Programming Assignment #6
A User-Space File System

Introduction to Operating Systems

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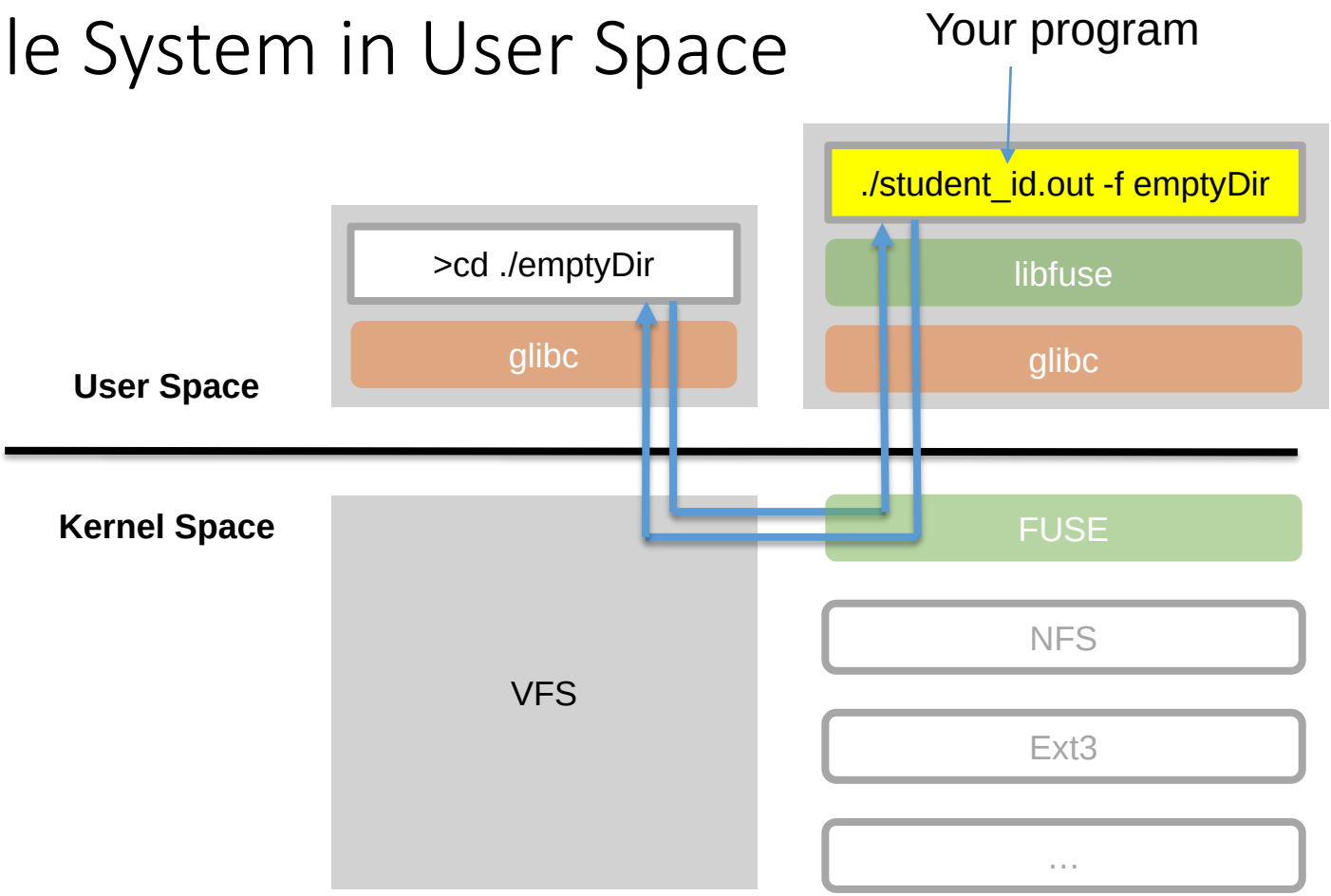
Objective

- Implementing a user-space file system that mounts a tar file onto a specified directory
- Files in the tar files can be accessed through the system directory tree

- This assignment is based on FUSE of Linux
    - Your program will run as a FUSE server
    - Test your FUSE server from another terminal

FUSE – File System in User Space



- FUSE: a kernel component plus a user-space library
- Purpose: accessing existing files/services through the file system interface
  - E.g., an FTP file system, a zip file system, etc.

The Complete FUSE Operation Set

```
int(*  getattr )(const char *, struct stat *, struct fuse_file_info *fi)
int(*  readlink )(const char *, char *, size_t)
int(*  mknod )(const char *, mode_t, dev_t)
int(*  mkdir )(const char *, mode_t)
int(*  unlink )(const char *)
int(*  rmdir )(const char *)
int(*  symlink )(const char *, const char *)
int(*  rename )(const char *, const char *, unsigned int flags)
int(*  link )(const char *, const char *)
int(*  chmod )(const char *, mode_t, struct fuse_file_info *fi)
int(*  chown )(const char *, uid_t, gid_t, struct fuse_file_info *fi)
int(*  truncate )(const char *, off_t, struct fuse_file_info *fi)
int(*  open )(const char *, struct fuse_file_info *)
int(*  read )(const char *, char *, size_t, off_t, struct fuse_file_info *)
int(*  write )(const char *, const char *, size_t, off_t, struct fuse_file_info *)
int(*  statfs )(const char *, struct statvfs *)
int(*  flush )(const char *, struct fuse_file_info *)
int(*  release )(const char *, struct fuse_file_info *)
int(*  fsync )(const char *, int, struct fuse_file_info *)
int(*  setxattr )(const char *, const char *, const char *, size_t, int)
int(*  getxattr )(const char *, const char *, char *, size_t)
int(*  listxattr )(const char *, char *, size_t)
int(*  removexattr )(const char *, const char *)
int(*  opendir )(const char *, struct fuse_file_info *)
int(*  readdir )(const char *, void *, fuse_fill_dir_t, off_t, struct fuse_file_info *, enum fuse_readdir_flags)
int(*  releasedir )(const char *, struct fuse_file_info *)
int(*  fsyncdir )(const char *, int, struct fuse_file_info *)
void *(*  init )(struct fuse_conn_info *conn, struct fuse_config *cfg)
void(*  destroy )(void *private_data)
int(*  access )(const char *, int)
int(*  create )(const char *, mode_t, struct fuse_file_info *)
int(*  lock )(const char *, struct fuse_file_info *, int cmd, struct flock *)
int(*  utimens )(const char *, const struct timespec tv[2], struct fuse_file_info *fi)
int(*  bmap )(const char *, size_t blocksize, uint64_t *idx)
int(*  ioctl )(const char *, unsigned int cmd, void *arg, struct fuse_file_info *, unsigned int flags, void *data)
int(*  poll )(const char *, struct fuse_file_info *, struct fuse_pollhandle *ph, unsigned *reventsp)
int(*  write_buf )(const char *, struct fuse_bufvec *buf, off_t off, struct fuse_file_info *)
int(*  read_buf )(const char *, struct fuse_bufvec **bufp, size_t size, off_t off, struct fuse_file_info *)
int(*  flock )(const char *, struct fuse_file_info *, int op)
int(*  fallocate )(const char *, int, off_t, off_t, struct fuse_file_info *)
ssize_t(*  copy_file_range )(const char *path_in, struct fuse_file_info *fi_in, off_t offset_in, const char *path_out, s
off_t(*  lseek )(const char *, off_t off, int whence, struct fuse_file_info *)
```

Necessary FUSE Operations

```
struct fuse_operations {
            int (*readdir)(const char *, void *, fuse_fill_dir_t, off_t, struct fuse_file_info
*);
            int (*getattr)(const char *, struct stat *);
            int (*read)(const char *, char *, size_t, off_t, struct fuse_file_info *);
            //many other functions…
}
```

- The complete FUSE operation set contains many callback functions, but only three are necessary for this assignment
  - **readdir**: Get a list of files and directories that reside in the directory. (Get file names only)
  - **getattr**: Get attributes of a file/directory.
  - **read**: Get the content of a file
- Leave null for the other operations

readdir

```
int readdir(const char *path, void *buffer, fuse_fill_dir_t filler, off_t offset, struct fuse_file_info *fi);
```

- **Arguments**
  - path: Relative path to the file/directory.
  - buffer: You should store file names into this buffer using the provided filler
  - filler: A tool to store the file names into buffer
    - `filler(buffer, “file1.txt”, NULL, 0);`
    - `filler(buffer, “dir1”, NULL, 0);`
  - offset and fi: Not used in this assignment
- **Return values**
  - Always return 0.

getattr

```
int getattr(const char *path, struct stat *st);
```

- **Arguments**
  - path: Relative path to the file/directory.
  - st: You should fill the necessary fields of this structure.
- About structure stat: https://pubs.opengroup.org/onlinepubs/009695399/basedefs/sys/stat.h.html
- Necessary Fields of st: st_uid, st_gid, st_mtime, st_size and st_mode
  - st_mode of the root directory (“/”) should be set to: S_IFDIR | 0444 (act like a read only directory)
  - Other directories: S_IFDIR | accessMode
  - Regular files: S_IFREG | accessMode
- **Return values**
  - Return 0 on success.
  - Return a nonzero value on failure. (If cannot find the specified file/directory)

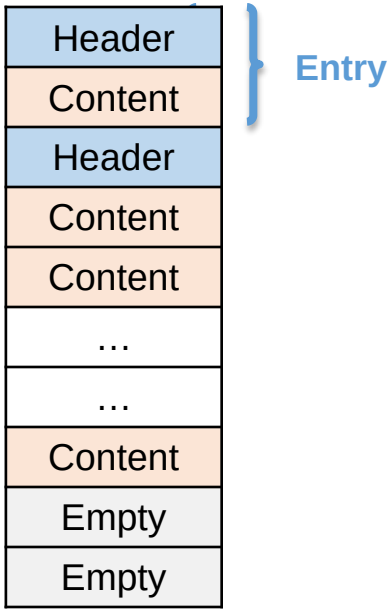
read

```
int read(const char *path, char *buffer, size_t size, off_t offset, struct fuse_file_info *fi);
```

- **Arguments**
  - path: Relative path to the file/directory.
  - buffer: You should store the requested file content into this buffer.
  - size: Max # of chars to store in the buffer. (Should not overrun)
  - offset: Skip *offset* chars from the beginning of the file and then start reading.
  - fi: Not used in this assignment
- **Return values**
  - Return number of bytes read successfully. (Less than or equal to *size*)

Tar File Format

- A tar file contains a series of entries, each of which contains a header and contents
  - One entry per file
  - Header: metadata of a file
  - Contents: contents of the file
- You are responsible for reading and parsing the information of a tar file
- Detailed explanation of tar format: http://www.onicos.com/staff/iz/formats/tar.html



Skeleton of Your FUSE Server

```
#define FUSE_USE_VERSION 30

#include <fuse.h>

#include <string.h>

int my_readdir(const char *path, void *buffer, fuse_fill_dir_t filler, off_t offset, struct
fuse_file_info *fi) { /*do something*/ }

int my_getattr(const char *path, struct stat *st) { /*do something*/ }

int my_read(const char *path, char *buffer, size_t size, off_t offset, struct fuse_file_info
*fi) { /*do something*/ }

static struct fuse_operations op;

int main(int argc, char *argv[])

{

    memset(&op, 0, sizeof(op));

    op.getattr = my_getattr;

    op.readdir = my_readdir;

    op.read = my_read;

    return fuse_main(argc, argv, &op, NULL);

}
```

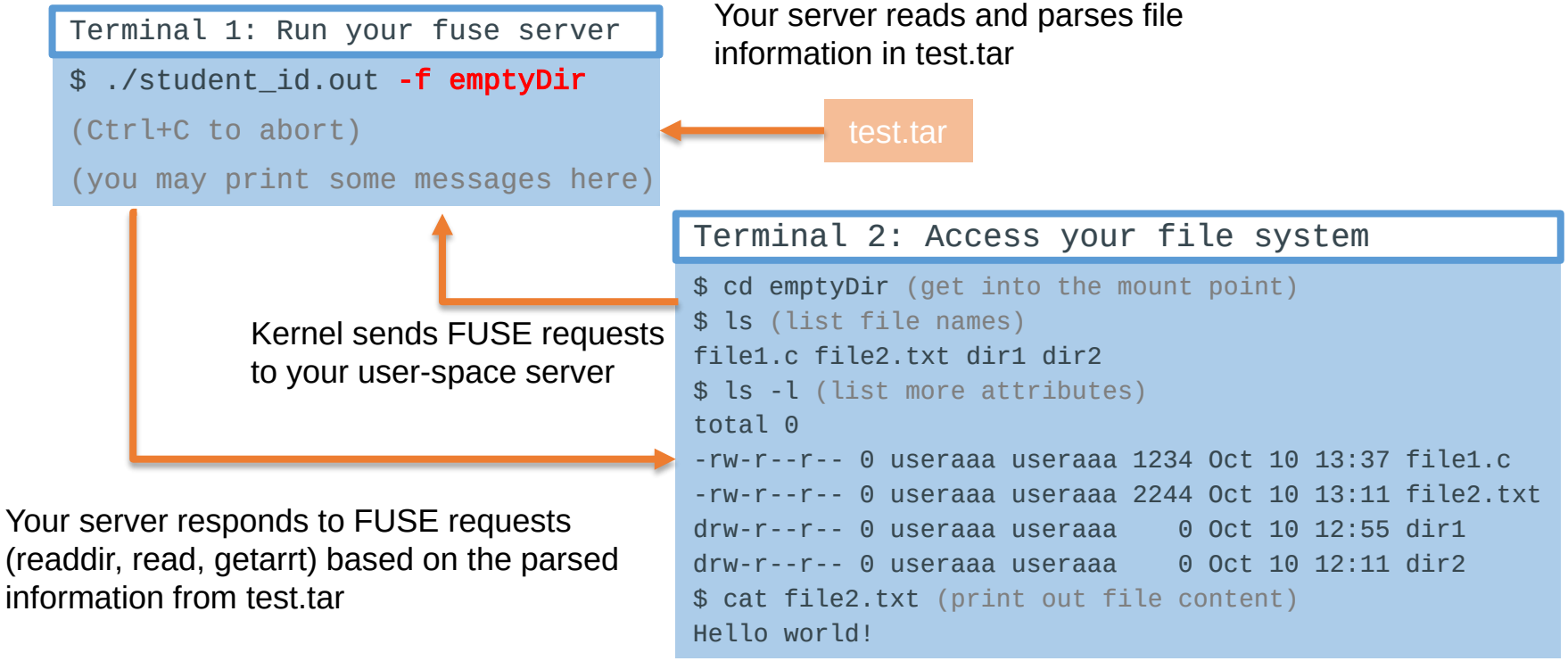
Compiling Your FUSE server

```
$ gcc student_id.c -o student_id.out `pkg-config fuse --cflags --libs`
OR
$ g++ student_id.cpp -o student_id.out `pkg-config fuse --cflags --libs`
```

Working Directory

- File name of the tar file is fixed: `test.tar`
- Put the tar file and your program in the same directory while testing
  - `test.tar`
  - `student_id.out`
  - `emptyDir (Create this empty directory as the mount point)`

Testing Your FUSE server



Bonus (+10 pt)

- TAR archive will not perform in-place update, instead, it will append the new version of the updated file at the end of archive.
- There will be multiple files with the same file name in the bonus tar file. (Differentiated by last-modify-time)
- You can see the files using tar command

```
$ tar --list --verbose --file=test.tar
-rw-rw-r-- useraaa/useraaa 19 2019-11-26 16:08 blue.txt
-rw-rw-r-- useraaa/useraaa 11 2019-11-26 16:08 red.txt
-rw-rw-r-- useraaa/useraaa 12 2019-11-26 15:58 yellow.txt
-rw-rw-r-- useraaa/useraaa 13 2019-11-26 16:09 blue.txt
-rw-rw-r-- useraaa/useraaa 23 2019-11-26 16:14 blue.txt
-rw-rw-r-- useraaa/useraaa 22 2019-11-26 16:14 red.txt
```

Bonus

- Your FUSE server should report the newest version only

```
$ ls -l
total 0
-rw-rw-r-- 0 useraaa useraaa 23 Nov 26 16:14 blue.txt
-rw-rw-r-- 0 useraaa useraaa 22 Nov 26 16:14 red.txt
-rw-rw-r-- 0 useraaa useraaa 12 Nov 26 15:58 yellow.txt
$ cat blue.txt
sea
sky
cloud
dory
```

Testing OS Environment

- Do this assignment using the VM provided by TA
  - See the online course schedule for the download link of the VM
  - Only VM player works with this image…
  - TAs will test your program using this VM
- There is a demo script placed under `~/Documents/` TAs will use the same script and prepare different tar files to validate your implementation.
- Run the script: `./demo.sh <path to student_id.out>`
- Compare your result with the answer:

  `./compare.sh <testcase number>`
- Do not use external library to parse tar files
- Do not untar file files and copy them to the mount point…

Hints

- If you get a broken mount point during testing, use the following command to force unmount
  - `sudo umount -l <your_mount_point>`
- If you want to generate another tar file for testing
  - `tar -cf test.tar <list all files and directories you want to pack>`

Header of your .c or .cpp

/*

Student No.: 31415926

Student Name: John Doe

Email: xxx@yyy.zzz

SE tag: xnxcxtxuxoxsx

Statement: I am fully aware that this program is not supposed to be posted to a public server, such as a public GitHub repository or a public web page.

*/