Lab Assignment #3-mdadm Linear Device (Writes and Testing)

CMPSC311 - Introduction to Systems Programming

Summer 2024 - Prof. Suman Saha

Due date: July 05, 2024 (11:59 PM) EST

Like all lab assignments in this class, you are prohibited from copying any content from the Internet including (discord or other group messaging apps) or discussing, sharing ideas, code, configuration, text, or anything else or getting help from anyone in or outside of the class. Failure to abide by this requirement will result in penalty as described in our course syllabus.

Your internship is going great. You have gained experience with C programming, you have experienced your first segmentation faults, and you've come out on top. You are brimming with confidence and ready to handle your next challenge.

Implementing mdadm_write

Your next job is to implement write functionality for mdadm and then thoroughly test your implementation. Specifically, you will implement the following function:

```
int mdadm_write
(uint32_t start_addr, uint32_t write_len, const uint8_t write_buf)
```

Recall that the command for writing is JBOD_WRITE_BLOCK (see ReadMe_Lab2.pdf from Lab 2).

As you can tell, it has an interface that is similar to that of the `mdadm_read function,` which you have already implemented. Specifically, it writes `write_len` bytes from the user-supplied `write_buf` buffer to your storage system, starting at address `start_addr`. You may notice that the `write_buf` parameter now has a const specifier. We put the const there to emphasize that it is an *in* parameter; that is, `mdadm_write` should only read from this parameter and not modify it. It is a good practice to specify const specifier for your in

parameters that are arrays or structs. Similar to `mdadm_read`, writing to an out-of-bound linear address should fail. Write larger than 1024 bytes should fail; in other words, `write_len` can be 1024 at most. On success return the amount of bytes written.
There are a few more restrictions that you will find out as you try to pass the tests. Once you implement the above function, you have the basic functionality of your storage system in place. We have expanded the tester to include new tests for the write operations, in addition to existing read operations. You should try to pass these write tests first.

Implementing mdadm_write permissions

The cryptocurrency startup that you are interning at is also very concerned about the security of their storage systems. To ensure that data is written by the correct people and at the correct times, you will also be required to write the following functions to set the write permissions of the storage system:

```
int mdadm_write_permission(void);
int mdadm_revoke_write_permission(void);
```

As you can see, there are no parameters for these functions. Each of these will tell your storage device whether writing is allowed at that point.

`mdadm_write_permission` will tell the system that writing is now allowed.

`mdadm_revoke_write_permission` will “turn off” write permissions to the system; that is, it will tell the system that writing is no longer allowed.

As you might expect, you must turn write permission ON before writing to the system. You should also always check if this permission is on each time you write to the system.

Just as all other functions that you have been required to implement, you will need to use `jbod_operation(op, *block)` to interact with the storage system.

The following ENUM commands are provided to you:

JBOD_WRITE_PERMISSION: sets the write permission to 1 so that writing will be allowed. When the `command` field of `op` is set to this, all other fields in `op` are ignored by JBOD driver. The `block` argument is passed as `NULL`.

JBOD_REVOKE_WRITE_PERMISSION: sets the write permission to -1 so that writing will no longer be allowed. When the `command` field of `op` is set to this, all other fields in `op` are ignored by JBOD driver. The `block` argument is passed as `NULL`.

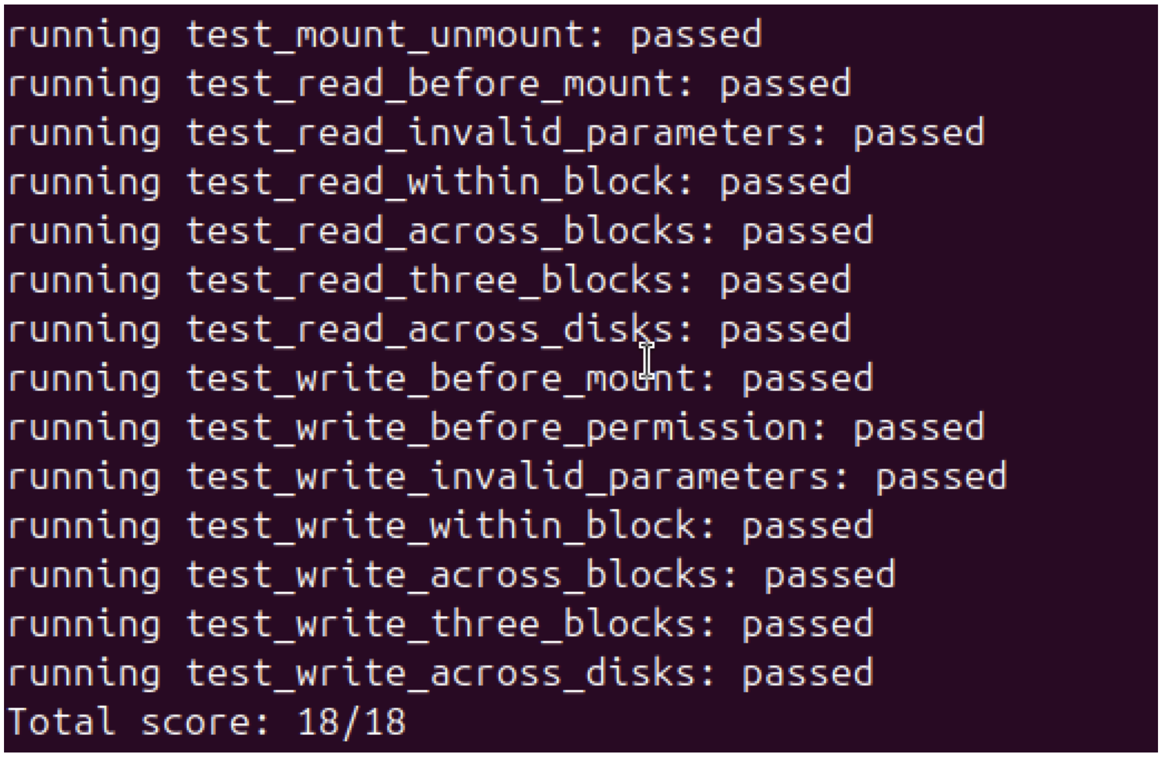
**HINT: check your write permission in your code before writing.

Testing using trace replay

As we discussed before, your mdadm implementation is a layer right above JBOD, and the purpose of mdadm is to unify multiple small disks under a unified storage system with a single address space. An application built on top of mdadm will issue a mdadm_mount, mdadm_write_permission and then a series of mdadm_write and mdadm_read commands to implement the required functionality, and eventually, it will issue mdadm_unmount command. Those read/write commands can be issued at arbitrary addresses with arbitrary payloads and our small number of tests may have missed corner cases that may arise in practice.

Therefore, in addition to the unit tests, we have introduced trace files, which contain the list of commands that a system built on top of your mdadm implementation can issue. We have also added to the tester a functionality to replay the trace files. Now the tester has two modes of operation. If you run it without any arguments, it will run the unit tests:

```
$ ./tester
```



```
running test_mount_unmount: passed
running test_read_before_mount: passed
running test_read_invalid_parameters: passed
running test_read_within_block: passed
running test_read_across_blocks: passed
running test_read_three_blocks: passed
running test_read_across_disks: passed
running test_write_before_mount: passed
running test_write_before_permission: passed
running test_write_invalid_parameters: passed
running test_write_within_block: passed
running test_write_across_blocks: passed
running test_write_three_blocks: passed
running test_write_across_disks: passed
Total score: 18/18
```

If you run it with -w pathname arguments, it expects the pathname to point to a trace file that contains the list of commands. In your repository, there are three trace files under the traces directory: simple-input, linear-input, random-input. Let's look at the contents of one of them using the head command, which shows the first 10 lines of its argument:

```
$ head traces/simple-input
```

```
MOUNT
WRITE_PERMIT
WRITE 0 256 0
READ 1006848 256 0
WRITE 1006848 256 93
WRITE 1007104 256 94
WRITE 1007360 256 95
READ 559872 256 0
WRITE 559872 256 139
READ 827904 256 0
```

The first command mounts the storage system. The second command is a write command, and the arguments are similar to the actual mdadm_write function arguments; that is, write at address 0, 256 bytes of bytes with contents of 0. The third command reads 256 bytes from address 1006848 (the third argument to READ is ignored). And so on.

You can replay them on your implementation using the tester as follows:

```
$ ./tester -w traces/simple-input
```

```
SIG(disk,block) 0 0 : 0xb3 0x76 0x88 0x5a 0xc8 0x45 0x2b 0x6c 0xbf 0x9c
SIG(disk,block) 0 1 : 0xb3 0x76 0x88 0x5a 0xc8 0x45 0x2b 0x6c 0xbf 0x9c
SIG(disk,block) 0 2 : 0xb3 0x76 0x88 0x5a 0xc8 0x45 0x2b 0x6c 0xbf 0x9c
SIG(disk,block) 0 3 : 0xb3 0x76 0x88 0x5a 0xc8 0x45 0x2b 0x6c 0xbf 0x9c
...
```

If one of the commands fails, for example because the address is out of bounds, then the tester aborts with an error message saying on which line the error happened. If the tester can successfully replay the trace until the end, it takes the cryptographic checksum of every block of every disk and prints them out on the screen, as above. Now you can use this information to tell if the final state of your disks is consistent with the final state of the reference implementation, if the above trace was replayed on a reference implementation. You can do that by comparing your output to that of the reference implementation. The files that contain the corresponding cryptographic checksums from reference implementation are also under traces directory and they end with - expected-output. For example, here's how you can test if your implementation's trace output matches with that of reference implementation's output for the simple-input trace:

```
$ ./tester -w traces/simple-input >my-output
$ diff -u my-output traces/simple-expected-output
```

The first line replays the trace file and redirects the output to my-output file in the current directory, while the second line runs the diff tool, which compares to files contents – when the files are identical, no output is displayed, which means your implementation's final state after the commands in the trace file matches the reference implementation's state. If there is a difference in the diff command output, then there is a bug in your implementation; you can see which blocks contents differ and that may help you with debugging.

Grading rubric The grading would be done according to the following rubric:

- Passing test cases 70%
- Passing trace files 15%
- Adding meaningful descriptive comments 5%
- Successful "make" and execution without error and **warnings** 5%
- Submission of commit id 5%

Penalties: 10% per day for late submission (up to 3 days). The lab assignment will not be graded if it is more than 3 days late.