexHandle::hash_insert(const uint64_t key,
int32_t previous_offset, MetaInfo &meta)
        {
            MetaInfo tmp_meta_info;
            int32_t ret = TFS_SUCCESS;
            int32_t current_offset = 0;
            // 1 确定key存放的slot的位置
            int32_t slot = static_cast<uint32_t>(key) % this-
>bucket_size();

            // 2 确定meta 节点存储在文件中的存放当前节点的偏移量

            if(free_head_offset()!= 0){
                ret = file_op_->pread_file(reinterpret_cast<char
*>(&tmp_meta_info),sizeof(MetaInfo),free_head_offset());

                if(TFS_SUCCESS != ret)  return ret;
                current_offset = index_header()-
>free_head_offset_;
                index_header()->free_head_offset_ =
tmp_meta_info.get_next_meta_offset();

                if(DEBUG)
                    printf("reuse metainfo ,current offset:
%d\n",current_offset);
            }else{


                current_offset   = index_header()-
>index_file_size_;
                index_header()->index_file_size_ +=
sizeof(MetaInfo);
            }




            // 3. 将metainfo写入索引文件中
            meta.set_inner_offset(0);
            ret = file_op_->pwrite_file(reinterpret_cast<const
char *>(&meta),
                                        sizeof(MetaInfo),
current_offset);
            if (TFS_SUCCESS != ret)
            {
                index_header()->index_file_size_ -=
sizeof(MetaInfo);
                return ret;
            }
            // 4. 将meta节点插入哈希链表

            if (0 != previous_offset)
            {
                ret = file_op_->pread_file(reinterpret_cast<char
*>(&tmp_meta_info), sizeof(MetaInfo), previous_offset);
                if (TFS_SUCCESS != ret)
                {
                    index_header()->index_file_size_ -=
sizeof(MetaInfo);
                    return ret;
                }
```

```
 tmp_meta_info.set_next_meta_offset(current_offset);

                ret = file_op_-
>pwrite_file(reinterpret_cast<const char *>(&tmp_meta_info),
                                            sizeof(MetaInfo),
current_offset);

                if (TFS_SUCCESS != ret)
                {
                    index_header()->index_file_size_ -=
sizeof(MetaInfo);
                    return ret;
                }
            }

            else
            {
                bucket_slot()[slot] = current_offset;
            }

            return TFS_SUCCESS;
        }

        void IndexHandle::commit_block_data_offset(const int
file_size)
        {
            reinterpret_cast<IndexHeader *>(this->file_op_-
>get_map_data())
                ->data_file_offset_ += file_size;
        }

        bool IndexHandle::update_block_info(const OperType
oper_type, const uint32_t modify_size)
        {
            if (block_info()->block_id_ == 0)
                return EXIT_BLOCKID_ZERO_ERROR;
            if (oper_type == C_OPER_INSERT)
            {
                ++block_info()->version_;
                ++block_info()->file_count_;
                ++block_info()->seq_no_;
                block_info()->size_ += modify_size;
            }
            else if (oper_type == C_OPER_DELETE)
            {
                ++block_info()->version_;
                --block_info()->file_count_;
                block_info()->size_ -= modify_size;
                ++block_info()->del_file_count_;
                block_info()->del_size_ += modify_size;
            }
            if (DEBUG)
            {
                printf("\n\nupdate  block   info\n\tblockid: %u\n\tversion: %u\n\tfile_count: %u\n\tseq_no: %u\n\tsize: %u\n\tdel_size: %u\n\tdel_file_count: %u\n\n",
                       block_info()->block_id_, block_info()->version_, block_info()->file_count_, block_info()->seq_no_,
                       block_info()->size_, block_info()->del_size_, block_info()->del_file_count_);

                printf("type:%d,modify_size:%d\n", oper_type, modify_size);
            }
            return TFS_SUCCESS;
        }

        int32_t IndexHandle::read_segment_meta(const uint64_t key, MetaInfo &meta)
        {
            int32_t current_offset = 0;
            int32_t previous_offset = 0;

            auto ret = hash_find(key, current_offset, previous_offset);

            if (tfs::TFS_SUCCESS == ret)
            {
                ret = file_op_->pread_file(reinterpret_cast<char *>(&meta), sizeof(MetaInfo), current_offset);
                return ret;
            }
            else
            {
                if (tfs::DEBUG)
                    printf("read segment read not except?\n");
                return ret;
            }
        }
        int32_t IndexHandle::delete_segment_meta(const uint64_t key)
        {

            int32_t current_offset = 0;
            int32_t previous_offset = 0;

            int32_t ret = hash_find(key, current_offset, previous_offset);
            if (TFS_SUCCESS != ret)
                return ret;

            MetaInfo meta_info;
            ret = file_op_->pread_file(reinterpret_cast<char *>(&meta_info), sizeof(MetaInfo), current_offset);
            if (ret != TFS_SUCCESS)
                return ret;
            int32_t next_pos = meta_info.get_next_meta_offset();

            // 为首节点
            if (previous_offset == 0)
            {
                int32_t slot = static_cast<uint32_t>(key) % this->bucket_size();
                this->bucket_slot()[slot] = next_pos;
            }
            else
            { // 普通节点

                MetaInfo pre_meta_info;
                ret = file_op_->pread_file(reinterpret_cast<char *>(&pre_meta_info), sizeof(MetaInfo), previous_offset);
                if (ret != TFS_SUCCESS)
                    return ret;

                pre_meta_info.set_next_meta_offset(next_pos);
                ret = file_op_->pwrite_file(reinterpret_cast<const char *>(&pre_meta_info), sizeof(MetaInfo), previous_offset);

                if (ret != TFS_SUCCESS)
                    return ret;
            }

            // 加入可重用节点链表


 meta_info.set_next_meta_offset(free_head_offset());//index_header()->free_head_offset
            if(DEBUG){
                printf("delete_segment_meta- reuse meta_info,current_offset: %d\n",current_offset);

            }
            ret = file_op_->pwrite_file(reinterpret_cast<const char *>(&meta_info), sizeof(MetaInfo),current_offset);

            if(TFS_SUCCESS != ret) return ret;

            index_header()->free_head_offset_ = current_offset;
            update_block_info(C_OPER_DELETE, meta_info.get_size());

            return TFS_SUCCESS;
        }



    }

}
```

```
#ifndef TFS_INDEX_HANDLE_H_
#define TFS_INDEX_HANDLE_H_

#include "head.h"
#include "mmap_file_op.h"
#include "mmap_file.h"

namespace lucifer
{

    namespace tfs
    {

        struct IndexHeader
        {
```

```
        public:
            BlockInfo   block_info_;        // meta block info
            int32_t     bucket_size_;       // hash bucket size
            int32_t     data_file_offset_;  // offset to wirte
next data in block
            int32_t     index_file_size_;   // offset  after
index+header + all buckets
            int32_t     free_head_offset_;  // free meta node
list for reuse

            IndexHeader() { memset(this, 0,
sizeof(IndexHeader)); }


        };

        class IndexHandle
        {
        public:

            IndexHandle(const std::string& base_path, const
int32_t& main_block_id);
            IndexHandle();
            virtual ~IndexHandle();

            int             create(const int32_t
logic_block_id,const int32_t bucket_size,const MMapOption
map_option);
            int             load  (const int32_t
logic_block_id,const int32_t bucket_size,const MMapOption
map_option);
            int             remove(const uint32_t
logic_block_id);
            int             flush ();
            void            commit_block_data_offset(const int
file_size);
            bool            update_block_info(const OperType
oper_type,const uint32_t modify_size);

            int32_t         bucket_size()const;
            int32_t         get_block_data_offset();
            int32_t         write_segment_meta(const uint64_t
key,MetaInfo &meta);
```

```
            int32_t         read_segment_meta(const uint64_t
key,MetaInfo &meta);
            int32_t         hash_find(const uint64_t key,int32_t
&current_offset,int32_t &previous_offset);
            int32_t*        bucket_slot();
            int32_t         hash_insert(const uint64_t
key,int32_t previous_offset,MetaInfo &meta);
            int32_t         delete_segment_meta(const uint64_t
key);
            int32_t         free_head_offset()const;

            //整理快文件
            int32_t         space_reclamation(FileOperation*);

            IndexHeader*    index_header();
            BlockInfo*      block_info();
        private:
            inline bool hash_compatre(const uint64_t
left_key,const uint64_t right_key)
                {return (left_key == right_key);}

        private:
            MMapFileOperation*  file_op_;
            bool                is_load_;


        };

    }
}

#endif // TFS_INDEX_HANDLE_H_
```

提供的一些测试代码

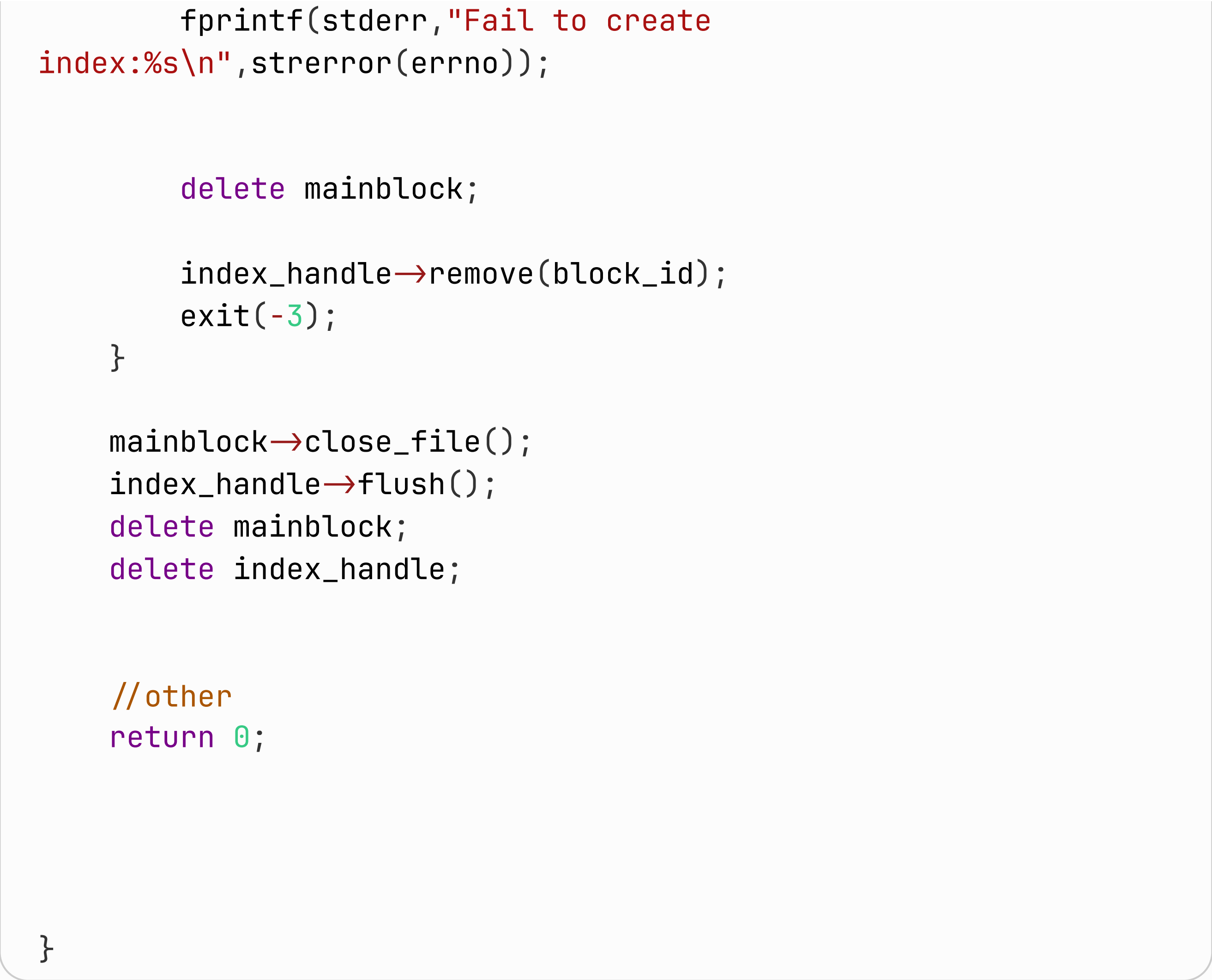
```
#include "head.h"
#include "file_op.h"
#include "index_handle.h"

using namespace lucifer;
```

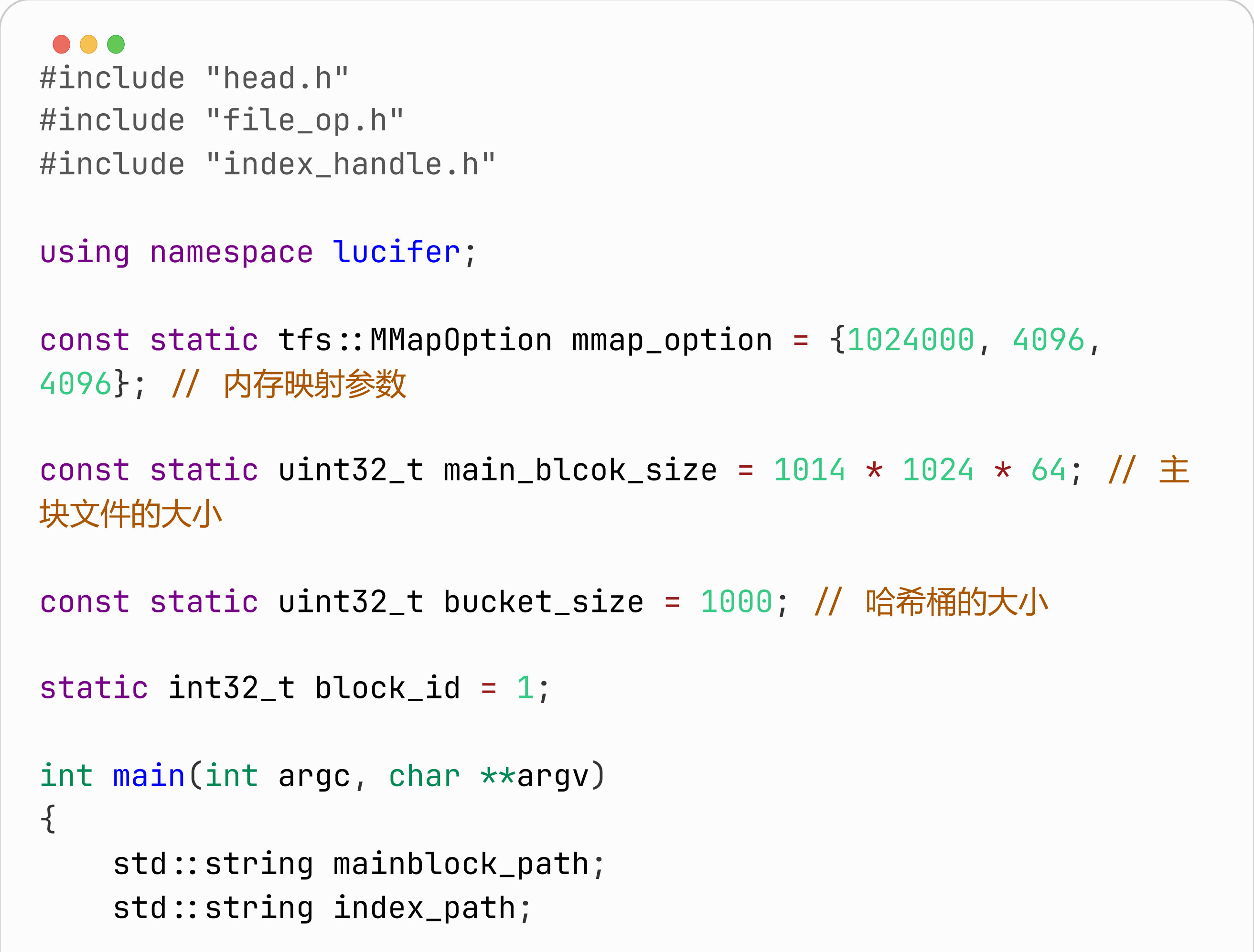
```cpp
const static tfs::MMapOption mmap_option = {1024000, 4096, 4096}; // 内存映射参数

const static uint32_t main_blcok_size = 1014 * 1024 * 64; // 主块文件的大小

const static uint32_t bucket_size = 1000; // 哈希桶的大小

static int32_t block_id = 1;

int main(int argc, char **argv)
{
    std::string mainblock_path;
    std::string index_path;
    int32_t ret = tfs::TFS_SUCCESS;
    tfs::IndexHandle *index_handle = new tfs::IndexHandle(".", block_id);

    std::cout << "Type you bock id:" << std::endl;
    std::cin >> block_id;

    if (block_id < 0){
        std::cerr << "Invalid blockid,exit" << std::endl;
        exit(-1);
    }


    ret = index_handle->load(block_id, bucket_size, mmap_option);

    if (ret != tfs::TFS_SUCCESS){
        fprintf(stderr, "Fail to load index:%s ret: %d\n", strerror(errno),ret);

        delete index_handle;

        index_handle->remove(block_id);
        exit(-2);
    }
    //删除指定文件的meta info
    uint64_t file_id;

    std::cout << "Type you file_id:" << std::endl;
    std::cin >> file_id;
    if (file_id < 1){
        std::cerr << "Invalid blockid,exit" << std::endl;
        exit(-2);
    }

    ret = index_handle->delete_segment_meta(file_id);

    if(tfs::TFS_SUCCESS != ret){
        fprintf(stderr, "Fail to delete segment meta:%s ret:
%d\n", strerror(errno),ret);

        delete index_handle;
        index_handle->remove(block_id);
        exit(-3);
    }

    ret = index_handle->flush();
    if(ret != tfs::TFS_SUCCESS){
        fprintf(stderr,"flush error");
    }

    printf("delete successful \n");


    //delete index_handle;
    return 0;


}
```

```
#include "head.h"
#include "file_op.h"
#include "index_handle.h"


using namespace lucifer;

const static tfs::MMapOption mmap_option =
{1024000,4096,4096};//内存映射参数

const static uint32_t main_blcok_size = 1014*1024*64;//主块文件的
大小
```

```
const static uint32_t bucket_size = 1000;//哈希桶的大小

static int32_t block_id = 1;

int main(int argc,char **argv)
{
    std::string mainblock_path;
    std::string index_path;
    int32_t ret = tfs::TFS_SUCCESS;

    std::cout<<"Type you bock id:"<<std::endl;
    std::cin>>block_id;
    if(block_id < 0){
        std::cerr<<"Invalid blockid,exie"<<std::endl;
        exit(-1);
    }
    //生成主块文件
    std::stringstream tmp_stream;
    tmp_stream << "."<< tfs::MAINLOCK_DIR_PREFIX  <<block_id;
    tmp_stream >> mainblock_path;

    tfs::FileOperation * mainblock = new
tfs::FileOperation(mainblock_path,O_RDWR|O_LARGEFILE|O_CREAT);

    ret = mainblock->ftruncate_file(main_blcok_size);
    if(ret != 0){
        fprintf(stderr,"Fail to truncate
file:%s\n",strerror(errno));

        std::cerr<<"Fail to truncate file"<<std::endl;
        delete mainblock;

        exit(-2);
    }

    //生成索引文件
    tfs::IndexHandle * index_handle = new
tfs::IndexHandle(".",block_id);
    if(tfs::DEBUG)
        printf("Create index init\n");
    ret = index_handle-
>create(block_id,bucket_size,mmap_option);
    if(ret != tfs::TFS_SUCCESS)
    {
```

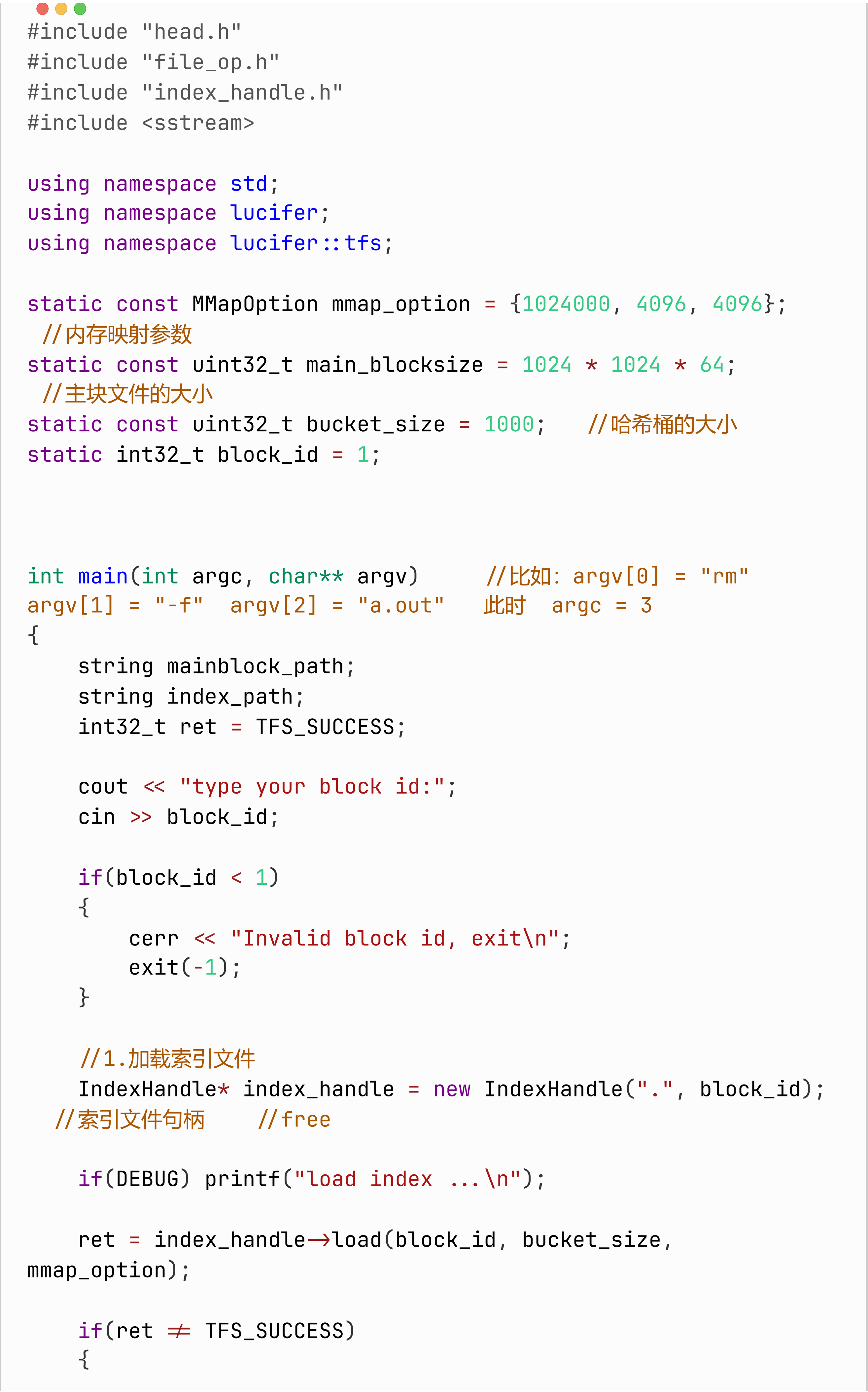


```
        fprintf(stderr,"Fail to create
index:%s\n",strerror(errno));


        delete mainblock;

        index_handle->remove(block_id);
        exit(-3);
    }

    mainblock->close_file();
    index_handle->flush();
    delete mainblock;
    delete index_handle;


    //other
    return 0;





}
```



```
#include "head.h"
#include "file_op.h"
#include "index_handle.h"

using namespace lucifer;

const static tfs::MMapOption mmap_option = {1024000, 4096,
4096}; // 内存映射参数

const static uint32_t main_blcok_size = 1014 * 1024 * 64; // 主
块文件的大小

const static uint32_t bucket_size = 1000; // 哈希桶的大小

static int32_t block_id = 1;

int main(int argc, char **argv)
{
    std::string mainblock_path;
    std::string index_path;
```

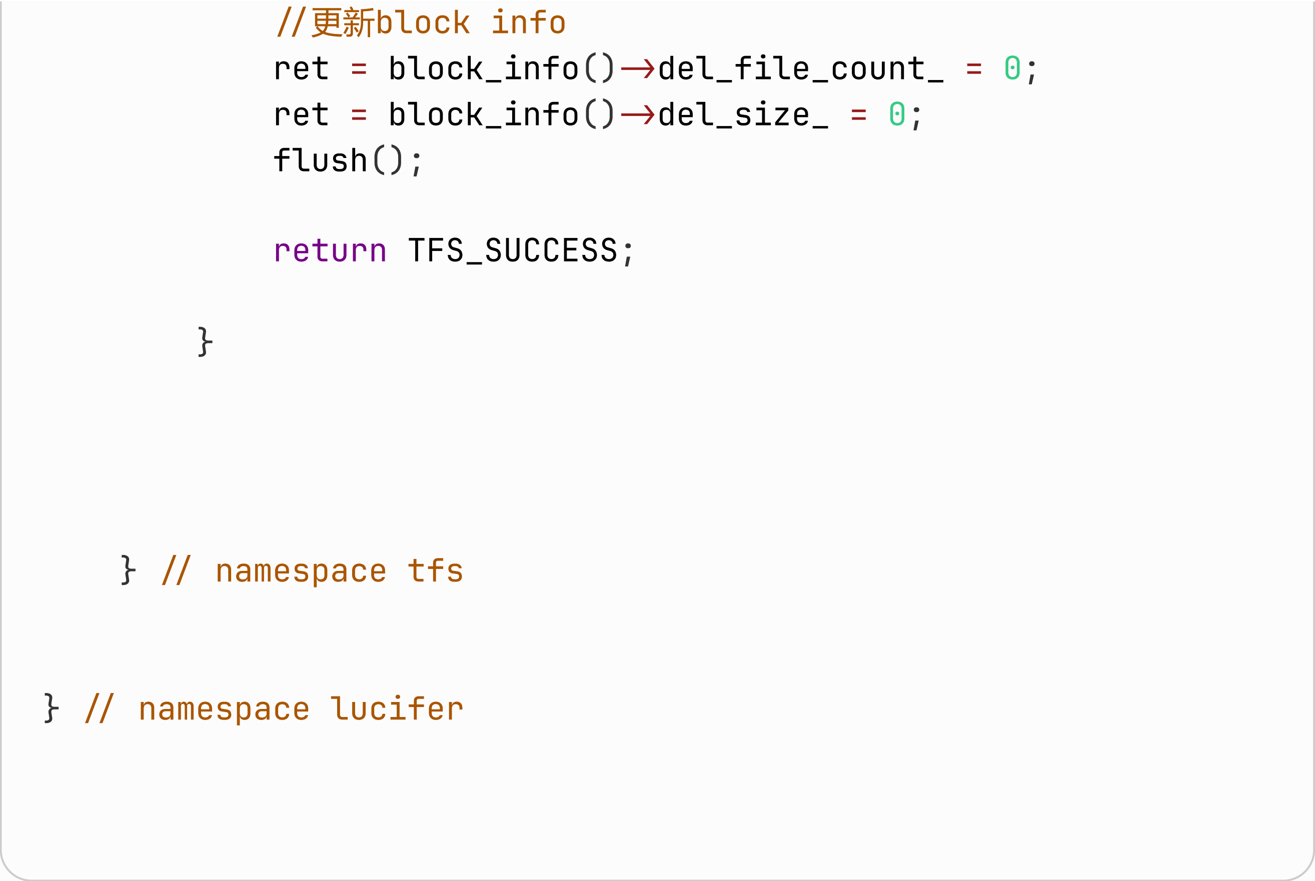
```cpp
    int32_t ret = tfs::TFS_SUCCESS;
    tfs::IndexHandle *index_handle = new tfs::IndexHandle(".", block_id);

    std::cout << "Type you bock id:" << std::endl;
    std::cin >> block_id;

    if (block_id < 0){
        std::cerr << "Invalid blockid,exit" << std::endl;
        exit(-1);
    }


    ret = index_handle->load(block_id, bucket_size, mmap_option);

    if (ret != tfs::TFS_SUCCESS){
        fprintf(stderr, "Fail to load index:%s\n", strerror(errno));
        std::cerr << "Fail to load index ";
        std::cout << std::endl;
        delete index_handle;

        index_handle->remove(block_id);
        exit(-2);
    }

    //2.读取文件的meta info
    uint64_t file_id;

    std::cout << "Type you file_id:" << std::endl;
    std::cin >> file_id;


    if (file_id < 1){
        std::cerr << "Invalid blockid,exit" << std::endl;
        exit(-2);
    }


    tfs::MetaInfo meta;

    ret = index_handle->read_segment_meta(file_id,meta);
    if(tfs::TFS_SUCCESS != ret)
    {
        fprintf(stderr,"read_segment_meta error,file_id %lu,ret
%d",file_id,ret);
        exit(-3);
    }
    //3根据meta info读取文件
    //读取主块文件
    std::stringstream tmp_stream;
    tmp_stream << "." << tfs::MAINLOCK_DIR_PREFIX << block_id;
    tmp_stream >> mainblock_path;

    tfs::FileOperation *mainblock = new
tfs::FileOperation(mainblock_path, O_RDWR);

    char *buffer = new char[meta.get_size()+1];

    ret = mainblock-
>pread_file(buffer,meta.get_size(),meta.get_inner_offset());

    if(ret != tfs::TFS_SUCCESS)
    {
        fprintf(stderr, "read from mainblock %d failed.
ret:%d\n", block_id,ret);
        mainblock->close_file();
        delete mainblock;
        delete index_handle;
    }
    else
    {
        if(tfs::DEBUG) printf("write successfully. ret : %u,
block_id:%d\n", ret, block_id);
    }

    buffer[meta.get_size()] = '\0';

    printf("read size %d\ncontent :
%s\n",meta.get_size(),buffer);
    mainblock->close_file();
    delete mainblock;


    delete index_handle;
    return 0;
}
```



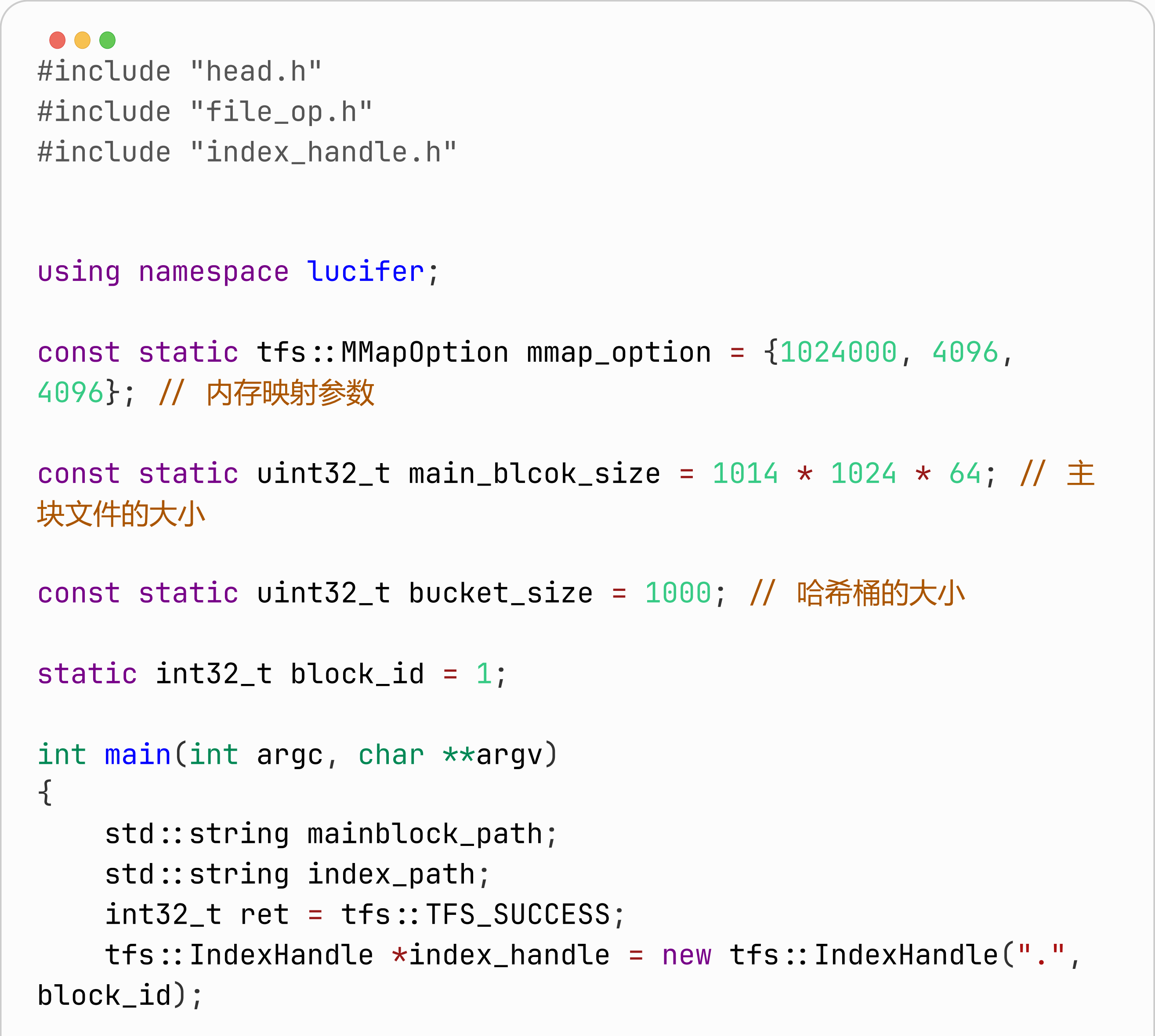
```
#include "head.h"
#include "file_op.h"
#include "index_handle.h"
#include <sstream>

using namespace std;
using namespace lucifer;
using namespace lucifer::tfs;

static const MMapOption mmap_option = {1024000, 4096, 4096};
 //内存映射参数
static const uint32_t main_blocksize = 1024 * 1024 * 64;
 //主块文件的大小
static const uint32_t bucket_size = 1000;    //哈希桶的大小
static int32_t block_id = 1;



int main(int argc, char** argv)     //比如: argv[0] = "rm"
argv[1] = "-f"  argv[2] = "a.out"   此时  argc = 3
{
    string mainblock_path;
    string index_path;
    int32_t ret = TFS_SUCCESS;

    cout << "type your block id:";
    cin >> block_id;

    if(block_id < 1)
    {
        cerr << "Invalid block id, exit\n";
        exit(-1);
    }

    //1.加载索引文件
    IndexHandle* index_handle = new IndexHandle(".", block_id);
  //索引文件句柄    //free

    if(DEBUG) printf("load index ...\n");

    ret = index_handle->load(block_id, bucket_size,
mmap_option);

    if(ret != TFS_SUCCESS)
    {
        fprintf(stderr, "load index %d faild.\n", block_id);
        //delete mainblock;
        delete index_handle;
        exit(-2);
    }


    //主块文件
    stringstream tmp_stream;
    tmp_stream << "." << MAINBLOCK_DIR_PREFIX << block_id;
    tmp_stream >> mainblock_path;

    FileOperation* mainblock = new FileOperation(mainblock_path, O_RDWR | O_LARGEFILE | O_CREAT);      //free


    ret = index_handle->space_reclamation(mainblock);


    if(ret != TFS_SUCCESS)
    {
        fprintf(stderr, "tidy block failed. ret: %d, reason: %s\n", ret, strerror(errno));
        mainblock->close_file();

        delete mainblock;
        delete index_handle;
        exit(-3);
    }


    mainblock->close_file();

    delete mainblock;
    delete index_handle;

    return 0;
}
```

```
#include "head.h"
#include "mmap_file.h"
#include "mmap_file_op.h"
#include "index_handle.h"
```

```
namespace lucifer
{
    namespace tfs

    {

        int32_t IndexHandle::space_reclamation(FileOperation* file_op ){

            //查找del_file_count
            //根据文件编号 逐步从头部开始写 hash_find就continue 有就往前写
            //截断文件
            //更新索引信息
            if(!file_op)
                return EXIT_BLOCK_NOT_EXIST;

            if(block_info()->del_file_count_ <= 0)        //块删除文件数量小于0
            {
                fprintf(stderr, "block id %u do not have del_file. del_file_count: %d\n", block_info()->block_id_, block_info()->del_file_count_);
                return EXIT_BLOCK_DEL_FILE_COUNT_LESSZERO;
            }
                if(block_info()->del_size_ <= 0)             //块删除文件大小小于0
            {
                fprintf(stderr, "block id %u do not have del_file_size. del_file_size:%d\n", block_info()->block_id_, block_info()->del_size_);
                return EXIT_BLOCK_DEL_SIZE_LESSZEOR;
            }

            int32_t file_count = block_info()->file_count_;    //文件数量
            int32_t ret = TFS_SUCCESS;
            int32_t over_write_offset = 0;       //整个文件写入块后的偏移量
            int32_t current_write_offset = 0;    //文件未写全，块中的偏移量

            int64_t residue_bytes = 0;          //写入后还剩下需要写的字节数
            uint64_t key = 1;         //保存文件编号

                        //整理块
            for(int i = 1; i <= file_count; )
            {
                MetaInfo meta_info;            //保存临时读到的metainfo
                char buffer[4096] = { '0' };                //保存的文件
                int nbytes = sizeof(buffer);        //该次需要写入的字节数

                ret = read_segment_meta(key, meta_info);

                current_write_offset = meta_info.get_inner_offset();
                residue_bytes = meta_info.get_size();

                if(DEBUG) fprintf(stderr, "i: %d, file_id: %ld, key: %ld, ret: %d\n", i, meta_info.get_key(), key, ret);

                if(TFS_SUCCESS == ret)            //已经在哈希链表中读到
                {

                    if(meta_info.get_size() <= sizeof(buffer))      //一次读完
                    {
                        ret = file_op->pread_file(buffer, meta_info.get_size(), meta_info.get_inner_offset());
                        if(ret == TFS_SUCCESS)    //文件读成功,将文件重新写入块中
                        {
                            ret = file_op->pwrite_file(buffer, meta_info.get_size(), over_write_offset);
                            if(ret == TFS_SUCCESS)          //文件写入成功
                            {
                                over_write_offset += meta_info.get_size();
                                key++;
                            }
                            else         //文件未写成功 / 未写全
                            {
                                return ret;           //可以考虑
将读取文件的地址传回(buffer的地址)
                            }
                        }
                        else           //文件未读成功 / 未读全
                        {
                            return ret;
                        }
                    }
                    else           //需要分多次读写
                    {
                        nbytes = sizeof(buffer);

                        for(int j = 0; j < 1; )
                        {
                            ret = file_op->pread_file(buffer,
nbytes, current_write_offset);
                            if(ret == TFS_SUCCESS)          //文
件读成功,将部分文件重新写入块中
                            {
                                //fprintf(stderr, "nbytes:
%d\n", nbytes);
                                ret = file_op-
>pwrite_file(buffer, nbytes, over_write_offset);
                                if(ret == TFS_SUCCESS)
 //文件写入成功
                                {
                                    current_write_offset +=
nbytes;
                                    over_write_offset += nbytes;
                                    residue_bytes -= nbytes;

                                    //fprintf(stderr,
"residue_bytes: %ld\n", residue_bytes);

                                    if(0 == residue_bytes)
                                    {
                                        key++;
                                        j++;          //结束循环
                                        continue;
                                    }

                                    if(nbytes > residue_bytes)
                                    {
                                        nbytes = residue_bytes;
                                        continue;
                                    }

                                }
                                else            //文件未写成功 / 未写全
                                {
                                    return ret;            //可以考虑将读取文件的地址传回(buffer的地址)
                                }
                            }
                            else
                            {
                                return ret;    //文件未读成功 / 未读全
                            }
                        }
                    }

                }
                else if(EXIT_META_NOT_FOUND_ERROR != ret)  //not found key(状态)
                {
                    return ret;
                }
                else if(EXIT_META_NOT_FOUND_ERROR == ret)      //哈希链表中没有找到,该文件已被删除
                {
                    key++;
                    continue;
                }

                i++;


            }

            ret = file_op->flush_file();
            //截断文件
            ret = file_op->ftruncate_file(block_info()->size_);

            //更新索引文件信息
            index_header()->data_file_offset_ = block_info()->size_;
```



```
            //更新block info
            ret = block_info()->del_file_count_ = 0;
            ret = block_info()->del_size_ = 0;
            flush();

            return TFS_SUCCESS;

        }





    } // namespace tfs


} // namespace lucifer
```



```
#include "head.h"
#include "file_op.h"
#include "index_handle.h"


using namespace lucifer;

const static tfs::MMapOption mmap_option = {1024000, 4096, 4096}; // 内存映射参数

const static uint32_t main_blcok_size = 1014 * 1024 * 64; // 主块文件的大小

const static uint32_t bucket_size = 1000; // 哈希桶的大小

static int32_t block_id = 1;

int main(int argc, char **argv)
{
    std::string mainblock_path;
    std::string index_path;
    int32_t ret = tfs::TFS_SUCCESS;
    tfs::IndexHandle *index_handle = new tfs::IndexHandle(".", block_id);
    std::cout << "Type you bock id:" << std::endl;
    std::cin >> block_id;

    if (block_id < 0)
    {
        std::cerr << "Invalid blockid,exit" << std::endl;
        exit(-1);
    }


    ret = index_handle->load(block_id, bucket_size,
mmap_option);

    if (ret != tfs::TFS_SUCCESS)
        {
            fprintf(stderr, "Fail to load index:%s ret: %d\n",
strerror(errno),ret);

            delete index_handle;

            index_handle->remove(block_id);
            exit(-2);
        }
    if (tfs::DEBUG)
        printf("load index ok\n");

    delete index_handle;
    return 0;
}
```

```
#include "head.h"
#include "file_op.h"
#include "index_handle.h"



using namespace lucifer;

const static tfs::MMapOption mmap_option = {1024000, 4096,
4096}; // 内存映射参数

const static uint32_t main_blcok_size = 1014 * 1024 * 64; // 主
块文件的大小
```

```
const static uint32_t bucket_size = 1000; // 哈希桶的大小

const static bool debug = true;
static int32_t block_id = 1;

int main(int argc, char **argv)
{
    std::string mainblock_path;
    std::string index_path;
    int32_t ret = tfs::TFS_SUCCESS;



    std::cout << "Type your block id:" << std::endl;
    std::cin >> block_id;

    if (block_id < 1)
    {
        std::cerr << "Invalid block id , exit." << std::endl;
        exit(-1);
    }


    tfs::IndexHandle *index_handle = new tfs::IndexHandle(".",
block_id); // 索引文件句柄

    if(tfs::DEBUG)
        printf("Load index in block_write\n");


    ret = index_handle->load(block_id, bucket_size,
mmap_option);

    if (ret != tfs::TFS_SUCCESS){
        fprintf(stderr, "load index %d failed.\n", block_id);
        delete index_handle;
        exit(-2);
    }

    if (tfs::DEBUG)
        printf("load index successful \n");

    //写入主块文件
    std::stringstream tmp_stream;
    tmp_stream << "." << tfs::MAINLOCK_DIR_PREFIX << block_id;
    tmp_stream >> mainblock_path;

    tfs::FileOperation *mainblock = new tfs::FileOperation(mainblock_path, O_RDWR | O_LARGEFILE | O_CREAT);


    char buffer[4096];
    memset(buffer, '6', 4096);



    int32_t data_offset = index_handle->get_block_data_offset();
    uint32_t file_no = index_handle->block_info()->seq_no_;

    ret = mainblock->pwrite_file(buffer, sizeof(buffer), data_offset);

    if (ret != tfs::TFS_SUCCESS)
    {
        fprintf(stderr, "write to mainblock failed.ret:%d, reason:%s\n", ret, strerror(errno));
        mainblock->close_file();

        delete mainblock;
        delete index_handle;
        exit(-3);
    }

    //3.写入metaonfo索引
    struct tfs::MetaInfo meta;

    meta.set_file_id(file_no);
    meta.set_inner_offset(data_offset);
    meta.set_size(sizeof(buffer));

    ret = index_handle->write_segment_meta(meta.get_key(),meta);
    if(debug)
        printf("write segment meta ret is %d\n",ret);

    if(ret == tfs::TFS_SUCCESS){
        //succsssful updata block info
        //1. 更新索引头部信息
        index_handle->commit_block_data_offset(sizeof(buffer));
        //2.更新块信息
        index_handle-
>update_block_info(tfs::C_OPER_INSERT,sizeof(buffer));
        ret = index_handle->flush();
        if(debug)
            printf("write_segmentmeta is TFS_SUCCESS\n");
        if(ret!=tfs::TFS_SUCCESS)
        {
            fprintf(stdout,"flush mainblock %d faild. file no:
%u \n",block_id,file_no);

        }


    }else{
        fprintf(stderr,"write_segment_meta - mainblock %d
failed.file no %u\n",block_id,file_no);
    }


     if(ret != tfs::TFS_SUCCESS)
    {
        fprintf(stderr, "write to mainblock %d failed. file
no:%u\n", block_id, file_no);
        mainblock->close_file();
    }
    else
    {
        if(tfs::DEBUG) printf("write successfully. file no: %u,
block_id:%d\n", file_no, block_id);
    }


    mainblock->close_file();
    delete mainblock;
    delete index_handle;
    return 0;
}
```

```
#include "file_op.h"
#include "head.h"
```

```
using namespace std;
using namespace lucifer;

int main(int argc, char* argv[])
{
    constexpr const char * filename = "file_op.txt";
    tfs::FileOperation * fileOP = new
tfs::FileOperation(filename,O_LARGEFILE|O_RDWR|O_CREAT);
    int fd = fileOP->open_file();
    if(fd < 0)
    {
        cout << "open file failed" << endl;
        return -1;
    }

    char buffer[65];
    memset(buffer,'8',sizeof(buffer));

  {
      int ret = fileOP->pwrite_file(buffer,sizeof(buffer),1024);
    if(ret < 0)
    {
        cout << "pwrite file failed" << endl;
        return -1;
    }

  }
  memset(buffer,0,sizeof(buffer));
  {
    auto ret = fileOP->pread_file(buffer,sizeof(buffer),1024);
    if(ret < 0)
    {
        cout << "pread file failed" << endl;
        return -1;
    }
    buffer[64] = '\0';
    cout << "pread file success" << endl;
    cout << "data: " << buffer << endl;
  }

    fileOP->close_file();

    delete fileOP;
    return 0;
}
```