Objectives:

1. Implementing mutual exclusion
2. Queuing updates
3. Handling concurrent operations

Project Specification:

This lab is intended to be built upon Lab #2. While it is not a requirement that this lab utilize your code from Lab #2, all of the functionality from Lab #1 and Lab #2 must be included in Lab #3.

These will be **individual** projects. You may write the program in any language that is supported under any Integrated Development Environment (IDE). Keep in mind that available controls, objects, libraries, et cetera, may make some of these tasks easier in one language than in another. Finally, because of the lack of restrictions on IDEs, you will have to have that IDE available to demo to the TA (e.g., you will demo the program on your own laptop).

This lab has specific submission requirements. Failure to follow these submission requirements will result in your lab not being accepted for a grade.

Lab #1 Infrastructure

You will write a program that will generate a composite directory listing from multiple servers. Your project will consist of a client process and two server processes and function as a command line instruction.

Each server, Server A and Server B, will feature a pre-designated directory named `directory_a` and `directory_b`, respectively. When executed, your client will establish a connection to Server A, which will generate a listing of the contents of `directory_a` (this listing is analogous to the `ls -l` command on Linux/Bash or `dir` on Windows). Server A will then establish a connection to Server B, which will generate a listing of the contents of `directory_b` and return the listing to Server A.

Server A should combine the listing of contents of `directory_a` and `directory_b` into a single list sorted by file name. The list should only include the file name, file size, and either the time the file was created or the time the file was last modified. Server A will return the composite list to the Client, which will print the data to the command line.

Lab #2 Infrastructure

Server A and Server B will autonomously synchronize the contents of `directory_a` and `directory_b` during runtime, including both files and file metadata. During runtime, any change to the contents of a directory on one server, including adding, deleting, or modifying a file, should be applied at the other server. Files will be added, deleted, or modified with the host's native file manager (e.g., Windows Explorer for Windows or Finder on macOS), and for the purposes of this lab assignment neither directory will include subdirectories.

Upon startup, Servers A and B will generate an inventory of the contents of their designated directories and compare contents. Any content discrepancy should be addressed, with duplicated files being made consistent based on the most-recent modified-at time.

Any change to the contents of the directory during runtime should be recognized within five seconds. The user should be notified of the servers' actions in real-time, and the notifications should include which file is being synchronized when applicable. The mechanism by which the directory contents are made consistent is left to the developer's discretion.

Lab #3 Additions

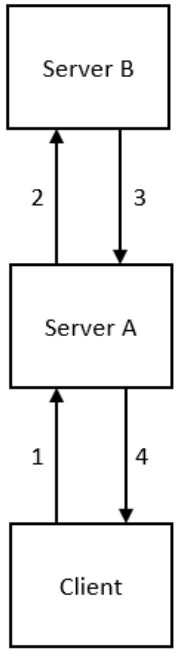
The client will index files 0 to n - 1 when listing directory contents to the user. The user will have the ability to lock files at Server A by running a command: `./lab3 -lock -<index>`.

While a file is locked at Server A, any updates to a locked file in `directory_b` will be placed into a FIFO queue at Server A. When a user unlocks a file by executing `./lab3 -unlock -<index>` at the client, updates to that locked file will be applied in the order they were received.

Any file not locked should continue to be updated according to the instructions in Lab #2.

Example:

At time T_1, the user retrieves an indexed list of directory contents by executing `./lab3` at the client.



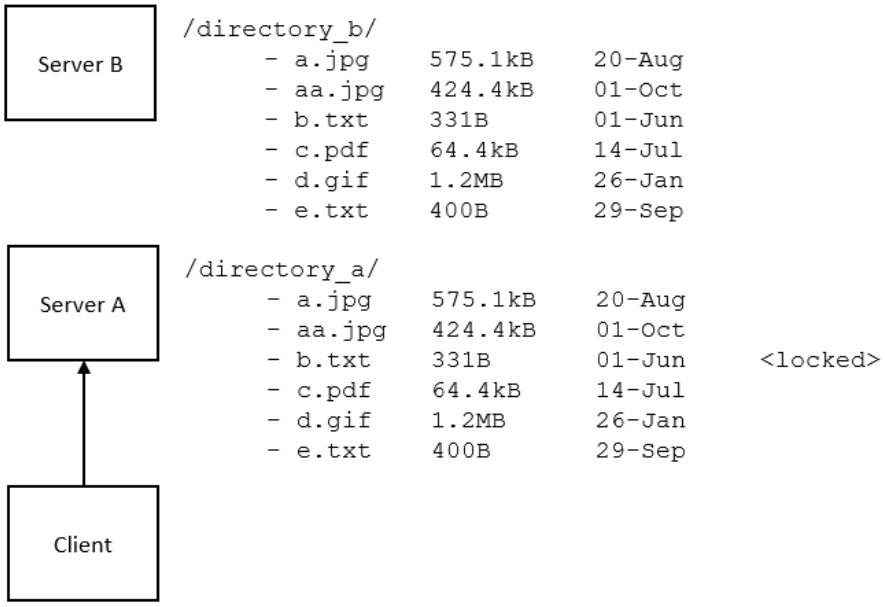

```
/directory_b/
      - a.jpg     575.1kB     20-Aug
      - aa.jpg    424.4kB     01-Oct
      - b.txt     331B        01-Jun
      - c.pdf     64.4kB      14-Jul
      - d.gif     1.2MB       26-Jan
      - e.txt     400B        29-Sep

/directory_a/
      - a.jpg     575.1kB     20-Aug
      - aa.jpg    424.4kB     01-Oct
      - b.txt     331B        01-Jun
      - c.pdf     64.4kB      14-Jul
      - d.gif     1.2MB       26-Jan
      - e.txt     400B        29-Sep
```

T_1: Client Query

```
user@Client:~$ ./lab3
[0] a.jpg       575.1kB         20-Aug
[1] aa.jpg      424.4kB         01-Oct
[2] b.txt       331B            01-Jun
[3] c.pdf       64.4kB          14-Jul
[4] d.gif       1.2MB           26-Jan
[5] e.txt       400B            29-Sep
```

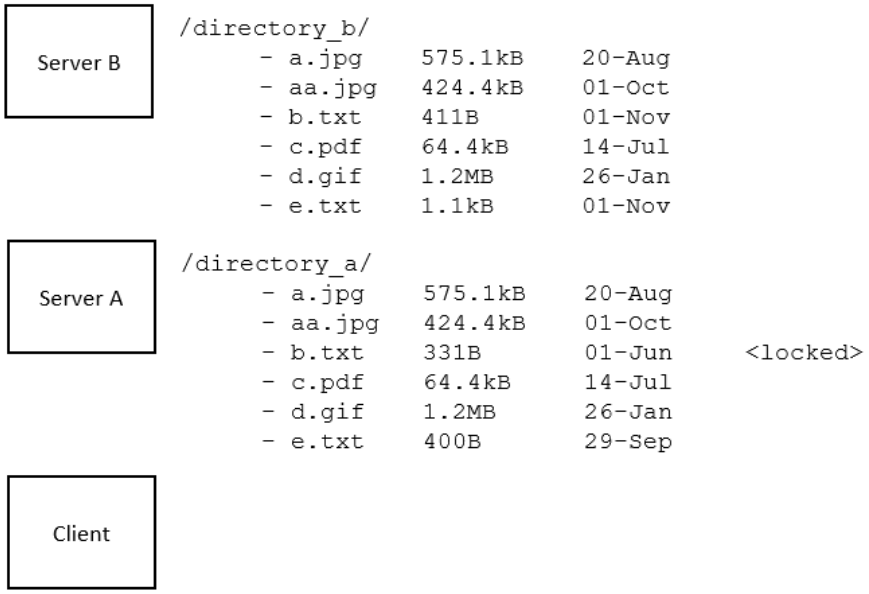
At time T_2, the user locks `b.txt` at Server A by executing `./lab3 -lock -2`.



T_2: Client Locks File

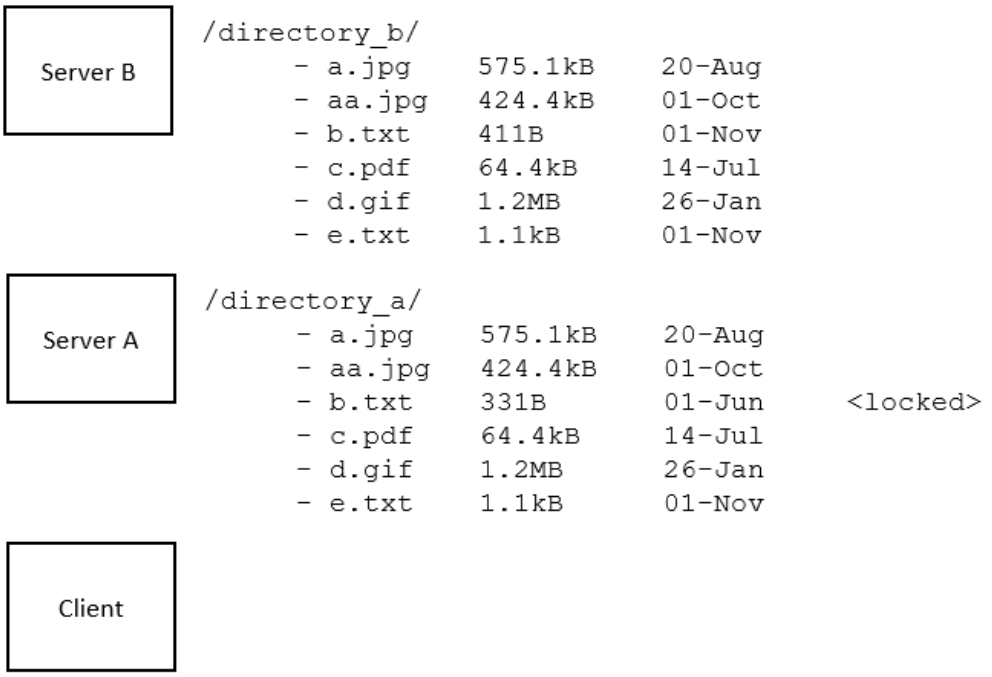
```
user@Client:~$ ./lab3 -lock -2
```

At time T_3, `b.txt` and `e.txt` are updated in `directory_b`.



T_3: File Update at `directory_b`

At time T_4, the file update to the unlocked file is applied at `directory_a` and the file update to the locked file is queued.

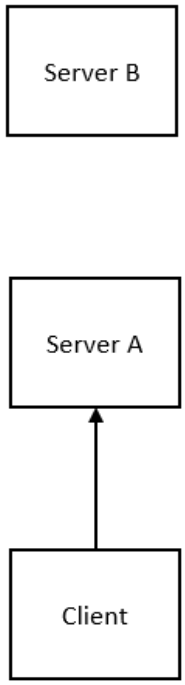


T_4: Update at `directory_a`

At time T_5, the user queries Server A for the present status of `directory_a`.

```
user@Client:~$ ./lab3
[0] a.jpg       575.1kB         20-Aug
[1] aa.jpg      424.4kB         01-Oct
[2] b.txt       331B            01-Jun     <locked>
[3] c.pdf       64.4kB          14-Jul
[4] d.gif       1.2MB           26-Jan
[5] e.txt       1.1kB           29-Sep
```

At time T_6, the user unlocks `b.txt`. The file is unlocked in `directory_a` and Server A applies the queued updates to `b.txt`.



T_6: Client Unlocks File

```
user@Client:~$ ./lab3 -unlock -2
```

The system should continue to function as described above until Server A and Server B are manually killed by the user.

Submission Requirements:

In addition to the Submission Guidelines listed below, you will create a single directory in your zip file that will contain nothing other than source code that you wrote or modified for this assignment. That is, if you wrote your program in Java, this directory should have nothing other than .java files that you have personally modified. This directory should be named your loginID and have no subdirectories.

Notes:

- Locked files at `directory_a` will not be manipulated via the host's native file manager during testing.
- Locked files will not have their index changed when testing (e.g., only files indexed "below" a locked file will be deleted).
- There is no upper bound on the number of operations that might be queued or the number of files that might be locked.
- All processes may run on the same physical machine.
- Server A and Server B may be run from different command line instances.
- The IP address and port number of Server A and Server B may be hardcoded.
- The formats of the dates and file sizes are developer's discretion.
- Files may be added, deleted, or modified at any time.
- The contents of the designated directories will be verified with the host's native file manager.
- The program must operate independently of a browser engine.