TR
Technical Report

Cloud Storage Mounting on Android OS

This is the final report for the independent study course CS 6970 taken by Dr. Prabhaker Mateti.

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Abstract

Currently, most cloud storage applications available for Android devices simply give the user an interface in which to sync his/her files and folders. There is not an application that will mount the cloud storage directory so that it appears to be part of the Operating System's file system. This would allow the user to access their cloud based directories and files from any application. For the file the user needs to access, he/she would avoid having to download it to the local file system in order to allow another application on the device access to that file. Once that application has completed it's tasks against that file, the user would then need to remember to sync that file back to their cloud storage in order for that file to remain up-to-date. This is inconvenient, a hassle, and vulnerable to human error.

The scenario described above is the motivation for the project upon which this course and final paper are based. How can I alleviate those extra syncing steps and allow the user to access their cloud storage content directly? The solution is to mount a cloud storage directory to the internal storage of an Android device, at the Operating System level. I journeyed toward this goal with the understanding that open source projects were available with solutions close to what I was trying to accomplish. This shed hope on the implementation aspect of the project. I could take what was already created and build upon it. This, unfortunately, proved to be more difficult than I initially had envisioned.

Many of the solutions were created for the purpose of mounting on Linux alone. Even still, this seemed to be a great starting point since Android is built on the Linux Operating System. In saying that, porting a solution that works on Linux over to Android should not be difficult. However, I ran into issues due to unfamiliar territory. Specifically, cross compiling in order to obtain an Android compatible executable. I ran into several obstacles along the way that did not allow me to achieve the ultimate goal of mounting the cloud storage directory on an Android device at the Operating System level. This attempt was based solely on my experience with OCamlFUSE which was written in OCaml and was designed to mount a Google Drive directory on Linux.

I did several other activities outside of the OCamlFUSE project in an effort to explore other options. Once I had decided that OCamlFUSE was no longer an option,

I needed to turn my attention to something else. It was beneficial that I was trying other options in conjunction with OCamlFUSE. As a result of this side work, I had discovered RClone and was able to install it onto my Android device. I was able to successfully mount my Google Drive directory to the Android file system. While working with RClone, I also discovered that it supports many other cloud storage providers. So, I went on to explore the other options available within RClone.

It continues to be unsettling that the OCamlFUSE solution could not easily be ported over to the Android device. Future work should include continuing to dig into cross compilers for OCaml and attempting to compile OCamlFUSE for use on an Android device. There are also several other solutions that could be explored. I feel that I only grazed the surface of cloud storage mounting solutions and cross compilation solutions available on GitHub. Given more time, I would have experimented with more solutions to find out which could crack the code for OCamlFUSE.

Acknowledgements

This template is based on the Laursen's DTU Thesis template. [Lyn]
Dr. Mateti has been my professor and mentor for this project.

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CHAPTER 1

Project Scope

[Doc]

1.1 Introduction

This chapter outlines the scope of the project that is being explored, researched, and implemented for CS 6970. It includes the description, scope, and deliverables of the project as well as details on what criteria is expected to be met in order for this project to be deemed accepted. Another important purpose for this document is so that all stakeholders involved in this project have a common understanding of the scope, expectations, and goals of this project. August 5, 2019 is the expected completion date and submission of all deliverables for this project.

1.2 Project Purpose and Justification

The Cloud Storage Mounting on Android OS project has been approved for researching, planning, designing, building, and implementation. The project involves mounting a cloud storage directory at the Operating System level so that the directory can be accessed from other applications running on the mobile device. The purpose is to make that cloud storage appear to be native to the device rather than hosted elsewhere. The successful implementation of this project will meet the requirements for the course CS 6970 as well as produce software that will greatly reduce the friction of cloud storage access for mobile device users.

1.3 Scope Description

The scope of the Cloud Storage Mounting on Android OS project will involve research, planning, designing, building, and implementing a solution for mounting a cloud storage at the Operating System level of an Android mobile device. Open source resources will be used as tools for implementation as well as starting points.

1.4 High Level Requirements

The only requirement specified for this particular project is to properly perform mounting of a cloud storage directory so that it can be accessed from anywhere on the mobile device.

1.5 Boundaries

The scope of the Cloud Storage Mounting on Android OS project includes all work involving research, planning, designing, building, and implementing a solution for mounting a cloud storage at the Operating System level of an Android mobile device. Tasks that will also be involved include gathering requirements, writing up requested documents and documentation as well as the technical report, deploying the solution, and testing the solution on an Android mobile device. The scope of this project will not include an implementation for Windows or Apple mobile devices or implementations for other cloud storage providers outside of Google Drive, unless time permits otherwise.

1.6 Strategy

The Cloud Storage Mounting on Android OS project will be implemented by one developer using a machine running Linux and has Android Studio installed. The developer will research open source options to use as a template to begin the implementation. The implementation will be tested locally on the Linux machine to debug and make sure functionality is operating as expected. Then, either by using the mobile device emulator or the physical Android device (ASUS Nexus 7 tablet), the implementation will be tested on a mobile device for completeness.

1.7 Deliverables

The Cloud Storage Mounting on Android OS project will yield an Android APK file that can be downloaded and installed on an Android mobile device. A technical report detailing the project will be delivered as well. All deliverables will be upload onto GitHub [Alk].

1.8 Acceptance Criteria

- Meet scheduled deadlines.
- Develop a report that documents successes and failures during the project.

- Store all project artifacts in a GitHub account.
- Complete at least 3 labs accompanied by respective lab reports.
- Demonstrate progressive learning of project components.

1.9 Constraints

The project must be completed between May 13, 2019 and August 5, 2019. That is about 12 weeks. Development will be performed on a personal Linux (Ubuntu 18.10) machine. Testing will be performed on the same machine and an ASUS Nexus 7 tablet that is running Android version 6.0.1 and has been rooted.

1.10 Assumptions

The application will be installed on only Android devices. The user on the device has root access. The directory being mounted is on the Google Cloud provider, not any other provider.

CHAPTER 2

Background

This project focuses primarily on the topic of file system mounting. As such, certain aspects should be explained to give the reader some conceptual and technical context before diving into the project details. We will need to define file systems, mounting, and how mounting is accomplished on a Linux machine. The other important aspect of this project revolves around the inner workings of an Android device and it's operating system. So, I will explore Android rooting, Android APKs, and the role of Android init. This will lead us to the topic that ties everything together, which involves kernel modules and the ability to inject desired code into the kernel upon request.

2.1 File System

A file system is comprised of a file volume and supplemental code. The file volume represents the actual contents of the device. File volumes are organized into a hierarchy of directories containing files at the leaf nodes. File systems can be designed in different ways. The Linux file system and Android storage both use ext4 as their design, while Windows uses vfat as it's design. Both Linux and Android have the capability to utilize the vfat design. In fact, Android uses the vfat design for removable disks.

Regardless of the design, however, there are operations available. In order to make a file system, the command `mkfs` can be used. To mount an external file volume to an existing directory in the file system, the command `mount` can be used. The existing directory used for mounting is called the mount point. In order to unmount the file volume, simply use the command `umount`.

Mounting is an important operation to keep in mind throughout this paper. Mounting makes a new and, usually, remote file volume accessible through an existing, local file volume. As mentioned before, that existing file volume is referred to as the mount point. Any content that already existed within that mount point directory will no longer be accessible while the additional file volume is mounted. Once it is unmounted, then everything within that existing file volume will return and be accessible as it was before. In this way, file volumes can be mounted just about anywhere. As for removable disks, there is a designated mount point that is used. These disks can

either be mounted to the `/mnt` directory or a directory within that directory. Many of these operations can only be performed by a root user, an account that has the highest privileges within the system. This will be discussed further in section 2.2 below.

2.2 Android Internals

Upon purchase from the manufacturer, all Android devices are not rooted by default. However, rooting an Android device is an important step needed before many other meaningful actions can be taken on the device, especially at the Operating System level. Rooting a device allows the user to log in as the root user and execute operations with elevated permissions. The Android Debug Bridge (`adb`) is used heavily when rooting an Android device. This is a tool that can be used to interact with the device from a computer using the terminal on the computer and the ip address of the device. This tool is also very useful for installing APKs on Android devices from the computer or performing many other tasks without having to use the terminal on the device itself.

An Android Package (APK) is a compressed file which contains the Java code solution for the given application. The extension of the APK file is simply `.apk` versus `.zip`. The device has logic to handle a file with that extension differently than a ZIP file. If a user desires to see the code behind an Android application, he/she can rename the extension of the file to `.zip` and extract the contents in order to explore the code. Another approach is to use the Android Studio application and choose the option to "Profile or Debug APK". The second option is very straightforward and the user can utilize the convenient tools within Android Studio to better explore the code.

However, an Android device needs to boot up before it can be rooted or have APKs installed onto it. This is where the program `init` steps in. This program is an important step in the boot process of an Android device. It is responsible for getting the system setup by initializing services in a certain, specified order. It monitors these services and restarts them if they crash, so that they remain running from the start of the system to when it shuts down. It obtains it's instructions from a file called `init.rc`. If the user desired certain commands or applications to execute during the booting of the device, this init file would be the place to specify that instruction. Some applications do not require code execution at boot time, but rather on demand. In this case, kernel modules can be utilized. [Mat]

2.3 Kernel

Kernel modules make it possible to inject code into the kernel upon request. This helps to avoid attempting to include every imaginable capability into the kernel itself,

bloating the kernel as a result. The modular approach allows the user to plug his/her code in when and where desired. Modules are not applications, however. An order of execution cannot be enforced, many processes can be utilizing one module, there is a sensitivity to interruptions of the executing module, and resource cleanup must be manually maintained. This capability still makes it more flexible to allow the user to run certain modules on demand and tailor the experience to his/her specific needs. [Mol]

CHAPTER 3
Development Plan

3.1 Scope

Please refer to the Project Scope section [1] for details.

3.2 Project Planning and Oversight

This project will be planned and managed using a tool called Trello [Tre]. Columns are used to specify the status of each work item referred to as a 'card'. Each card describes the task that needs to be completed. Checklists can be added to a card in order to plan the work breakdown and check things off as they are completed. Dr. Mateti and I are both members of this board and can be assigned to different cards in order to specify who needs to work on certain items. Each card has a conversation functionality where we can both add comments in order to communicate about the work completed and provide updates. When a card is updated, each of us receives an email and mobile notification.

The columns are 'To Do', 'In Progress', 'Ready for Review', 'Done', and 'Postponed'.

I added cards into the 'To Do' column at the onset of this project in order to make sure that I had goals for myself to reach. I broke the project down into six milestones. These depicted progress made on the technical report. Every other week, an updated draft is due. I specified those due dates on each card. As Dr. Mateti discovered items he wanted me to research or perform, he would add cards to the 'To Do' column as well.

When I was ready to pick those items up and begin working on them, I would move the card into the 'In Progress' column. Once I completed the task, I would put a comment on the card and move it into 'Ready for Review' so that Dr. Mateti was aware that I was finished with the item and needed his feedback. If it was an item that did not need feedback, I would move it straight into the 'Done' column. If it required feedback, Dr. Mateti would respond with a comment on the card and I would move the card into a column based on the feedback. If more work needed to be done, I would move the card back into 'In Progress'. If Dr. Mateti was happy with

the work, I would move that card into ‘Done’ and move on to the next card.

Dr. Mateti added a column called ‘Postponed’ for items that we had planned to work on at the start of the project. However, we found that we were running out of time and wanted to prioritize other items above certain research labs. Those cards were moved into ‘Postponed’. If time permits, we will revisit those items, but they are not high priority right now.

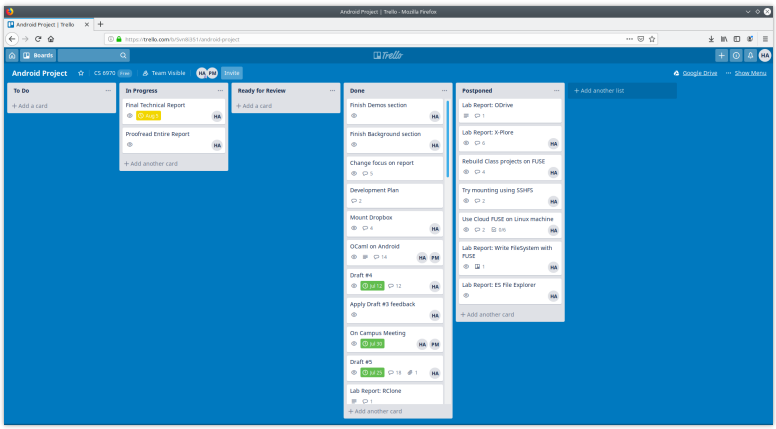

Figure 3.1: Trello: Project Management Tool.

3.3 Establishing a Software Development Environment

1. Setup Linux Operating System
2. Dr. Mateti provided a rooted Nexus 7 tablet
3. Install OCamlFUSE
4. Install Visual Studio Code

CHAPTER 4

OCamlFUSE

OCamlFUSE is a FUSE file system implementation written by Alessandro Strada to mount a Google Drive directory onto the Linux file system. It provides capabilities for reading from and writing to files and folders, accessing documents saved in Google product formats, handling duplicate files, and many other remote file system operations. [Stra]

4.1 Explore OCamlFUSE Source Code

4.1.1 Summary

1. Source code downloaded from GitHub. [Stra]

2. ML versus MLI file. The first thing I noticed was that there were duplicate files in the source folder that simply had different extensions. After some research, I found that the extension ML stands for Meta Language which is the umbrella programming language that contains OCaml. I suspect that the extension MLI stands for Meta Language Interface, but I cannot be certain of that since I was unable to find its expansion in my research. The reason I suspect it is Interface is because of what I observed when I looked at the files themselves. I opened bufferPool.ml and bufferPool.mli and compared them to each other. In the ML file, I found full function implementations while in the MLI file, I found a listing of function signatures. So, the MLI files must be interfaces that are used by other classes so as to hide the implementation in the ML from users. Dr. Mateti clarified for me that MLI files are compiled from ML files.

3. SLOCCOUNT

```
hanen@hanen:~$ sloccount /home/hanen/Desktop/google-drive-
ocamlfuse-beta/
Have a non-directory at the top, so creating directory top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//LICENSE
to top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//Makefile
to top_dir
```

```
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//README.md
to top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//_config.yml
to top_dir
Creating filelist for bin
Creating filelist for doc
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//dune-project
to top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//google-
drive-ocamlfuse.opam to top_dir
Creating filelist for test
Creating filelist for tools
Have a non-directory at the top, so creating directory src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
appDir.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
bufferPool.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
bufferPool.mli
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
buffering.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
buffering.mli
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
cache.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
cache.mli
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
cacheData.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
cacheData.mli
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
concurrentGlobal.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
```

```
config.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
context.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
dbCache.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
dbCache.mli
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
drive.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/dune
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
gaeProxy.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
keyValueStore.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
memoryCache.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
memoryCache.mli
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
mime.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
oauth2.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
state.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
threadPool.ml
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
threadPool.mli
to src_top_dir
Adding /home/hanen/Desktop/google-drive-ocamlfuse-beta//src/
```

```
utils.ml
to src_top_dir
Categorizing files.
Finding a working MD5 command....
Found a working MD5 command.
Computing results.

SLOC    Directory       SLOC-by-Language (Sorted)
7834    src_top_dir     ml=7834
663     bin             ml=663
211     test            ml=211
76      tools           sh=76
0       doc             (none)
0       top_dir         (none)

Totals grouped by language (dominant language first):
ml:            8708 (99.13%)
sh:              76 (0.87%)

Total Physical Source Lines of Code (SLOC)                = 8,784
Development Effort Estimate, Person-Years (Person-Months) = 1.96
(23.50)
 (Basic COCOMO model, Person-Months = 2.4 * (KSLOC**1.05))
Schedule Estimate, Years (Months)                         = 0.69
(8.30)
 (Basic COCOMO model, Months = 2.5 * (person-months**0.38))
Estimated Average Number of Developers (Effort/Schedule)  = 2.83
Total Estimated Cost to Develop                           =
$ 264,557
 (average salary = $56,286/year, overhead = 2.40).
SLOCCount, Copyright (C) 2001-2004 David A. Wheeler
SLOCCount is Open Source Software/Free Software, licensed under
the GNU GPL.
SLOCCount comes with ABSOLUTELY NO WARRANTY, and you are welcome
to redistribute it under certain conditions as specified by the
GNU GPL license;
see the documentation for details.
Please credit this data as "generated using David A. Wheeler's
'SLOCCount'."
```

4. Quick Code Exploration

   a) There is a Make module in the concurrentGlobal file.

b) The file drive.ml appears to have the bulk of logic behind this implementation.

c) I picked a function from the buffer.mli interface file called `write_to_block` and did a project wide search for it. I found it referenced in the drive.ml file as
`Buffering.MemoryBuffers.write_to_block`. I do not understand why the case is different in the reference. Buffering when calling the function versus buffering in the definition of the file. I would not have made that connection before, but now am aware of it.

d) Gapi shows up all over the code. It stands for Google API.

4.1.2 Pseudo-code

4.1.2.1 Class: appDir

1. Getters and Setters

   a) `config_path: string`

   b) `data_dir: string`

   c) `cache_dir: string`

   d) `log_dir: string`

   e) `state_path: string`

   f) `app_log_path: string`

   g) `curl_log_path: string`

2. `function xdg_data_home`
   Try to get the value of the environment variable `XDG_DATA_HOME` and return that value.
   If exception thrown trying to get this value, return that it was not found.

3. `function xdg_config_home`
   Try to get the value of the environment variable `XDG_CONFIG_HOME` and return that value.
   If exception thrown trying to get this value, return that it was not found.

4. `function xdg_cache_home`
   Try to get the value of the environment variable `XDG_CACHE_HOME` and return that value.
   If exception thrown trying to get this value, return that it was not found.

5. `function get_config_path`
   input: `config_path: string, xdg_base_directory: boolean, base_dir: string, fs_label: string`

if `config_path` is not empty, then return `config_path` and false (not base directory)
else if `xdg_base_directory` is true, then make directory `xdg_config_dir` and return `xdg_config_path` and true (is base directory)
else if `xdg_config_path` exists, then return `xdg_config_path` and true (is base directory)
else return `default_base_dir` + `fs_label` + "config" if `base_dir` is empty or `base_dir` + `fs_label` + "config"| if `base_dir` is not empty and false (not base directory)

6. `function create`
   input: `config: ConfigFileStore.data, config_path: string, base_dir: string, fs_label: string, xdg_base_directory: boolean`
   set `data_dir` to `config.Config.data_directory` if `config.Config.data_directory` is not empty
   set `data_dir` to `xdg_data_home` + "gdfuse" + `fs_label` if `xdg_base_directory` is true
   otherwise, set `data_dir` to `default_base_dir` + `fs_label` if `base_dir` is empty or set `data_dir` to `base_dir` + `fs_label` if `base_dir` is not empty
   set `cache_dir` to `config.Config.cache_directory` if `config.Config.cache_directory` is not empty
   set `cache_dir` to `xdg_cache_home` + "gdfuse" + `fs_label` if `xdg_base_directory` is true
   otherwise, set `cache_dir` to `data_dir` + "cache"
   set `log_dir` to `config.Config.log_directory` if `config.Config.log_directory` is not empty
   set `log_dir` to `cache_dir` + "log" if `xdg_base_directory` is true
   otherwise, set `log_dir` to `data_dir`
   set `state_path` to `data_dir` + "state"
   set `app_log_path` to `log_dir` + "gdfuse.log"
   set `curl_log_path` to `log_dir` + "curl.log"
   return `config_path`, `data_dir`, `cache_dir`, `log_dir`

7. `function create_directories`
   input: `app_dir: object`
   make directory for `data_dir` from `app_dir`
   make directory for `cache_dir` from `app_dir`
   make directory for `log_dir` from `app_dir`

4.1.2.2 Class: buffering

Block: module

1. `function create`
   input: `offset: object`, `size: integer`, `mutex: object`, `condition: object`, `buffer_pool: object`
   create block and set defaults.
2. `function blit_to_arr`
3. `function blit_from_arr`
4. `function flush`
   input: `block: object`
   if state equals dirty, then

MemoryBuffers: module

1. `function get_block_index`
2. `function get_block_start_pos`
3. `function remove_block`
4. `function remove_full_block`
5. `function remove_partial_block`
6. `function release_lru_buffer_if_needed`
7. `function release_lru_buffer_if_no_free_buffer_left`
8. `function release_lru_buffer_if_request_blocked`
9. `function flush`
10. `function flush_block`
11. `function flush_blocks`
12. `function flush_lru_buffer_if_needed`
13. `function flush_lru_buffer_if_no_free_buffer_left`
14. `function flush_lru_buffer_if_request_blocked`
15. `function get_block`
16. `function read_block`
17. `function read_ahead`
18. `function remove_buffers`
19. `function write_to_block`

20. `function evict_cache`
    input: `buffers: object`
    Loop 10 times and check if the thread needs to be evicted. If it does, then exit.
    Call `flush_lru_buffer_if_request_blocked` and
    `release_lru_buffer_if_request_blocked`.

21. `function create_eviction_thread`
    input: `buffers: object`
    create a thread.

22. `function stop_eviction_thread`
    input: `buffers: object`
    set the `stop_eviction_thread` flag to true, so that the thread is exited.

4.1.2.3 Class: bufferPool

1. `function create`
   input: `pool_size: integer`, `buffer_size: integer`
   set `max_buffers` to `pool_size` / `buffer_size` if `pool_size % buffer_size` = 0
   otherwise, set `max_buffers` to `pool_size` / `buffer_size` + 1
   return object containing `max_buffers`, `buffer_count`, `buffer_size`, `free_buffers`, `pending_requests`

2. `function acquire_buffer`
   input: `mutex: object`, `condition: object`, `buffer_pool: object`
   try to get a free buffer from the Queue.
   if the Queue is empty, then:
   if `buffer_count` < `max_buffers`, then increase `buffer_count` by 1 and return a new buffer with the buffer's id set to `buffer_count`, mutex set to Mutex.Create(), and condition set to Condition.Create()
   else, increase `pending_requests` by 1 and while `free_buffers` is equal to zero, wait. Once, waiting is done, decrease `pending_requests` by 1 and get buffer.

3. `function release_buffer`
   input: `buffer: object`, `condition: object`, `buffer_pool: object`
   add a buffer to the Queue
   wake a thread up

4.1.2.4 Class: cache

1. `function create_cache`
   create cache with defaults.

2. `function get_content_path`
   input: `cache: object`, `resource: object`
   concatenate the cache directory with the remote id.

3. `function delete_files_from_cache`
   input: `cache: object`, `resource: list`
   create `remove_file` inline method if the file path exists, then remove the file.

4. `function setup_db`
   input: `cache: object`
   if in memory, setup cache.

5. `function clean_up_cache`
   input: `cache: object`
   if cache directory exists, then remove it.

6. `function compute_cache_size`
   input: `cache: object`
   if cache directory exists, then concatenate the cache directory and file name.
   if the path exists and the path is not equal to the database path, then increment the size by the current file size.

7. `function flush`
   input: `cache: object`
   if cache is in memory, then flush the cache.

4.1.2.5 Class: cacheData

Resource: module

1. `function file_mode_bits_to_kind`
2. `function file_mode_bits_to_perm`
3. `function render_xattrs`
4. `function parse_xattrs`
5. `function find_app_property`
6. `function app_property_to_int64`
7. `function get_file_mode_bits`
8. `function file_mode_bits_to_app_property`
9. `function mode_to_app_property`
10. `function get_uid`

11. function uid_to_app_property
12. function get_gid
13. function gid_to_app_property
14. function get_link_target
15. function link_target_to_app_property
16. function get_xattrs
17. function xattr_to_app_property
18. function xattr_no_value_to_app_property
19. function is_folder
20. function is_document_mime_type
21. function is_document
22. function is_symlink
23. function is_valid
24. function is_large_file
25. function to_stream
26. function get_format_from_mime_type
27. function get_format
28. function get_icon_from_mime_type
29. function get_icon
30. function mime_type_of_format
31. function mime_type_of_format

Metadata: module

1. function is_valid

4.1.2.6 Class: concurrentGlobal

1. `function with_lock`
2. `function get_no_lock`
3. `function set_no_lock`
4. `function get`
5. `function set`
6. `function clear`
7. `function update`

4.1.2.7 Class: config

1. `function umask`
2. `function default_max_upload_chunk_size`
3. `function default`
4. `function default_debug`
5. `function of_table`
6. `function to_table`
7. `function debug_print`
8. `function create_gapi_config`

4.1.2.8 Class: context

1. `function save_state_store`
2. `function save_state_from_context`
3. `function save_config_store`
4. `function get_cache`

4.1.2.9 Class: dbCache

1. `function fail`
2. `function expect`
3. `function get_result`
4. `function wrap_exec_not_null_no_headers`
5. `function wrap_exec`
6. `function reset_stmt`
7. `function finalize_stmt`
8. `function final_step`
9. `function bind`
10. `function data_to_int64`
11. `function data_to_bool`
12. `function data_to_string`
13. `function data_to_float`
14. `function get_next_row`
15. `function select_first_row`
16. `function select_all_rows`
17. `function prepare_begin_tran_stmt`
18. `function prepare_commit_tran_stmt`
19. `function prepare_rollback_tran_stmt`
20. `function prepare_insert_stmt`
21. `function prepare_insert_with_id_stmt`
22. `function prepare_update_stmt`
23. `function prepare_update_state_stmt`
24. `function prepare_update_state_and_size_stmt`
25. `function prepare_delete_all_with_parent_path`
26. `function prepare_trash_all_with_parent_path`

27. function prepare_invalidate_stmt
28. function prepare_invalidate_all_stmt
29. function prepare_invalidate_trash_bin_stmt
30. function prepare_invalidate_path_stmt
31. function prepare_trash_stmt
32. function prepare_update_all_timestamps_stmt
33. function prepare_delete_stmt
34. function prepare_delete_all_with_path_stmt
35. function prepare_delete_not_found_with_path_stmt
36. function prepare_delete_with_parent_path_stmt
37. function prepare_delete_all_stmt
38. function prepare_select_with_path_stmt
39. function prepare_select_with_remote_id_stmt
40. function prepare_select_with_parent_path_stmt
41. function prepare_select_order_by_last_update
42. function prepare_select_all_resources
43. function prepare_insert_stmt
44. function prepare_update_cache_size_stmt
45. function prepare_set_clean_shutdown_stmt
46. function open_db
47. function close_db
48. function with_db
49. function with_transaction
50. function bind_resource_parameters
51. function step_insert_resource
52. function insert_resource
53. function update_resource

```
54. function update_resource_state
55. function update_resource_state_and_size
56. function _delete_resource
57. function delete_resource
58. function delete_not_found_resource_with_path
59. function _delete_resources_with_parent_path
60. function delete_resources
61. function insert_resources
62. function flush_resources
63. function invalidate_resources
64. function invalidate_path
65. function invalidate_all
66. function invalidate_trash_bin
67. function trash_resources
68. function delete_all_with_parent_path
69. function trash_all_with_parent_path
70. function update_all_timestamps
71. function row_to_resource
72. function select_resource
73. function select_resource_with_path
74. function select_first_resource_with_remote_id
75. function select_resources_with_remote_id
76. function select_resources_with_parent_path
77. function select_resources_order_by_last_update
78. function select_all_resources
79. function save_metadata
80. function insert_metadata
```

81. `function row_to_metadata`
82. `function select_metadata`
83. `function update_cache_size`
84. `function set_clean_shutdown`
85. `function setup_db`
86. `function check_clean_shutdown`
87. `function set_clean_shutdown`
88. `function reset_clean_shutdown`

4.1.2.10 Class: drive

1. `function get_remote_id_fingerprint`
   input: `word_length: integer`, `remote_id: object`
   if `word_length` is greater than 4, return an error message.
   get the hash md5 result.
   get the hex encoding result.
   return the substring of these results from the offset (32 - `word_length` * 8) to the length (`word_length` * 8).

2. `function disambiguate_filename`
   input: `filename: string`, `full_file_extension: string`, `remote_id: object`, `filename_table: hashtable`
   if the file name supplied is already being used, then log that a file name collision has been detected and recursively search for the first unique file name. Increment the counter of the file name in the hashtable and return the unique file name that was found.
   otherwise, log that a file name collision was not detected, add the supplied file name to the hashtable, and return the file name itself.

3. `function is_in_trash_directory`
   input: `path: string`, `config: object`
   return false, if the path supplied is a trash directory or trash is disabled.
   otherwise, return whether the path supplied starts with the trash directory.

4. `function is_lost_and_found_root`
   input: `path: string`, `trashed: boolean`, `config: object`
   return false, if trashed is true or not lost and found.
   otherwise, return whether the path supplied is equal to the lost and found directory.

5. `function is_lost_and_found`
   input: `path: string`, `trashed: boolean`, `config: object`
   return false, if trashed is true or not lost and found.
   otherwise, return whether the path supplied starts with the lost and found directory.

6. `function is_shared_with_me_root`
   input: `path: string`, `trashed: boolean`, `config: object`
   return false, if trashed is true or not shared with me.
   otherwise, return whether the path supplied is equal to the shared with me directory.

7. `function is_shared_with_me`
   input: `path: string`, `trashed: boolean`, `config: object`
   return false, if trashed is true or not shared with me.
   otherwise, return whether the path supplied starts with the shared with me directory.

8. `function get_path_in_cache`
   input: `path: string`, `config: object`
   if path is equal to the root directory, then return the root directory and false for whether it is trashed.
   if path is equal to the trash directory and trash is not disabled, then return the root directory and true for whether it is trashed.
   if the path is within the trash directory, then return the path in the cache and true for whether it is trashed.
   otherwise, return the path supplied and a false for whether it is trashed.

9. `function match_service_error`
   input: `reason: string`
   return error that matches reason supplied.

10. `function handle_default_exceptions`
    input: `reason: string`
    return error that matches reason supplied.

4.1.2.11 Class: gaeProxy

1. `function gae_proxy_request`
2. `function get_string_field`
3. `function get_tokens`
4. `function start_server_polling`
5. `function refresh_access_token`

4.1.2.12 Class: keyValueStore

1. `function load`
2. `function save`

4.1.2.13 Class: memoryCache

1. `function delete_all_with_path`
2. `function insert_resource`
3. `function update_resource`
4. `function update_resource_state`
5. `function update_resource_state_and_size`
6. `function delete_resource`
7. `function delete_not_found_resource_with_path`
8. `function delete_resources`
9. `function delete_resources_with_parent_path`
10. `function insert_resources`
11. `function is_invalidable`
12. `function invalidate_resource`
13. `function invalidate_resources`
14. `function invalidate_path`
15. `function invalidate_all`
16. `function invalidate_trash_bin`
17. `function trash_resources`
18. `function delete_all_with_parent_path`
19. `function trash_all_with_parent_path`
20. `function update_all_timestamps`
21. `function select_resource_with_path`
22. `function select_first_resource_with_remote_id`

23. `function select_resources_with_remote_id`
24. `function select_resources_with_parent_path`
25. `function select_resources_order_by_last_update`
26. `function insert_metadata`
27. `function select_metadata`
28. `function update_cache_size`
29. `function setup`
30. `function flush_db`
31. `function flush_db_thread`
32. `function create_flush_db_thread`
33. `function start_flush_db_thread`
34. `function stop_flush_db_thread`

4.1.2.14 Class: mime

1. `function map_filename_to_mime_type`

4.1.2.15 Class: oauth2

1. `function do_request`
2. `function get_access_token`

4.1.2.16 Class: state

1. Getters and Setters
    a) `auth_request_id: string`
    b) `auth_request_date: GapiDate.t`
    c) `refresh_token: string`
    d) `last_access_token: string`
    e) `access_token_date: GapiDate.t`
    f) `saved_version: string`

2. `function empty`
   set `auth_request_id`, `refresh_token`, `last_access_token`, and `saved_version` to empty string.
   set `auth_request_date` and `access_token_date` to GapiDate.epoch.

3. `function of_table`
   input: `table: object`
   get each class variable from the table.

4. `function to_table`
   input: `data: object`
   add each class variable to the table.

4.1.2.17 Class: threadPool

1. `function create`

2. `function signal_work_done`

3. `function add_work`

4. `function pending_threads`

5. `function shutdown`

4.1.2.18 Class: utils

1. `function get_thread_id`
   return id of current thread.

2. `function try_finally`
   input: `f: lambda`, `finally: lambda`
   try to run f and finally and return the result.
   if that is unsuccessful, raise an exception.

3. `function with_in_channel`
   input: `path: string`, `f: lambda`
   try to run the input f and `close_in` and return the result.
   if that is unsuccessful, raise an exception.

4. `function with_out_channel`

5. `function log_message`
   input: `format: object`
   if verbose is true, then use ifprintf to print full log message.
   if verbose is false, then use fprintf to print simple log message.

6. `function log_with_header`

7. `function log_exception`

8. `function with_lock`

9. `function try_with_m`
   input: `f: lambda`, `handle_exception: lambda`, `s: object`
   try to run the provided function f with s as a parameter. if this fails, run `handle_exception` with the exception e and the provided s argument as parameters.

10. `function raise_m`
    input: `m: object`
    raise exception m that is passed in.

11. `function try_finally_m`

12. `function lock`

13. `function unlock`

14. `function with_lock_m`

15. `function safe_find`

16. `function get_from_string_table`

17. `function flags_to_string`
    input: `flags: list`
    map the list of flags provided to it's respective string representation.

18. `function xattr_flags_to_string`
    return ”AUTO” if flag is Fuse.AUTO
    return ”CREATE” if flag is Fuse.CREATE
    return ”REPLACE” if flag is Fuse.REPLACE

19. `function start_browser`
    input: `browser: string`, `url: string`
    run Unix command to launch the browser and visit the provided url.
    if browser is not provided, then the defaults will be ”xdg-open”, ”firefox”, ”google-chrome”, ”chromium-browser”, and ”open”.

20. `function with_retry`
    input: `f: lambda`, `label: string`
    recursively try to run f.
    if that attempt is unsuccessful and the `max_retries` has been reached, then raise an exception.
    if that attempt is unsuccessful and the `max_retries` has not been reached, then increase n by 1 and continue to recursively attempt to run f.

21. `function safe_makedir`
    input: `dir: string`
    if directory does not exist, make the directory.

4.1.3 Mount Google Drive on Linux Machine

4.1.3.1 Install OCamlFUSE

4.1.3.2 Allow Permissions through Browser

4.1.3.3 Make Directory and Mount Drive

1. Run commands to install OCamlFUSE

```
sudo add-apt-repository ppa:alessandro-strada/ppa
sudo apt-get-update
sudo apt-get install google-drive-ocamlfuse
sudo google-drive-ocamlfuse
```

2. Allow Permissions through Browser Allow gdfuse to see, edit, create, and delete all of your Google Drive files. Select Google account and allow access permissions.

3. Make Directory and Mount Drive

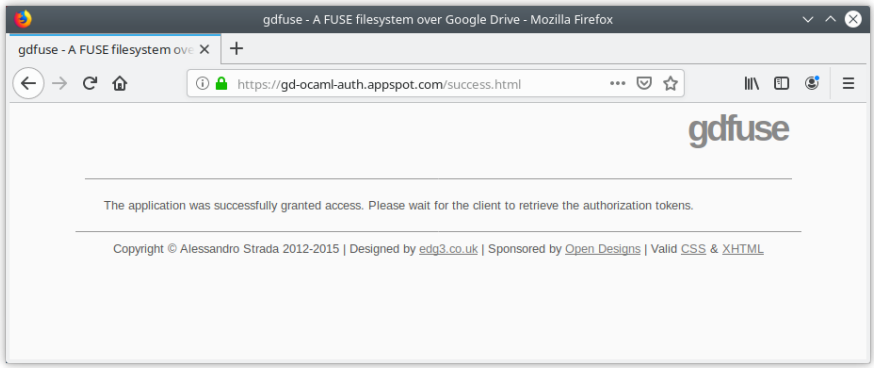

Figure 4.1: Screenshot ocaml7.png.

```
hanen@hanen:mkdir ~/GoogleDrive
hanen@hanen:google-drive-ocamlfuse ~/GoogleDrive
hanen@hanen:cd GoogleDrive
hanen@hanen:ls
'2019-Hanen-CS 6970'    Misc
```

That final output matches the contents of the Google Drive in the browser as seen in Figure 4.2

4.1.4 Mount Google Drive on Android Tablet

As a primary goal of this project, the next step is to have OCamlFUSE function similarly to the previous section using an Android device. Therefore, my attention turned to cross compilers in an effort to compile the OCaml code of OCamlFUSE into an executable that would be compatible with Android (ARM processor). I discovered several cross compilers and decided to try a few.

4.1.4.1 OCaml-Cross

Following the first compiler I found [Whi], I did not manage to get very far before I ran into errors. The following are the commands I ran and their output:

```
hanen@hanen:~/Desktop/google-drive-ocamlfuse-beta$ sudo su
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta# opam repository
add android git://github.com/whitequark/opam-cross-android
[WARNING] Running as root is not recommended
[android] synchronised from git://github.com/whitequark/opam-cross-android
[WARNING] The repository 'android' at git://github.com/whitequark/opam-
```

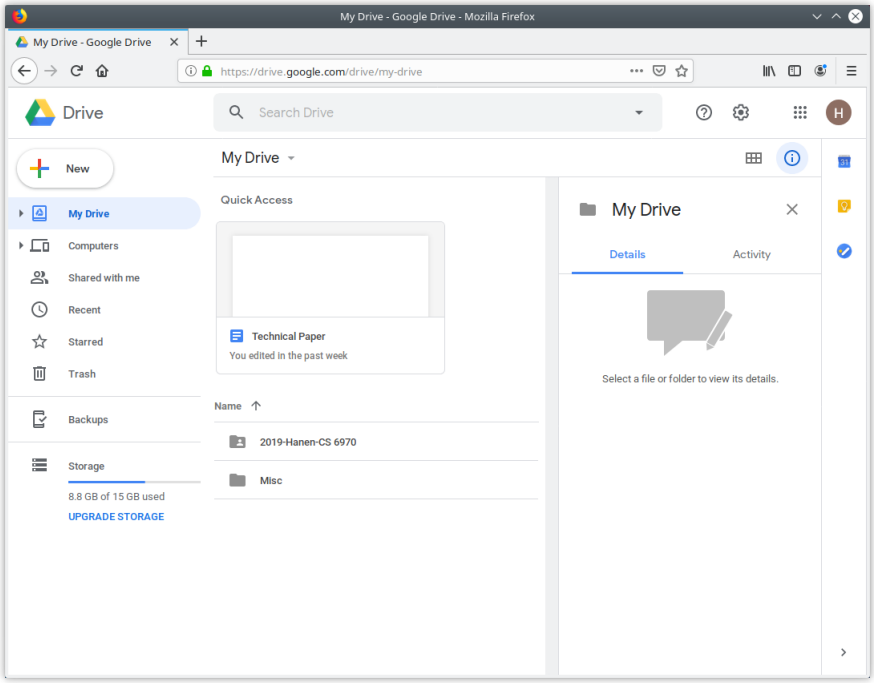

Figure 4.2: Content of GD as seen through the browser.

```
cross-android doesn't have a 'repo'
          file, and might not be compatible with this version of opam.
[NOTE] Repository at git://github.com/whitequark/opam-cross-android
doesn't define its version, assuming
       it's 1.2.

<><> Upgrading repositories from older opam format ><><><><><><><><><>
Upgrading repository "android"...
[ERROR] Unconvertible 'available:' disjunction in
        /root/.opam/repo/android/packages/ocaml-android32.4.04.0/opam
[NOTE] Repository android has been added to the selections of switch
default only.
       Run `opam repository add android --all-switches|--set-default'
       to use it in all existing switches,
       or in newly created switches, respectively.

root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta# opam
switch 4.04.0+32bit
```

```
[WARNING] Running as root is not recommended
[ERROR] No switch 4.04.0+32bit is currently installed. Did you
mean 'opam switch create 4.04.0+32bit'?
        Installed switches are:
          - default

root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta# opam
switch create 4.04.0+32bit
[WARNING] Running as root is not recommended

<><> Gathering sources ><><><><><><><><><><><><><><><><><><><><><><><><><>
[ocaml-variants.4.04.0+32bit] downloaded from cache at
https://opam.ocaml.org/cache

<><> Processing actions <><><><><><><><><><><><><><><><><><><><><><><><><>
* installed base-bigarray.base
* installed base-threads.base
* installed base-unix.base
[ERROR] The compilation of ocaml-variants failed at
"/root/.opam/opam-init/hooks/sandbox.sh build
        ./configure -prefix /root/.opam/4.04.0+32bit
        -with-debug-runtime -cc gcc -m32 -as as --32 -aspp gcc
        -m32 -c -host i386-linux -partialld ld -r -melf_i386".

#=== ERROR while compiling ocaml-variants.4.04.0+32bit ==========#
# context     2.0.4 | linux/x86_64 |  | https://opam.ocaml.org#3389beb3
# path        ~/.opam/4.04.0+32bit/.opam-switch/build/ocaml-
variants.4.04.0+32bit
# command     ~/.opam/opam-init/hooks/sandbox.sh build ./configure -prefix
/root/.opam/4.04.0+32bit -with-debug-runtime -cc gcc -m32 -as as --32
-aspp gcc -m32 -c -host i386-linux -partialld ld -r -melf_i386
# exit-code   2
# env-file    ~/.opam/log/ocaml-variants-11817-ad8886.env
# output-file ~/.opam/log/ocaml-variants-11817-ad8886.out
### output ###
# Configuring OCaml version 4.04.0
# Configuring for host i386-pc-linux-gnu ...
# Configuring for target i386-pc-linux-gnu ...
# Using compiler gcc -m32.
# Compiler family and version: gcc-8-3.
# [ERROR!] Unable to compile the test program.
#  Make sure the C compiler gcc -m32  is properly installed.
```

```
<><> Error report <><><><><><><><><><><><><><><><><><><><><><><><><><><><>
  The following actions failed
   build ocaml-variants 4.04.0+32bit

  The following changes have been performed (the rest was aborted)
  * install base-bigarray base
  * install base-threads  base
  * install base-unix     base

# Run eval $(opam env) to update the current shell environment
Switch initialisation failed: clean up? ('n' will leave the
switch partially installed) [Y/n] y
```

Right away, there is an error reporting the inability to find the android repository and that the version of OPam being used may not be compatible. I try to ignore this and trudge forward with the switch command, but the response gives me a heads up that the switch I am attempting to use has not been created. The response is very helpful and gives me the exact command I need to execute in order to create the switch I'm trying to use. So, I execute this command only to find more errors. These are beyond the scope of my understanding of OPam and OCaml, so I unable to proceed. I Google for hours, but find no viable way around this.

4.1.4.2 OCaml-ARM

My Googling leads me to another cross compiler that I decide to attempt [Mil]. Again, I am faced with issues I must try to work around. This is not as simple as following the list of commands supplied on the GitHub page. The first few commands execute without any obstacles.

```
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta#
sudo dpkg --add-architecture armhf
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta#
sudo dpkg --add-architecture i386
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta#
sudo apt-get update
Hit:1 http://security.ubuntu.com/ubuntu cosmic-security
InRelease
Hit:2 http://packages.microsoft.com/repos/vscode stable
InRelease
Ign:3 http://packages.cloud.google.com/apt gcsfuse-cosmic
InRelease
Hit:4 http://ppa.launchpad.net/alessandro-strada/ppa/ubuntu
cosmic InRelease
Hit:5 http://us.archive.ubuntu.com/ubuntu cosmic InRelease
```

```
Err:6 http://packages.cloud.google.com/apt gcsfuse-cosmic
Release
  404  Not Found [IP: 172.217.12.46 80]
Hit:7 http://apt.insynchq.com/ubuntu cosmic InRelease
Hit:8 http://us.archive.ubuntu.com/ubuntu cosmic-updates
InRelease
Hit:9 http://us.archive.ubuntu.com/ubuntu cosmic-backports
InRelease
Ign:10 http://security.ubuntu.com/ubuntu
cosmic-security/main armhf Packages
Ign:11 http://security.ubuntu.com/ubuntu
cosmic-security/restricted armhf Packages
Ign:12 http://security.ubuntu.com/ubuntu
cosmic-security/universe armhf Packages
Ign:13 http://security.ubuntu.com/ubuntu
cosmic-security/multiverse armhf Packages
Hit:14 http://ppa.launchpad.net/avsm/ppa/ubuntu
cosmic InRelease
Ign:10 http://security.ubuntu.com/ubuntu
cosmic-security/main armhf Packages
Ign:11 http://security.ubuntu.com/ubuntu
cosmic-security/restricted armhf Packages
Ign:12 http://security.ubuntu.com/ubuntu
cosmic-security/universe armhf Packages
Ign:13 http://security.ubuntu.com/ubuntu
cosmic-security/multiverse armhf Packages
Ign:10 http://security.ubuntu.com/ubuntu
cosmic-security/main armhf Packages
Ign:11 http://security.ubuntu.com/ubuntu
cosmic-security/restricted armhf Packages
Ign:12 http://security.ubuntu.com/ubuntu
cosmic-security/universe armhf Packages
Ign:13 http://security.ubuntu.com/ubuntu
cosmic-security/multiverse armhf Packages
Ign:10 http://security.ubuntu.com/ubuntu
cosmic-security/main armhf Packages
Ign:11 http://security.ubuntu.com/ubuntu
cosmic-security/restricted armhf Packages
Ign:12 http://security.ubuntu.com/ubuntu
cosmic-security/universe armhf Packages
Ign:13 http://security.ubuntu.com/ubuntu
cosmic-security/multiverse armhf Packages
Ign:10 http://security.ubuntu.com/ubuntu
cosmic-security/main armhf Packages
```

```
Ign:11 http://security.ubuntu.com/ubuntu
cosmic-security/restricted armhf Packages
Ign:12 http://security.ubuntu.com/ubuntu
cosmic-security/universe armhf Packages
Ign:13 http://security.ubuntu.com/ubuntu
cosmic-security/multiverse armhf Packages
Err:10 http://security.ubuntu.com/ubuntu
cosmic-security/main armhf Packages
  404  Not Found [IP: 91.189.91.23 80]
Ign:11 http://security.ubuntu.com/ubuntu
cosmic-security/restricted armhf Packages
Ign:15 http://us.archive.ubuntu.com/ubuntu
cosmic/main armhf Packages
Ign:12 http://security.ubuntu.com/ubuntu
cosmic-security/universe armhf Packages
Ign:13 http://security.ubuntu.com/ubuntu
cosmic-security/multiverse armhf Packages
Ign:16 http://us.archive.ubuntu.com/ubuntu
cosmic/restricted armhf Packages
Ign:17 http://us.archive.ubuntu.com/ubuntu
cosmic/universe armhf Packages
Ign:18 http://us.archive.ubuntu.com/ubuntu
cosmic/multiverse armhf Packages
Ign:15 http://us.archive.ubuntu.com/ubuntu
cosmic/main armhf Packages
Ign:16 http://us.archive.ubuntu.com/ubuntu
cosmic/restricted armhf Packages
Ign:17 http://us.archive.ubuntu.com/ubuntu
cosmic/universe armhf Packages
Ign:18 http://us.archive.ubuntu.com/ubuntu
cosmic/multiverse armhf Packages
Ign:15 http://us.archive.ubuntu.com/ubuntu
cosmic/main armhf Packages
Ign:16 http://us.archive.ubuntu.com/ubuntu
cosmic/restricted armhf Packages
Ign:17 http://us.archive.ubuntu.com/ubuntu
cosmic/universe armhf Packages
Ign:18 http://us.archive.ubuntu.com/ubuntu
cosmic/multiverse armhf Packages
Ign:15 http://us.archive.ubuntu.com/ubuntu
cosmic/main armhf Packages
Ign:16 http://us.archive.ubuntu.com/ubuntu
cosmic/restricted armhf Packages
Ign:17 http://us.archive.ubuntu.com/ubuntu
```

```
cosmic/universe armhf Packages
Ign:18 http://us.archive.ubuntu.com/ubuntu
cosmic/multiverse armhf Packages
Ign:15 http://us.archive.ubuntu.com/ubuntu
cosmic/main armhf Packages
Ign:19 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main armhf Packages
Ign:20 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/restricted armhf Packages
Ign:21 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/universe armhf Packages
Ign:22 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/multiverse armhf Packages
Ign:16 http://us.archive.ubuntu.com/ubuntu
cosmic/restricted armhf Packages
Ign:17 http://us.archive.ubuntu.com/ubuntu
cosmic/universe armhf Packages
Ign:18 http://us.archive.ubuntu.com/ubuntu
cosmic/multiverse armhf Packages
Err:15 http://us.archive.ubuntu.com/ubuntu
cosmic/main armhf Packages
  404  Not Found [IP: 91.189.91.23 80]
Ign:19 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main armhf Packages
Ign:20 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/restricted armhf Packages
Ign:21 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/universe armhf Packages
Ign:22 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/multiverse armhf Packages
Ign:16 http://us.archive.ubuntu.com/ubuntu
cosmic/restricted armhf Packages
Ign:17 http://us.archive.ubuntu.com/ubuntu
cosmic/universe armhf Packages
Ign:18 http://us.archive.ubuntu.com/ubuntu
cosmic/multiverse armhf Packages
Ign:19 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main armhf Packages
Ign:20 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/restricted armhf Packages
Ign:21 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/universe armhf Packages
Ign:22 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/multiverse armhf Packages
```

```
Ign:23 http://us.archive.ubuntu.com/ubuntu
cosmic-backports/main armhf Packages
Ign:24 http://us.archive.ubuntu.com/ubuntu
cosmic-backports/universe armhf Packages
Ign:19 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main armhf Packages
Ign:20 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/restricted armhf Packages
Ign:21 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/universe armhf Packages
Ign:22 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/multiverse armhf Packages
Ign:23 http://us.archive.ubuntu.com/ubuntu
cosmic-backports/main armhf Packages
Ign:24 http://us.archive.ubuntu.com/ubuntu
cosmic-backports/universe armhf Packages
Ign:19 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main armhf Packages
Ign:20 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/restricted armhf Packages
Ign:21 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/universe armhf Packages
Ign:22 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/multiverse armhf Packages
Ign:23 http://us.archive.ubuntu.com/ubuntu
cosmic-backports/main armhf Packages
Ign:24 http://us.archive.ubuntu.com/ubuntu
cosmic-backports/universe armhf Packages
Err:19 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main armhf Packages
  404  Not Found [IP: 91.189.91.23 80]
Ign:20 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/restricted armhf Packages
Ign:21 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/universe armhf Packages
Ign:22 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/multiverse armhf Packages
Ign:23 http://us.archive.ubuntu.com/ubuntu
cosmic-backports/main armhf Packages
Ign:24 http://us.archive.ubuntu.com/ubuntu
cosmic-backports/universe armhf Packages
Ign:23 http://us.archive.ubuntu.com/ubuntu
cosmic-backports/main armhf Packages
Ign:24 http://us.archive.ubuntu.com/ubuntu
```

```
cosmic-backports/universe armhf Packages
Err:23 http://us.archive.ubuntu.com/ubuntu
cosmic-backports/main armhf Packages
  404  Not Found [IP: 91.189.91.23 80]
Ign:24 http://us.archive.ubuntu.com/ubuntu
cosmic-backports/universe armhf Packages
Reading package lists... Done
E: The repository 'http://packages.cloud.google.com/apt
gcsfuse-cosmic Release' does not have a Release file.
N: Updating from such a repository can't be done
securely, and is therefore disabled by default.
N: See apt-secure(8) manpage for repository
creation and user configuration details.
N: Skipping acquire of configured file
'non-free/binary-armhf/Packages' as repository
'http://apt.insynchq.com/ubuntu cosmic InRelease'
doesn't support architecture 'armhf'
N: Skipping acquire of configured file
'contrib/binary-armhf/Packages' as repository
'http://apt.insynchq.com/ubuntu cosmic InRelease'
doesn't support architecture 'armhf'
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta#
sudo apt-get install gcc-4.9-arm-linux-gnueabihf
gcc-arm-linux-gnueabihf libc6-dev:armhf libgcc-4.9-dev:armhf
linux-libc-dev:i386 opam
Reading package lists... Done
Building dependency tree
Reading state information... Done
Package gcc-4.9-arm-linux-gnueabihf is not available,
but is referred to by another package.
This may mean that the package is missing, has been
obsoleted, or is only available from another source

E: Package 'gcc-4.9-arm-linux-gnueabihf' has no
installation candidate
E: Unable to locate package libc6-dev:armhf
E: Unable to locate package libgcc-4.9-dev:armhf
E: Couldn't find any package by glob 'libgcc-4.9-dev'
E: Couldn't find any package by regex 'libgcc-4.9-dev'
```

This is where the problems crop up. I have seen this many times throughout the span of working on this project; this issue of not being able to locate certain packages. I, unfortunately, have not pinpointed a solution for this particular bump in the road. In this particular case, I decide to take the last command, `sudo apt-get install`

`gcc-4.9-arm-linux-gnueabihf gcc-arm-linux-gnueabihf libc6-dev:armhf libgcc-4.9-dev:armhf linux-libc-dev:i386 opam`, and break it up into multiple `apt-get install` executions so that I can try to isolate the package that is causing the problem.

```
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta#
sudo apt-get install gcc-4.9-arm-linux-gnueabihfReading
package lists... Done
Building dependency tree
Reading state information... Done
Package gcc-4.9-arm-linux-gnueabihf is not available,
but is referred to by another package.
This may mean that the package is missing, has been
obsoleted, or
is only available from another source

E: Package 'gcc-4.9-arm-linux-gnueabihf' has no
installation candidate
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta#
sudo apt-get install gcc-arm-linux-gnueabihf    Reading
package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are
no longer required:
  libncursesw5 libtinfo5
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  binutils-arm-linux-gnueabihf cpp-8-arm-linux-gnueabihf
  cpp-arm-linux-gnueabihf gcc-8-arm-linux-gnueabihf
  gcc-8-arm-linux-gnueabihf-base gcc-8-cross-base
  libasan5-armhf-cross libatomic1-armhf-cross
  libc6-armhf-cross libc6-dev-armhf-cross
  libgcc-8-dev-armhf-cross libgcc1-armhf-cross
  libgomp1-armhf-cross libstdc++6-armhf-cross
  libubsan1-armhf-cross linux-libc-dev-armhf-cross
Suggested packages:
  binutils-doc gcc-8-locales cpp-doc
  gcc-8-multilib-arm-linux-gnueabihf gcc-8-doc
  libgcc1-dbg-armhf-cross
  libgomp1-dbg-armhf-cross libitm1-dbg-armhf-cross
  libatomic1-dbg-armhf-cross libasan5-dbg-armhf-cross
  liblsan0-dbg-armhf-cross libtsan0-dbg-armhf-cross
  libubsan1-dbg-armhf-cross libmpx2-dbg-armhf-cross
```

```
  libquadmath0-dbg-armhf-cross autoconf automake
  libtool flex bison gdb-arm-linux-gnueabihf gcc-doc
The following NEW packages will be installed:
  binutils-arm-linux-gnueabihf cpp-8-arm-linux-gnueabihf
  cpp-arm-linux-gnueabihf gcc-8-arm-linux-gnueabihf
  gcc-8-arm-linux-gnueabihf-base gcc-8-cross-base
  gcc-arm-linux-gnueabihf libasan5-armhf-cross
  libatomic1-armhf-cross libc6-armhf-cross
  libc6-dev-armhf-cross libgcc-8-dev-armhf-cross
  libgcc1-armhf-cross libgomp1-armhf-cross
  libstdc++6-armhf-cross libubsan1-armhf-cross
  linux-libc-dev-armhf-cross
0 upgraded, 17 newly installed, 0 to remove and 10 not
upgraded.
Need to get 22.3 MB of archives.
After this operation, 72.8 MB of additional disk space
will be used.
Do you want to continue? [Y/n] y
Get:1 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 gcc-8-arm-linux-gnueabihf-base
amd64 8.3.0-6ubuntu1~18.10.1cross1 [19.0 kB]
Get:2 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 cpp-8-arm-linux-gnueabihf
amd64 8.3.0-6ubuntu1~18.10.1cross1 [6,634 kB]
Get:3 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 cpp-arm-linux-gnueabihf
amd64 4:8.3.0-1ubuntu1.2 [3,520 B]
Get:4 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 binutils-arm-linux-gnueabihf
amd64 2.31.1-6ubuntu1.2 [2,799 kB]
Get:5 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 gcc-8-cross-base all
8.3.0-6ubuntu1~18.10.1cross1 [13.7 kB]
Get:6 http://us.archive.ubuntu.com/ubuntu
cosmic/main amd64 libc6-armhf-cross all
2.28-0ubuntu1cross1 [967 kB]
Get:7 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 libgcc1-armhf-cross all
1:8.3.0-6ubuntu1~18.10.1cross1 [37.2 kB]
Get:8 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 libgomp1-armhf-cross all
8.3.0-6ubuntu1~18.10.1cross1 [65.1 kB]
Get:9 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 libatomic1-armhf-cross all
```

```
8.3.0-6ubuntu1~18.10.1cross1 [6,896 B]
Get:10 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 libasan5-armhf-cross all
8.3.0-6ubuntu1~18.10.1cross1 [341 kB]
Get:11 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 libstdc++6-armhf-cross all
8.3.0-6ubuntu1~18.10.1cross1 [312 kB]
Get:12 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 libubsan1-armhf-cross all
8.3.0-6ubuntu1~18.10.1cross1 [107 kB]
Get:13 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 libgcc-8-dev-armhf-cross all
8.3.0-6ubuntu1~18.10.1cross1 [631 kB]
Get:14 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 gcc-8-arm-linux-gnueabihf amd64
8.3.0-6ubuntu1~18.10.1cross1 [7,395 kB]
Get:15 http://us.archive.ubuntu.com/ubuntu
cosmic-updates/main amd64 gcc-arm-linux-gnueabihf amd64
4:8.3.0-1ubuntu1.2 [1,428 B]
Get:16 http://us.archive.ubuntu.com/ubuntu cosmic/main amd64
linux-libc-dev-armhf-cross all 4.18.0-8.9cross1 [981 kB]
Get:17 http://us.archive.ubuntu.com/ubuntu cosmic/main amd64
libc6-dev-armhf-cross all 2.28-0ubuntu1cross1 [1,945 kB]
Fetched 22.3 MB in 6s (3,517 kB/s)
Selecting previously unselected package gcc-8-arm-linux-
gnueabihf-base:amd64.
(Reading database ... 245405 files and directories currently
installed.)
Preparing to unpack .../00-gcc-8-arm-linux-gnueabihf-
base_8.3.0-6ubuntu1~18.10.1cross1_amd64.deb ...
Unpacking gcc-8-arm-linux-gnueabihf-base:amd64 (8.3.0-6ubuntu1~
18.10.1cross1) ...
Selecting previously unselected package cpp-8-arm-linux-gnueabihf.
Preparing to unpack .../01-cpp-8-arm-linux-gnueabihf_8.3.0-6ubuntu1~
18.10.1cross1_amd64.deb ...
Unpacking cpp-8-arm-linux-gnueabihf (8.3.0-6ubuntu1~18.10.1cross1) ...
Selecting previously unselected package cpp-arm-linux-gnueabihf.
Preparing to unpack .../02-cpp-arm-linux-gnueabihf_4%3a8.3.0-
1ubuntu1.2_amd64.deb ...
Unpacking cpp-arm-linux-gnueabihf (4:8.3.0-1ubuntu1.2) ...
Selecting previously unselected package binutils-arm-linux-gnueabihf.
Preparing to unpack .../03-binutils-arm-linux-gnueabihf_2.31.1-
6ubuntu1.2_amd64.deb ...
Unpacking binutils-arm-linux-gnueabihf (2.31.1-6ubuntu1.2) ...
```

```
Selecting previously unselected package gcc-8-cross-base.
Preparing to unpack .../04-gcc-8-cross-base_8.3.0-6ubuntu1~
18.10.1cross1_all.deb ...
Unpacking gcc-8-cross-base (8.3.0-6ubuntu1~18.10.1cross1) ...
Selecting previously unselected package libc6-armhf-cross.
Preparing to unpack .../05-libc6-armhf-cross_2.28-
0ubuntu1cross1_all.deb ...
Unpacking libc6-armhf-cross (2.28-0ubuntu1cross1) ...
Selecting previously unselected package libgcc1-armhf-cross.
Preparing to unpack .../06-libgcc1-armhf-cross_1%3a8.3.0-6ubuntu1~
18.10.1cross1_all.deb ...
Unpacking libgcc1-armhf-cross (1:8.3.0-6ubuntu1~18.10.1cross1) ...
Selecting previously unselected package libgomp1-armhf-cross.
Preparing to unpack .../07-libgomp1-armhf-cross_8.3.0-6ubuntu1~
18.10.1cross1_all.deb ...
Unpacking libgomp1-armhf-cross (8.3.0-6ubuntu1~18.10.1cross1) ...
Selecting previously unselected package libatomic1-armhf-cross.
Preparing to unpack .../08-libatomic1-armhf-cross_8.3.0-6ubuntu1~
18.10.1cross1_all.deb ...
Unpacking libatomic1-armhf-cross (8.3.0-6ubuntu1~18.10.1cross1) ...
Selecting previously unselected package libasan5-armhf-cross.
Preparing to unpack .../09-libasan5-armhf-cross_8.3.0-6ubuntu1~
18.10.1cross1_all.deb ...
Unpacking libasan5-armhf-cross (8.3.0-6ubuntu1~18.10.1cross1) ...
Selecting previously unselected package libstdc++6-armhf-cross.
Preparing to unpack .../10-libstdc++6-armhf-cross_8.3.0-6ubuntu1~
18.10.1cross1_all.deb ...
Unpacking libstdc++6-armhf-cross (8.3.0-6ubuntu1~18.10.1cross1) ...
Selecting previously unselected package libubsan1-armhf-cross.
Preparing to unpack .../11-libubsan1-armhf-cross_8.3.0-6ubuntu1~
18.10.1cross1_all.deb ...
Unpacking libubsan1-armhf-cross (8.3.0-6ubuntu1~18.10.1cross1) ...
Selecting previously unselected package libgcc-8-dev-armhf-cross.
Preparing to unpack .../12-libgcc-8-dev-armhf-cross_8.3.0-6ubuntu1~
18.10.1cross1_all.deb ...
Unpacking libgcc-8-dev-armhf-cross (8.3.0-6ubuntu1~18.10.1cross1) ...
Selecting previously unselected package gcc-8-arm-linux-gnueabihf.
Preparing to unpack .../13-gcc-8-arm-linux-gnueabihf_8.3.0-6ubuntu1~
18.10.1cross1_amd64.deb ...
Unpacking gcc-8-arm-linux-gnueabihf (8.3.0-6ubuntu1~18.10.1cross1) ...
Selecting previously unselected package gcc-arm-linux-gnueabihf.
Preparing to unpack .../14-gcc-arm-linux-gnueabihf_4%3a8.3.0-
1ubuntu1.2_amd64.deb ...
Unpacking gcc-arm-linux-gnueabihf (4:8.3.0-1ubuntu1.2) ...
```

```
Selecting previously unselected package linux-libc-dev-armhf-cross.
Preparing to unpack .../15-linux-libc-dev-armhf-cross_4.18.0-
8.9cross1_all.deb ...
Unpacking linux-libc-dev-armhf-cross (4.18.0-8.9cross1) ...
Selecting previously unselected package libc6-dev-armhf-cross.
Preparing to unpack .../16-libc6-dev-armhf-cross_2.28-
0ubuntu1cross1_all.deb ...
Unpacking libc6-dev-armhf-cross (2.28-0ubuntu1cross1) ...
Setting up gcc-8-cross-base (8.3.0-6ubuntu1~18.10.1cross1) ...
Setting up libc6-armhf-cross (2.28-0ubuntu1cross1) ...
Setting up libgcc1-armhf-cross (1:8.3.0-6ubuntu1~18.10.1cross1) ...
Setting up libstdc++6-armhf-cross (8.3.0-6ubuntu1~18.10.1cross1) ...
Setting up libubsan1-armhf-cross (8.3.0-6ubuntu1~18.10.1cross1) ...
Setting up binutils-arm-linux-gnueabihf (2.31.1-6ubuntu1.2) ...
Setting up libgomp1-armhf-cross (8.3.0-6ubuntu1~18.10.1cross1) ...
Setting up linux-libc-dev-armhf-cross (4.18.0-8.9cross1) ...
Setting up libatomic1-armhf-cross (8.3.0-6ubuntu1~18.10.1cross1) ...
Processing triggers for libc-bin (2.28-0ubuntu1) ...
Processing triggers for man-db (2.8.4-2) ...
Setting up gcc-8-arm-linux-gnueabihf-base:amd64 (8.3.0-6ubuntu1~
18.10.1cross1) ...
Setting up libasan5-armhf-cross (8.3.0-6ubuntu1~18.10.1cross1) ...
Setting up libgcc-8-dev-armhf-cross (8.3.0-6ubuntu1~18.10.1cross1) ...
Setting up libc6-dev-armhf-cross (2.28-0ubuntu1cross1) ...
Setting up cpp-8-arm-linux-gnueabihf (8.3.0-6ubuntu1~18.10.1cross1) ...
Setting up cpp-arm-linux-gnueabihf (4:8.3.0-1ubuntu1.2) ...
Setting up gcc-8-arm-linux-gnueabihf (8.3.0-6ubuntu1~18.10.1cross1) ...
Setting up gcc-arm-linux-gnueabihf (4:8.3.0-1ubuntu1.2) ...
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta#
sudo apt-get install libc6-dev:armhf
Reading package lists... Done
Building dependency tree
Reading state information... Done
E: Unable to locate package libc6-dev:armhf
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta#
sudo apt-get install libgcc-4.9-dev:armhf
Reading package lists... Done
Building dependency tree
Reading state information... Done
E: Unable to locate package libgcc-4.9-dev:armhf
E: Couldn't find any package by glob 'libgcc-4.9-dev'
E: Couldn't find any package by regex 'libgcc-4.9-dev'
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta#
sudo apt-get install linux-libc-dev:i386
```

```
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  libncursesw5 libtinfo5
Use 'sudo apt autoremove' to remove them.
The following NEW packages will be installed:
  linux-libc-dev:i386
0 upgraded, 1 newly installed, 0 to remove and 10 not upgraded.
Need to get 1,009 kB of archives.
After this operation, 5,377 kB of additional disk space will be used.
Get:1 http://us.archive.ubuntu.com/ubuntu cosmic-updates/main i386
linux-libc-dev i386 4.18.0-25.26 [1,009 kB]
Fetched 1,009 kB in 1s (1,083 kB/s)
Selecting previously unselected package linux-libc-dev:i386.
(Reading database ... 247258 files and directories currently installed.)
Preparing to unpack .../linux-libc-dev_4.18.0-25.26_i386.deb ...
Unpacking linux-libc-dev:i386 (4.18.0-25.26) ...
Setting up linux-libc-dev:i386 (4.18.0-25.26) ...
```

I have found success in installing `gcc-arm-linux-gnueabihf` and `linux-libc-dev:i386`, but I am blocked when trying to install `gcc-4.9-arm-linux-gnueabihf`, `libc6-dev:armhf`, and `libgcc-4.9-dev:armhf`. Multiple attempts are not enough to install these packages so that this step is complete. Due to time limitation, I try to press forward and run the other commands to follow.

```
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta# opam init
[WARNING] Running as root is not recommended

<><> Required setup - please read <><><><><><><><><><><><><><><><><><><><><><>

  In normal operation, opam only alters files within ~/.opam.

  However, to best integrate with your system, some environment variables
  should be set. If you allow it to, this initialisation step will update
  your bash configuration by adding the following line to ~/.profile:

    test -r /root/.opam/opam-init/init.sh && . /root/.opam/opam-init/init.sh >
    /dev/null 2> /dev/null || true

  Otherwise, every time you want to access your opam installation, you will
  need to run:

    eval $(opam env)
```

```
  You can always re-run this setup with 'opam init' later.

Do you want opam to modify ~/.profile? [N/y/f]
(default is 'no', use 'f' to choose a different file) y
A hook can be added to opam's init scripts to ensure that the shell remains
in sync with the opam
environment when they are loaded. Set that up? [y/N] y

User configuration:
  ~/.profile is already up-to-date.
[NOTE] Make sure that ~/.profile is well sourced in your ~/.bashrc.

root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta# opam switch 4.02.1
[WARNING] Running as root is not recommended
[ERROR] No switch 4.02.1 is currently installed. Did you mean 'opam switch
create 4.02.1'?
        Installed switches are:
          - 4.04.0
          - default

root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta# opam switch
create 4.02.1
[WARNING] Running as root is not recommended

<><> Gathering sources ><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
[ocaml-base-compiler.4.02.1] downloaded from cache at
https://opam.ocaml.org/cache

<><> Processing actions <><><><><><><><><><><><><><><><><><><><><><><><><><><><>
* installed base-bigarray.base
* installed base-threads.base
* installed base-unix.base
* installed ocaml-base-compiler.4.02.1
* installed ocaml-config.1
* installed ocaml.4.02.1
* installed base-ocamlbuild.base
Done.
# Run eval $(opam env) to update the current shell environment
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta# eval
$(opam env)
[WARNING] Running as root is not recommended
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta# opam
install ocaml-src
```

```
[WARNING] Running as root is not recommended
The following actions will be performed:
  * install ocaml-src 4.02.1

<><> Gathering sources ><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
[ocaml-src.4.02.1] found in cache

<><> Processing actions <><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
* installed ocaml-src.4.02.1
Done.
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta# git clone
https://github.com/whirm/ocaml-arm
Cloning into 'ocaml-arm'...
remote: Enumerating objects: 183, done.
remote: Total 183 (delta 0), reused 0 (delta 0), pack-reused 183
Receiving objects: 100% (183/183), 29.74 KiB | 692.00 KiB/s, done.
Resolving deltas: 100% (84/84), done.
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta# cd ocaml-arm
root@hanen:/home/hanen/Desktop/google-drive-ocamlfuse-beta/ocaml-arm# make
[WARNING] Running as root is not recommended
cp -a /root/.opam/4.02.1/lib/ocaml-src ocaml-src
touch stamp-copy
cd ocaml-src && \
./configure -prefix /root/.opam/4.02.1/arm-linux-gnueabihf \
        -bindir /root/.opam/4.02.1/bin/arm-linux-gnueabihf \
        -mandir /home/hanen/Desktop/google-drive-ocamlfuse-
        beta/ocaml-arm/no-man \
        -cc "gcc -m32" -as "gcc -m32 -c" -aspp "gcc -m32 -c" \
        -no-pthread
Configuring for host x86_64-unknown-linux-gnu ...
Configuring for target x86_64-unknown-linux-gnu ...
Using compiler gcc -m32.
[ERROR!]Unable to compile the test program.
 Make sure the C compiler gcc -m32 -O  is properly installed.
make: *** [Makefile:132: stamp-configure] Error 2
```

The process seemed to be moving along well for the first few commands. However, I again ran into errors when trying to execute `make`. I am not certain if my compiler is setup incorrectly or if previous failing steps may have led to this failure. At this point, I must declare defeat with regards to cross compiling OCamlFUSE in order to execute the application on an Android device.

CHAPTER 5

Demo of the Cloud Storage Mounts

In this chapter, I will demonstrate mounting directories from various cloud storage providers using the tool RClone. Since I was unsuccessful in implementing OCaml-FUSE, demonstrations using OCamlFUSE will not be included in this chapter.

5.1 Google Drive

The Google Drive implementation is what I started with in lab reports. Please refer to B.2.2 for the Google Drive demo using RClone.

5.2 Dropbox

Next, I move on to Dropbox to demonstrate that RClone has implemented mounting for directories and files stored in the Dropbox cloud storage provider. The following is the terminal output.

```
$ rclone config
Current remotes:

Name                 Type
====                 ====
remote               drive

e) Edit existing remote
n) New remote
d) Delete remote
r) Rename remote
c) Copy remote
s) Set configuration password
```

```
q) Quit config
e/n/d/r/c/s/q> n
name> dpremote
Type of storage to configure.
Enter a string value. Press Enter for the default ("").
Choose a number from below, or type in your own value
1 / A stackable unification remote, which can appear to merge the
contents of several remotes
   \ "union"
2 / Alias for an existing remote
   \ "alias"
3 / Amazon Drive
   \ "amazon cloud drive"
4 / Amazon S3 Compliant Storage Provider (AWS, Alibaba, Ceph,
Digital Ocean, Dreamhost, IBM COS, Minio, etc)
   \ "s3"
5 / Backblaze B2
   \ "b2"
6 / Box
   \ "box"
7 / Cache a remote
   \ "cache"
8 / Dropbox
   \ "dropbox"
9 / Encrypt/Decrypt a remote
   \ "crypt"
10 / FTP Connection
   \ "ftp"
11 / Google Cloud Storage (this is not Google Drive)
   \ "google cloud storage"
12 / Google Drive
   \ "drive"
13 / Hubic
   \ "hubic"
14 / JottaCloud
   \ "jottacloud"
15 / Koofr
   \ "koofr"
16 / Local Disk
   \ "local"
17 / Mega
   \ "mega"
18 / Microsoft Azure Blob Storage
   \ "azureblob"
```

```
19 / Microsoft OneDrive
   \ "onedrive"
20 / OpenDrive
   \ "opendrive"
21 / Openstack Swift (Rackspace Cloud Files, Memset Memstore, OVH)
   \ "swift"
22 / Pcloud
   \ "pcloud"
23 / QingCloud Object Storage
   \ "qingstor"
24 / SSH/SFTP Connection
   \ "sftp"
25 / Webdav
   \ "webdav"
26 / Yandex Disk
   \ "yandex"
27 / http Connection
   \ "http"
Storage> dropbox
** See help for dropbox backend at: https://rclone.org/dropbox/ **

Dropbox App Client Id
Leave blank normally.
Enter a string value. Press Enter for the default ("").
client_id>
Dropbox App Client Secret
Leave blank normally.
Enter a string value. Press Enter for the default ("").
client_secret>
Edit advanced config? (y/n)
y) Yes
n) No
y/n> y
Upload chunk size. (< 150M).

Any files larger than this will be uploaded in chunks of this size.

Note that chunks are buffered in memory (one at a time) so rclone can
deal with retries.  Setting this larger will increase the speed
slightly (at most 10% for 128MB in tests) at the cost of using more
memory.  It can be set smaller if you are tight on memory.
Enter a size with suffix k,M,G,T. Press Enter for the default ("48M").
chunk_size>
Impersonate this user when using a business account.
```

```
Enter a string value. Press Enter for the default ("").
impersonate>
Remote config
Use auto config?
* Say Y if not sure
* Say N if you are working on a remote or headless machine
y) Yes
n) No
y/n> y
If your browser doesn't open automatically go to the following link:
http://127.0.0.1:53682/auth
Log in and authorize rclone for access
Waiting for code...
Got code
--------------------
[dpremote]
type = dropbox
token = {"access_token":"yeGRic_xxxx-M-xxxx-T","token_type":"bearer",
"expiry":"0001-01-01T00:00:00Z"}
--------------------
y) Yes this is OK
e) Edit this remote
d) Delete this remote
y/e/d> y
```

Refer to Figure 5.1, Figure 5.2, and Figure 5.3 for visualization of what occurs when the browser appears when user runs the commands above.

5.3 Microsoft OneDrive

Next, I move on to Microsoft OneDrive to demonstrate that RClone has implemented mounting for directories and files stored in the OneDrive cloud storage provider. The following is the terminal output.

```
$ rclone config
Current remotes:

Name                 Type
====                 ====
dpremote             dropbox
remote               drive

e) Edit existing remote
```

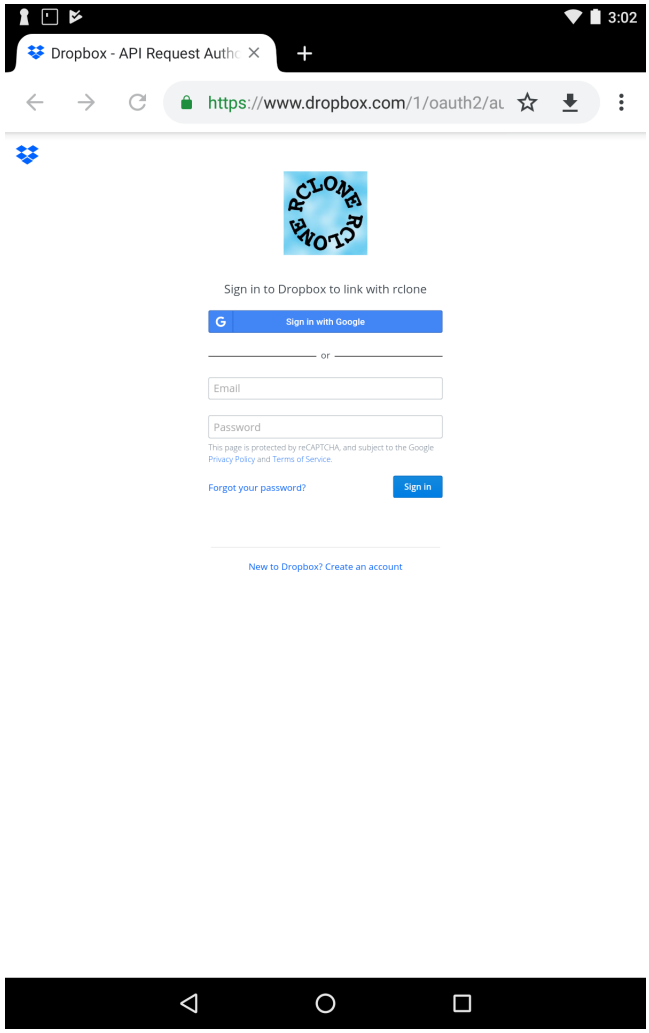

Figure 5.1: Browser appears prompting for Dropbox credentials.

```
n) New remote
d) Delete remote
r) Rename remote
c) Copy remote
s) Set configuration password
q) Quit config
e/n/d/r/c/s/q> n
name> onedremote
```

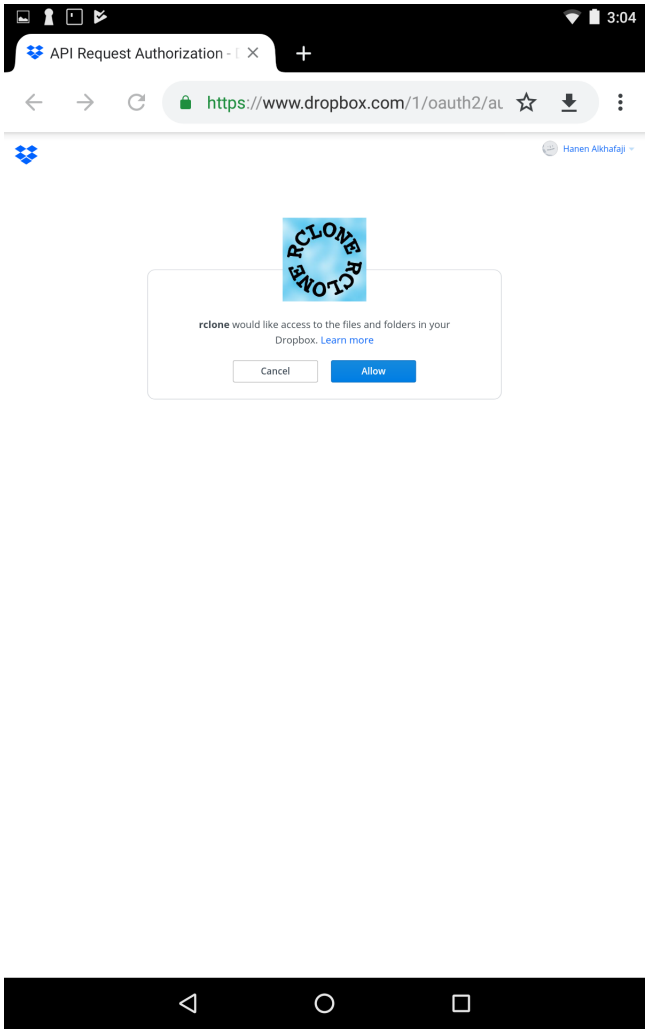

Figure 5.2: RClone requests permission to access Dropbox content.

```
Type of storage to configure.
Enter a string value. Press Enter for the default ("").
Choose a number from below, or type in your own value
1 / A stackable unification remote, which can appear to merge the
contents of several remotes
   \ "union"
2 / Alias for an existing remote
   \ "alias"
```

Figure 5.3: RClone is successfully connected to Dropbox.

```
3 / Amazon Drive
   \ "amazon cloud drive"
4 / Amazon S3 Compliant Storage Provider (AWS, Alibaba, Ceph,
Digital Ocean, Dreamhost, IBM COS, Minio, etc)
   \ "s3"
5 / Backblaze B2
   \ "b2"
6 / Box
```

```
   \ "box"
7 / Cache a remote
   \ "cache"
8 / Dropbox
   \ "dropbox"
9 / Encrypt/Decrypt a remote
   \ "crypt"
10 / FTP Connection
   \ "ftp"
11 / Google Cloud Storage (this is not Google Drive)
   \ "google cloud storage"
12 / Google Drive
   \ "drive"
13 / Hubic
   \ "hubic"
14 / JottaCloud
   \ "jottacloud"
15 / Koofr
   \ "koofr"
16 / Local Disk
   \ "local"
17 / Mega
   \ "mega"
18 / Microsoft Azure Blob Storage
   \ "azureblob"
19 / Microsoft OneDrive
   \ "onedrive"
20 / OpenDrive
   \ "opendrive"
21 / Openstack Swift (Rackspace Cloud Files, Memset Memstore, OVH)
   \ "swift"
22 / Pcloud
   \ "pcloud"
23 / QingCloud Object Storage
   \ "qingstor"
24 / SSH/SFTP Connection
   \ "sftp"
25 / Webdav
   \ "webdav"
26 / Yandex Disk
   \ "yandex"
27 / http Connection
   \ "http"
Storage> onedrive
```

```
** See help for onedrive backend at: https://rclone.org/onedrive/ **

Microsoft App Client Id
Leave blank normally.
Enter a string value. Press Enter for the default ("").
client_id>
Microsoft App Client Secret
Leave blank normally.
Enter a string value. Press Enter for the default ("").
client_secret>
Edit advanced config? (y/n)
y) Yes
n) No
y/n> y
Chunk size to upload files with - must be multiple of 320k.

Above this size files will be chunked - must be multiple of 320k. Note
that the chunks will be buffered into memory.
Enter a size with suffix k,M,G,T. Press Enter for the default ("10M").
chunk_size>
The ID of the drive to use
Enter a string value. Press Enter for the default ("").
drive_id>
The type of the drive ( personal | business | documentLibrary )
Enter a string value. Press Enter for the default ("").
drive_type>
Set to make OneNote files show up in directory listings.

By default rclone will hide OneNote files in directory listings because
operations like "Open" and "Update" won't work on them.  But this
behaviour may also prevent you from deleting them.  If you want to
delete OneNote files or otherwise want them to show up in directory
listing, set this option.
Enter a boolean value (true or false). Press Enter for the default
("false").
expose_onenote_files>
Remote config
Use auto config?
* Say Y if not sure
* Say N if you are working on a remote or headless machine
y) Yes
n) No
y/n> y
If your browser doesn't open automatically go to the following link:
```

```
http://127.0.0.1:53682/auth
Log in and authorize rclone for access
Waiting for code...
Got code
Choose a number from below, or type in an existing value
1 / OneDrive Personal or Business
   \ "onedrive"
2 / Root Sharepoint site
   \ "sharepoint"
3 / Type in driveID
   \ "driveid"
4 / Type in SiteID
   \ "siteid"
5 / Search a Sharepoint site
   \ "search"
Your choice> onedrive
Found 1 drives, please select the one you want to use:
0: OneDrive (business) id=b!AmMSbuU0XECVJSfFj3kIDHna4T8RxlZDhahlLNJ3
l55RInJ4tOvLToGs8g0fShDA
Chose drive to use:> 0
Found drive 'root' of type 'business', URL: https://raidermailwright-
my.sharepoint.com/personal/
alkhafaji_2_wright_edu/Documents
Is that okay?
y) Yes
n) No
y/n> y
--------------------
[onedremote]
type = onedrive
token = {"access_token":"xxxxxxxxxxxxxxxxxxxxx-_xx-xxxxxxxxxxxxxxxxx
-49n9Z6wpz-MQlU7XztJKgeWzo_-xxxxxxxxxx","token_type":"Bearer",
"refresh_token":"OAQABAAAAAAAxxxxx-xxxxxx-SyE93jJKbUL7nz-xxxxxx-
yKw4be8aK4g-xxxxxxxxxxxxxxxxx","expiry":
"2019-08-05T20:11:01.044813516Z"}
drive_id = b!AmMSbuU0XECVJSfFj3kIDHna4T8RxlZDhahlLNJ3l55RInJ4tOvL
ToGs8g0fShDA
drive_type = business
--------------------
y) Yes this is OK
e) Edit this remote
d) Delete this remote
y/e/d> y
```

Refer to Figure 5.4, Figure 5.5, and Figure 5.6 for visualization of what occurs when the browser appears when user runs the commands above.

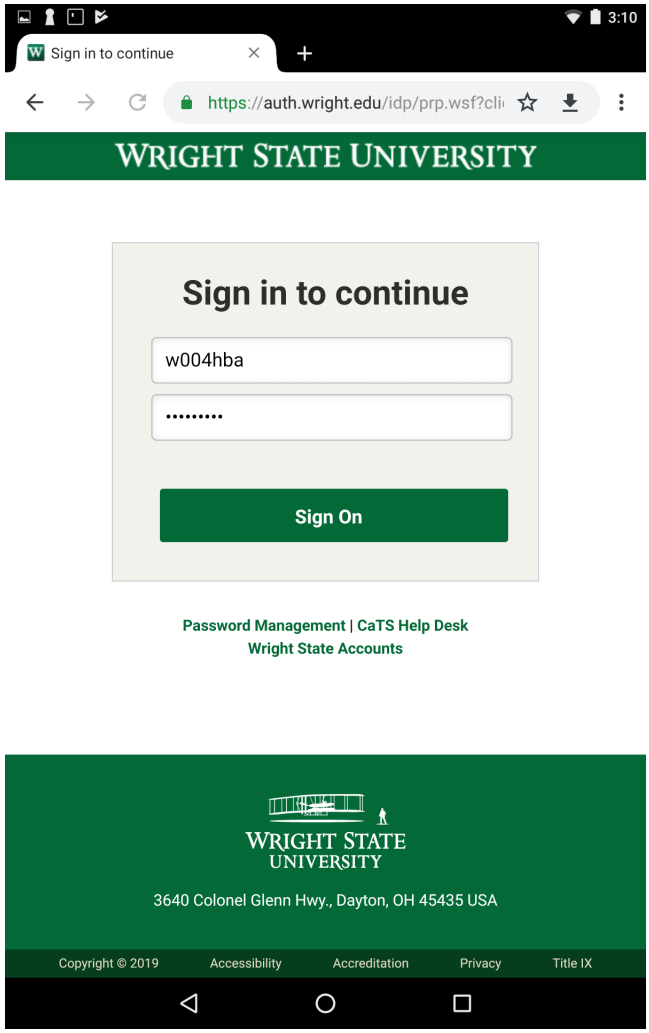

Figure 5.4: Browser appears prompting for OneDrive credentials.

5.4 pCloud

Next, I move on to pCloud to demonstrate that RClone has implemented mounting for directories and files stored in the pCloud storage provider. The following is the

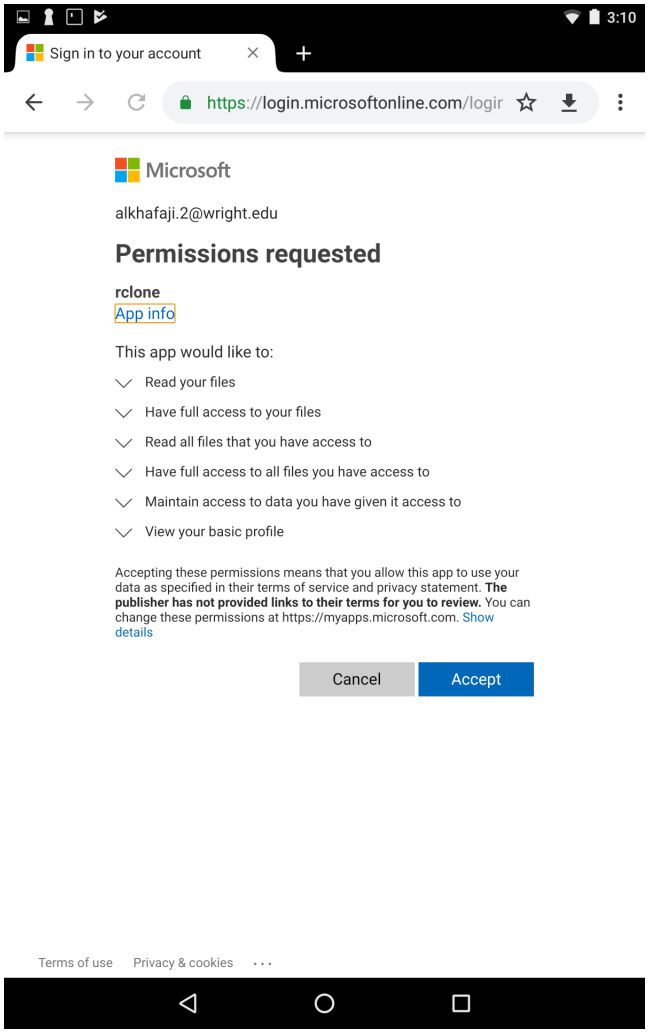

Figure 5.5: RClone requests permission to access OneDrive content.

terminal output.

```
$ rclone config
Current remotes:

Name                 Type
====                 ====
```

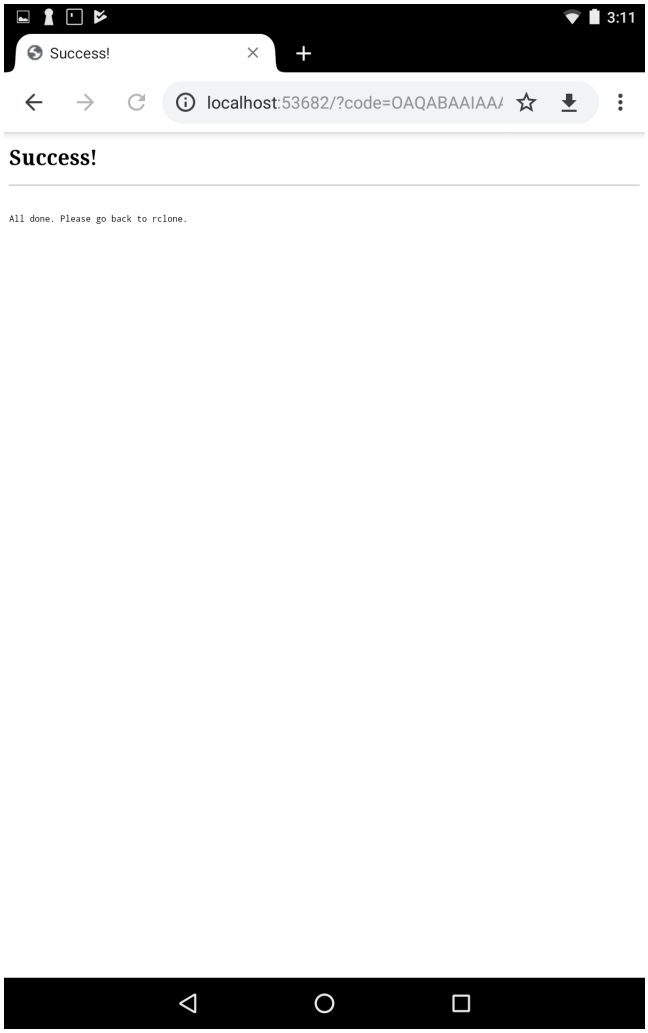

Figure 5.6: RClone is successfully connected to OneDrive.

```
dpremote             dropbox
onedremote           onedrive
remote               drive

e) Edit existing remote
n) New remote
d) Delete remote
r) Rename remote
```

```
c) Copy remote
s) Set configuration password
q) Quit config
e/n/d/r/c/s/q> n
name> pcloudremote
Type of storage to configure.
Enter a string value. Press Enter for the default ("").
Choose a number from below, or type in your own value
1 / A stackable unification remote, which can appear to merge the
contents of several remotes
   \ "union"
2 / Alias for an existing remote
   \ "alias"
3 / Amazon Drive
   \ "amazon cloud drive"
4 / Amazon S3 Compliant Storage Provider (AWS, Alibaba, Ceph,
Digital Ocean, Dreamhost, IBM COS, Minio, etc)
   \ "s3"
5 / Backblaze B2
   \ "b2"
6 / Box
   \ "box"
7 / Cache a remote
   \ "cache"
8 / Dropbox
   \ "dropbox"
9 / Encrypt/Decrypt a remote
   \ "crypt"
10 / FTP Connection
   \ "ftp"
11 / Google Cloud Storage (this is not Google Drive)
   \ "google cloud storage"
12 / Google Drive
   \ "drive"
13 / Hubic
   \ "hubic"
14 / JottaCloud
   \ "jottacloud"
15 / Koofr
   \ "koofr"
16 / Local Disk
   \ "local"
17 / Mega
   \ "mega"
```

```
18 / Microsoft Azure Blob Storage
   \ "azureblob"
19 / Microsoft OneDrive
   \ "onedrive"
20 / OpenDrive
   \ "opendrive"
21 / Openstack Swift (Rackspace Cloud Files, Memset Memstore, OVH)
   \ "swift"
22 / Pcloud
   \ "pcloud"
23 / QingCloud Object Storage
   \ "qingstor"
24 / SSH/SFTP Connection
   \ "sftp"
25 / Webdav
   \ "webdav"
26 / Yandex Disk
   \ "yandex"
27 / http Connection
   \ "http"
Storage> pcloud
** See help for pcloud backend at: https://rclone.org/pcloud/ **

Pcloud App Client Id
Leave blank normally.
Enter a string value. Press Enter for the default ("").
client_id>
Pcloud App Client Secret
Leave blank normally.
Enter a string value. Press Enter for the default ("").
client_secret>
Remote config
Use auto config?
* Say Y if not sure
* Say N if you are working on a remote or headless machine
y) Yes
n) No
y/n> y
If your browser doesn't open automatically go to the following link:
http://127.0.0.1:53682/auth
Log in and authorize rclone for access
Waiting for code...
Got code
--------------------
```

```
[pcloudremote]
type = pcloud
token = {"access_token":"Jc0rZDnONSzyJXpmZOIo7N7Zgm5qYeGg5qHLaLt
TCoV9pjdXsQHy","token_type":"bearer","expiry":
"0001-01-01T00:00:00Z"}
--------------------
y) Yes this is OK
e) Edit this remote
d) Delete this remote
y/e/d> y
```

Refer to Figure 5.7, Figure 5.8, and Figure 5.9 for visualization of what occurs when the browser appears when user runs the commands above.

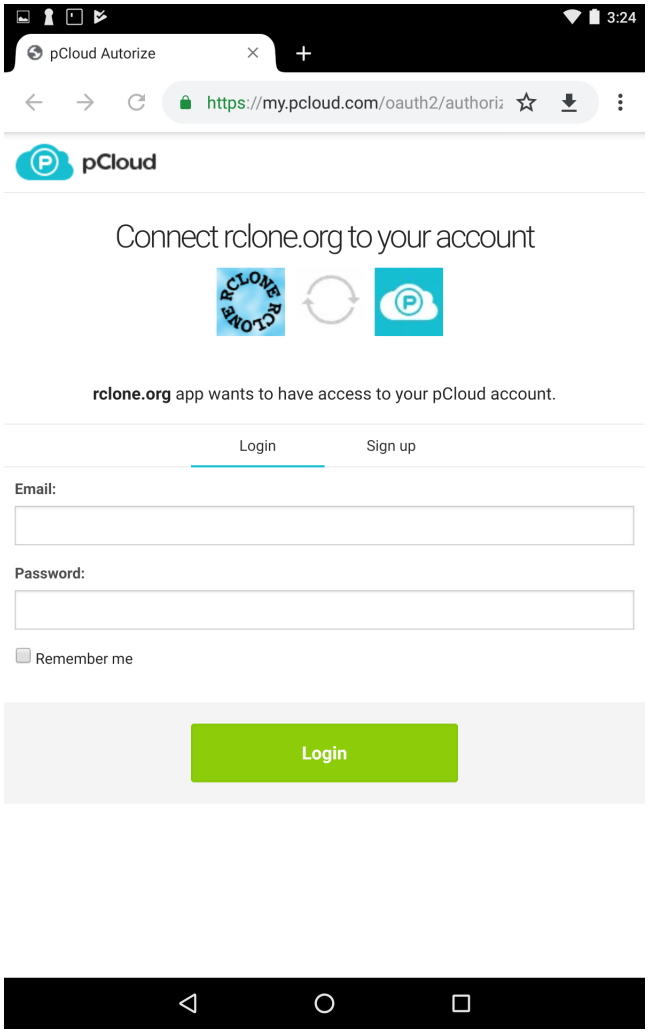

Figure 5.7: Browser appears prompting for pCloud credentials.

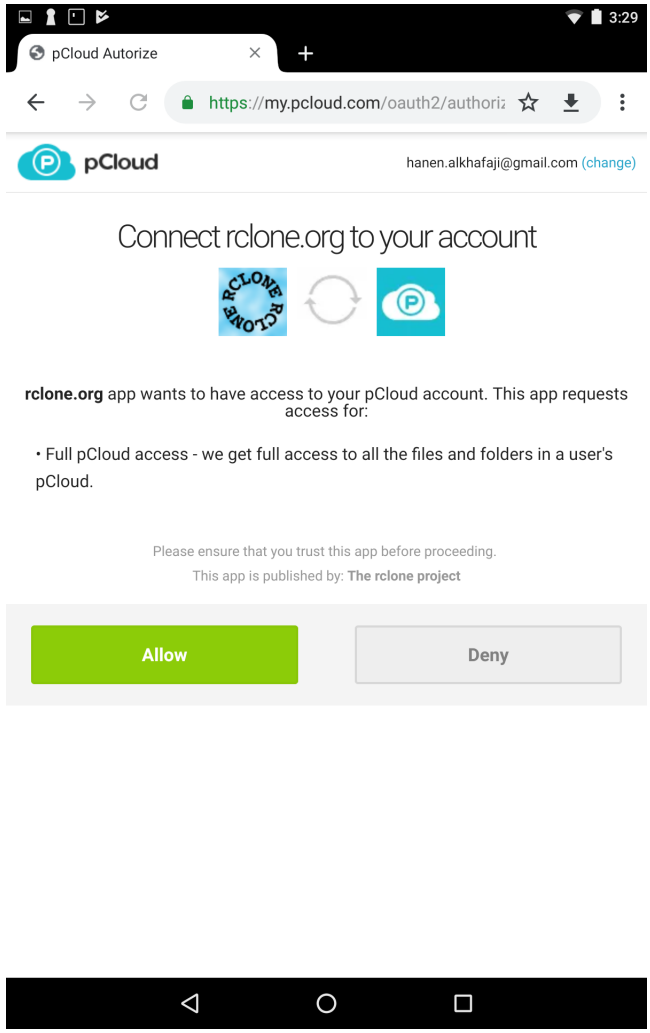

Figure 5.8: RClone requests permission to access pCloud content.

Figure 5.9: RClone is successfully connected to pCloud.

CHAPTER 6

Concluding Remarks and Future Work

6.1 Concluding Remarks

When asked if OCamlFUSE could be built for Android, developer Alessandro Strada responded in 2016 that the libraries he uses in his solution do not support static linking which makes building for Android not possible.[Strb] Unfortunately, I reached the same conclusion. The last attempt was to use an OCaml cross compiler utilizing OPam.[Whi] A cross compiler compiles code that is compatible with an operating system that is not the operating system on which the compiler is being executed. This proved to be difficult for me to achieve due to my lack of knowledge and experience with OPam.

Even though the end goal was not accomplished with OCamlFUSE, I was able to switch gears and use RClone to accomplish the task at hand. RClone allows mounting remote directories from multiple cloud storage providers including Google Drive, Dropbox, Microsoft OneDrive, and pCloud.

I used Linux extensively in this course, which was very beneficial for me since most of my professional work is performed using the Windows operating system. It is very important to me that I do not silo myself into using any one particular environment. I was also exposed to a new programming language, OCaml, in order to better understand the inner workings of the OCamlFUSE implementation. There were other options available which used familiar languages, but I truly wanted to put myself in a position of learning while working on the project for this course. I did not want to settle for something familiar, because that would not allow me to add another skill to my tool-set.

FUSE was another great interface to learn about. Dr. Mateti recommended it and it certainly made sense to focus on FUSE since Android uses this interface for its file system management. I made lots of decisions for this project solely based on the premise of learning something new. Although I did not complete certain lab reports for this project, I still felt it was beneficial that Dr. Mateti recommended I attempt

lab reports about ODrive, X-Plore, ES File Explorer, and SSHFS. These are all topics I briefly looked into, but did not have time to complete a full lab report. Now, I can recognize these words and understand that they are connected to file systems, Android devices, and mounting. This alone is more than I knew before taking this course. I am also much more familiar with the purpose of an OTG cable and how to effectively mount a USB. I now have a pretty solid understanding of InSync and RClone as a result of performing the tasks necessary to put together lab reports for each of those items.

6.2 Future Work

As mentioned before, certain tasks planned for this semester were not completed within the allotted time. These will be postponed for future semesters in order to achieve the completion of this project by the deadline. Given more time, these are the items that would have been completed:

1. Continued Efforts into OCamlFUSE Execution on Android
2. ODrive Lab Report
3. X-Plore Lab Report
4. Write FileSystem with FUSE Lab Report
5. ES File Explorer Lab Report
6. Mounting using SSHFS Lab Report

APPENDIX A

OCaml Programming Language

A.0.1 OCaml Development Environment

1. OCaml development environment (https://github.com/janestreet/install-ocaml)

   a) Install opam
   `sudo add-apt-repository ppa:avsm/ppa`
   `sudo apt update`
   `sudo apt install -y opam m4` This was a success!

   b) Initialize opam
   `sudo opam init -y --compiler=4.07.1`
   `sudo opam update -uy`
   `sudo echo $(opam env)`
   This was a success!

   c) Install libraries and tools
   `sudo opam install -y async core js_of_ocaml js_of_ocaml-ppx merlin utop ocp-indent`
   This installed so many things and took a while, but was a success!

   d) Test Installation

```
hanen@hanen:~$ git clone
https://github.com/janestreet/install-ocaml
Cloning into 'install-ocaml'...
remote: Enumerating objects: 20, done.
remote: Counting objects: 100% (20/20), done.
remote: Compressing objects: 100% (14/14), done.
remote: Total 58 (delta 10), reused 14 (delta 6),
pack-reused 38
Unpacking objects: 100% (58/58), done.
hanen@hanen:~$ cd install-ocaml/01-hello-world
hanen@hanen:~/install-ocaml/01-hello-world$ dune build
```

```
hello_world.exe
hanen@hanen:~/install-ocaml/01-hello-world$ dune exec
./hello_world.exe
Hello, World
```

e) Run Tests

```
hanen@hanen:~/install-ocaml/01-hello-world$
cd ../02-expect-tests
hanen@hanen:~/install-ocaml/02-expect-tests$
dune runtest
Done: 17/19 (jobs: 1)File "expect_test_example.ml",
line 1, characters 0-0:
diff (internal) (exit 1)
(cd _build/default && /usr/bin/diff -u
expect_test_example.ml expect_test_example.ml.corrected)
--- expect_test_example.ml
2019-06-08 15:37:18.946700012
-0400
+++ expect_test_example.ml.corrected
2019-06-08 15:37:21.494597583
-0400
@@ -2,5 +2,5 @@

let%expect_test _ =
let () = printf "foo" in
-  [%expect {| bar |}]
  +  [%expect {| foo |}]
    ;;
```

The test failed because there is a difference in the actual results versus what was expected. The following commands will copy the results into what was expected and show that the tests will pass after that because there will no longer be a difference.

```
hanen@hanen:~/install-ocaml/02-expect-tests$ dune promote
Promoting _build/default/expect_test_example.ml.corrected to
expect_test_example.ml.
hanen@hanen:~/install-ocaml/02-expect-tests$ dune runtest
hanen@hanen:~/install-ocaml/02-expect-tests$ git diff
diff --git a/02-expect-tests/expect_test_example.ml b/
02-expect-tests/expect_test_example.ml
index 75a19d9..9bb1c70 100644
--- a/02-expect-tests/expect_test_example.ml
+++ b/02-expect-tests/expect_test_example.ml
@@ -2,5 +2,5 @@ open! Core
```

```
let%expect_test _ =
let () = printf "foo" in
-  [%expect {| bar |}]
  +  [%expect {| foo |}]
    ;;
```

f) Editor Setup: Installed Visual Studio Code.
Install a plugin for OCaml through Visual Studio Code by opening Visual Studio Code, pressing Ctrl+P, and entering `ext install hackwaly.ocaml` into the text field. Once enter is pressed, Visual Studio code will automatically install the OCaml plugin.

A.0.2 Online OCaml Lessons

A.0.2.1 Simple Expressions

A.0.2.2 Imperative Programming

A.0.2.3 Functions

A.0.2.4 Commentary

A.0.2.5 Lessons Followed

1. Lesson 1 - Simple Expressions
This covered computing numeric values, defining strings, working with arrays, string manipulation, and defining and operating on tuples. Tuples can be made up of different data types. There are some functions built-in for tuples that have two elements. The functions presented in the tutorial were `fst` for getting the first element and `snd` for getting the second.

2. Lesson 2 - Imperative Programming
`let` is the keyword used to set the results of some computation to a named variable. However, once a variable is set to a particular value using the `let` keyword, it cannot be modified to a different value. A compilation error results. The way to get around this constraint is to use the keyword `ref` on the right side of the `let` statement. That reference can then be modified. (`let x = ref 42;;`) `printf` is used similar to C to print formatted text to the terminal. Looping syntax is very similar to many other programming languages, except when looping through a series of numbers backwards the word `downto` is used as opposed to `to` in the ascending direction. For comparison of values, the output is a boolean of either `true` or `false`. These greater than, less than, equal, or not equal to comparisons are not limited to only numeric values. The equal and not equal comparison symbols are similar to VB where a single equal sign represents an equivalence comparison while a less than sign followed by a

greater than sign represents a non-equivalence comparison. The only limitation is that there is not support for comparing values of different types. However, functions like `string_of_int` can be used to convert an integer to a string so that it can be safely compared to another string. `if then else` logic is very straight forward. `while` loops logic is also easy to understand and uses a `while do done` structure.

3. Lesson 3 - Functions
   Functions can be defined in one line using the `let` keyword very similar to defining a variable, but it takes arguments. One argument can be provided or several arguments in a tuple. Calling these functions is exactly the same as all other programming languages. Multiple values can be returned from a function by returning a tuple. Defined functions can also be called in a partial manner. This almost seems like extension methods from the C# world. A function that takes two arguments can be called with only one argument. However, it takes into account the value present at the time in which its called and uses that as the second parameter.
   ```
   let mul x y = x * y
   let double = mul 2
   double 8
   ```
   Anonymous functions are lambda expressions. They are functions defined without a name. These are useful for generating inline functions to be passed as a parameter to another function. In this case, they do not need to be assigned an identifier. Functions such as `List.map` and `List.fold_left` are useful for combining the power of anonymous functions and iterators to get a task done efficiently by iterating over a list and performing an operation on each value as the iterator visits each element.

4. Commentary
   This was a really great way for me to get my feet wet with the OCaml Programming Language. Before this course, I had not heard of this language before and had not tried to use it. I needed a tutorial like this one in order to understand the language better.

A.0.3 Adjust OCaml Example Projects

A.0.3.1 Go Fish

1. Original Source Code
   I found the code for this game on Rosetta Code under the OCaml implementation. The game play is based on one player and an AI player who is automated through the back-end randomization functionality. The user chooses a card and asks the AI player if it has that card. If the AI player does, then it must give it up. If the AI player does not, then the user must pick up a card from the

deck. The player who loses their entire hand of cards first wins. As the code is currently written, the players are named “a” and “b”. There is not a way to change that. Also, the user picks the card to ask about by typing in a number between a provided range which corresponds to the cards left in the player's hand.

2. Customization 1: Allowing Modification of Players' Names
After wrestling with the code and trying to better familiarize myself with OCaml, this ended up being a pretty straight forward task. It took much longer since I made several failed attempts along the way trying to understand how OCaml projects are structured. The following code ended up being the only piece I needed to change.

   From this:

```
(try
  if Random.bool()
      then make_turn "a" "b" player_a player_b
      else make_turn "b" "a" player_b player_a;
with Exit -> ());
```

   To this:

```
(try
  if Random.bool()
      then make_turn Sys.argv.(1) Sys.argv.(2) player_a player_b
      else make_turn Sys.argv.(2) Sys.argv.(1) player_b player_a;
with Exit -> ());
```

   The following is how it was executed through the terminal:

```
hanen@hanen:~/Desktop/gofish$ ocamlc -g -o gofish gofish.ml
File "gofish.ml", line 153, characters 21-36:
Warning 52: Code should not depend on the actual values of
this constructor's arguments. They are only for information
and may change in future versions. (See manual section 9.5)
```

   The following is a snippet of the game-play:

```
hanen@hanen:~/Desktop/gofish$ ./gofish "dr. mateti" "hanen"

player hanen asked for Sixs
player dr. mateti gives (Six-Clubs)
```

```
player hanen asked for Fours
player dr. mateti has no Fours

(Queen-Clubs), (Jack-Clubs), (Nine-Spades), (Eight-Diamonds),
(Nine-Hearts), (Nine-Clubs), (Queen-Spades), (Queen-Diamonds)
Ranks: Eight, Nine, Jack, Queen
choose from 1 to 4
```

A.0.3.2 Guess the Number

1. Original Source Code
   The game-play on this Guess the Number game is very simple. A random number generator is used to "think of a number" and the player puts in numbers until they guess the number that was chosen at random. The user cannot specify the maximum of the range and they are not given any feedback on how far off they are from the selected number.

   The following is the current state of the code:

```
#!/usr/bin/env ocaml

let () =
  Random.self_init();
  let n =
    if Random.bool () then
      let n = 2 + Random.int 8 in
      print_endline "Please guess a number between 1 and 10 excluded";
      (n)
    else
      let n = 1 + Random.int 10 in
      print_endline "Please guess a number between 1 and 10 included";
      (n)
  in
  while read_int () <> n do
    print_endline "The guess was wrong! Please try again!"
  done;
  print_endline "Well guessed!"
```

   The following is the current game-play in the terminal:

```
hanen@hanen:~/Desktop/gofish$ ocamlc -g -o guessnum guessnum.ml
hanen@hanen:~/Desktop/gofish$ ./guessnum
Please guess a number between 1 and 10 excluded
1
```

```
The guess was wrong! Please try again!
2
The guess was wrong! Please try again!
3
The guess was wrong! Please try again!
4
The guess was wrong! Please try again!
5
The guess was wrong! Please try again!
6
Well guessed!
```

2. Customization 1: Let User Specify Max of Range
   I wanted to give the user the ability to specify what the max of the range should be for the number that is selected randomly for guessing.

   The following is the new state of the code after the customization:

```
let () =
  Random.self_init();
  let n =
    if Random.bool () then
      let n = 2 + Random.int ((int_of_string Sys.argv.(1)) - 2) in
      Printf.printf "Please guess a number between 1 and %s excluded
      \n" Sys.argv.(1);
      (n)
    else
      let n = 1 + Random.int (int_of_string Sys.argv.(1)) in
      Printf.printf "Please guess a number between 1 and %s included
      \n" Sys.argv.(1);
      (n)
  in
  while read_int () <> n do
    print_endline "The guess was wrong! Please try again!"
  done;
  print_endline "Well guessed!"
```

   The following is the new game-play in the terminal:

```
hanen@hanen:~/Desktop/gofish$ ocamlc -g -o guessnum guessnum.ml
hanen@hanen:~/Desktop/gofish$ ./guessnum 5
Please guess a number between 1 and 5 excluded
2
The guess was wrong! Please try again!
```

```
3
Well guessed!
```

3. Customization 2: Warm/Cold Indicator For Guess
   I wanted to be able to implement some logic into the code that would let the user know if they are close or far off with their guess. Now that I am allowing the user to choose any number for the max of the range, this is a nice-to-have feature. If they choose their max at 100, it would be helpful to know if they are close or not with their guess.

APPENDIX B

Lab Reports

B.1 Mount USB Through OTG Using ADB

First, the USB device needs to be authorized based on it's IP address.

```
hanen@hanen:~$ adb tcpip 5555
error: device unauthorized.
This adb server's $ADB_VENDOR_KEYS is not set
Try 'adb kill-server' if that seems wrong.
Otherwise check for a confirmation dialog on your device.
hanen@hanen:~$ adb connect 192.168.1.105:5555
connected to 192.168.1.105:5555
```

However, sometimes that is not enough, especially once the computer running adb is disconnected from being attached to the tablet over USB cable.

```
hanen@hanen:~$ adb devices
List of devices attached
192.168.1.105:5555      unauthorized
0a655f09        device
```

The tablet was restarted. When prompted to allow for enabling USB debugging, a checkbox was selected to always allow that permission. This fixed the issue once the tablet was unplugged.

```
hanen@hanen:~$ adb kill-server
hanen@hanen:~$ adb start-server
* daemon not running; starting now at tcp:5037
* daemon started successfully
hanen@hanen:~$ adb connect 192.168.1.105:5555
connected to 192.168.1.105:5555
hanen@hanen:~$ adb devices
List of devices attached
192.168.1.105:5555      device
0a655f09        device
```

Now, it is time to partition the drive in order to mount.

```
hanen@hanen:~$ adb -s 192.168.1.105:5555 shell
1|shell@flo:/ $ sm list-disks
disk:8,0
shell@flo:/ $ sm partition disk:8,0 private
shell@flo:/ $
```

Under Settings -> Storage & USB, it will show that the portable device (the flash drive) was removed/no longer exists. This is the point in which the tablet restarts. Once it turns back on, the USB Drive has moved out of portable devices and into the collection of internal storage.

B.2 RClone

B.2.1 Linux Machine

Following the tutorial on Rclone, the commands were executed below. [Rcl]

```
hanen@hanen:~$ sudo apt install rclone
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no
longer required:
  libncursesw5 libtinfo5 linux-modules-4.18.0-22-generic
Use 'sudo apt autoremove' to remove them.
The following NEW packages will be installed:
  rclone
0 upgraded, 1 newly installed, 0 to remove and 9 not upgraded.
Need to get 4,743 kB of archives.
After this operation, 19.7 MB of additional disk space will be used.
Get:1 http://us.archive.ubuntu.com/ubuntu cosmic/universe amd64
rclone amd64 1.41-1 [4,743 kB]
Fetched 4,743 kB in 2s (2,381 kB/s)
Selecting previously unselected package rclone.
(Reading database ... 232149 files and directories currently installed.)
Preparing to unpack .../rclone_1.41-1_amd64.deb ...
Unpacking rclone (1.41-1) ...
Setting up rclone (1.41-1) ...
Processing triggers for man-db (2.8.4-2) ...
hanen@hanen:~$ rclone config
2019/07/12 23:21:03 NOTICE: Config file
"/home/hanen/.config/rclone/rclone.conf" not found - using defaults
No remotes found - make a new one
```

```
n) New remote
s) Set configuration password
q) Quit config
n/s/q> n
name> remote
Type of storage to configure.
Choose a number from below, or type in your own value
 1 / Alias for a existing remote
   \ "alias"
 2 / Amazon Drive
   \ "amazon cloud drive"
 3 / Amazon S3 Compliant Storage Providers (AWS, Ceph,
 Dreamhost, IBM COS, Minio)
   \ "s3"
 4 / Backblaze B2
   \ "b2"
 5 / Box
   \ "box"
 6 / Cache a remote
   \ "cache"
 7 / Dropbox
   \ "dropbox"
 8 / Encrypt/Decrypt a remote
   \ "crypt"
 9 / FTP Connection
   \ "ftp"
10 / Google Cloud Storage (this is not Google Drive)
   \ "google cloud storage"
11 / Google Drive
   \ "drive"
12 / Hubic
   \ "hubic"
13 / Local Disk
   \ "local"
14 / Microsoft Azure Blob Storage
   \ "azureblob"
15 / Microsoft OneDrive
   \ "onedrive"
16 / Openstack Swift (Rackspace Cloud Files, Memset Memstore, OVH)
   \ "swift"
17 / Pcloud
   \ "pcloud"
18 / SSH/SFTP Connection
   \ "sftp"
```

```
19 / Webdav
   \ "webdav"
20 / Yandex Disk
   \ "yandex"
21 / http Connection
   \ "http"
Storage> drive
Google Application Client Id - leave blank normally.
client_id>
Google Application Client Secret - leave blank normally.
client_secret>
Scope that rclone should use when requesting access from drive.
Choose a number from below, or type in your own value
 1 / Full access all files, excluding Application Data Folder.
   \ "drive"
 2 / Read-only access to file metadata and file contents.
   \ "drive.readonly"
   / Access to files created by rclone only.
 3 | These are visible in the drive website.
   | File authorization is revoked when the user deauthorizes
   the app.
   \ "drive.file"
   / Allows read and write access to the Application Data folder.
 4 | This is not visible in the drive website.
   \ "drive.appfolder"
   / Allows read-only access to file metadata but
 5 | does not allow any access to read or download file content.
   \ "drive.metadata.readonly"
scope> 1
ID of the root folder - leave blank normally.  Fill in to access
"Computers" folders. (see docs).
root_folder_id>
Service Account Credentials JSON file path  - leave blank normally.
Needed only if you want use SA instead of interactive login.
service_account_file>
Remote config
Use auto config?
 * Say Y if not sure
 * Say N if you are working on a remote or headless machine or
 Y didn't work
y) Yes
n) No
y/n> y
```

This will pop up an internet browser which will ask for permissions as illustrated in Figure B.1. Once the Allow button is clicked, a Success screen will display as illustrated in Figure B.2.

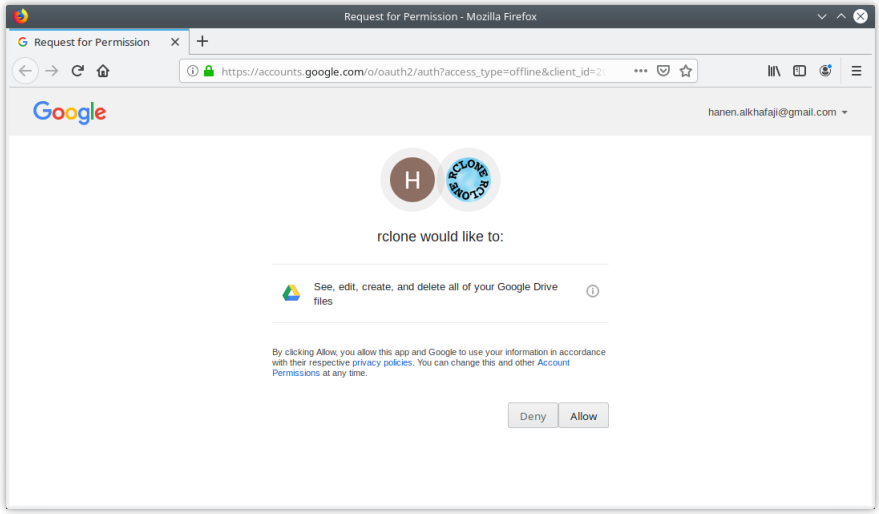

Figure B.1: First RClone Screenshot.

```
If your browser doesn't open automatically go to the following
link: http://127.0.0.1:53682/auth
Log in and authorize rclone for access
Waiting for code...
Got code
Configure this as a team drive?
y) Yes
n) No
y/n> n
--------------------
[remote]
client_id =
client_secret =
scope = drive
root_folder_id =
service_account_file =
token = {"access_token":"ya29.GltEB013ECs9MfyyGMcUfoSt_zNOt5
jhUObd7iON_VHepOcqyIVXC211TkJ1hdyKFEPb98rBKznYaGP1aoF4xIkHHBi
5O8Gre6t4VpwVXO6wGZkEELEr3sxzeu2L","token_type":"Bearer",
```

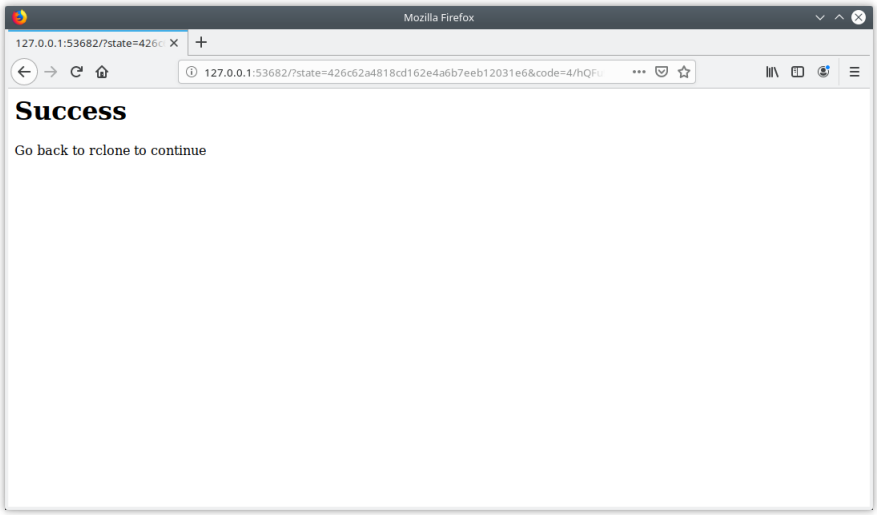

Figure B.2: Second RClone Screenshot.

```
"refresh_token":"1/TQ9fv-iDU4NqZkM5hngLF01tDhRfrtm_XKbDRdfarR8",
"expiry":"2019-07-13T00:24:12.763120806-04:00"}
--------------------
y) Yes this is OK
e) Edit this remote
d) Delete this remote
y/e/d> y
Current remotes:

Name                 Type
====                 ====
remote               drive

e) Edit existing remote
n) New remote
d) Delete remote
r) Rename remote
c) Copy remote
s) Set configuration password
q) Quit config
e/n/d/r/c/s/q> q
hanen@hanen:~$ rclone lsd remote:
          -1 2019-06-19 22:53:37        -1 2019-Hanen-CS-6970
```

```
-1 2019-06-04 10:46:41        -1 Misc
```

B.2.2 Android Tablet

As in the Linux Machine section above, the same commands are used on the Android device. In order to run commands, the Termux app must be installed from the Google Play Store. I struggled for awhile to get past some permission issues until I discovered a very helpful YouTube video [Kal], which helped me overcome this obstacle.

I used the steps from a GitHub page [Cra] to setup RClone on the Android tablet using Termux. It behaved exactly the same way with the exception of a few additional prompts that I was expected to interact with compared to the Linux machine. I responded to these additional prompts by simply pressing Enter without providing any input. This results in the application using the defaults. The following are the prompts I got before the browser popped up asking for permissions:

```
service_account_credentials
auth_owner_only
use_trash
skip_gdocs
skip_checksum_gphotos
shared_with_me
trashed_only
formats
export_formats
import_formats
allow_import_name_change
use_created_date
list_chunk
impersonate
alternate_export
upload_cutoff
chunk_size
acknowledge_abuse
keep_revision_forever
size_as_quote
v2_download_min_size
pacer_min_sleep
pacer_burst
server_side_across_configs
```

B.3 ODrive

B.4 InSync

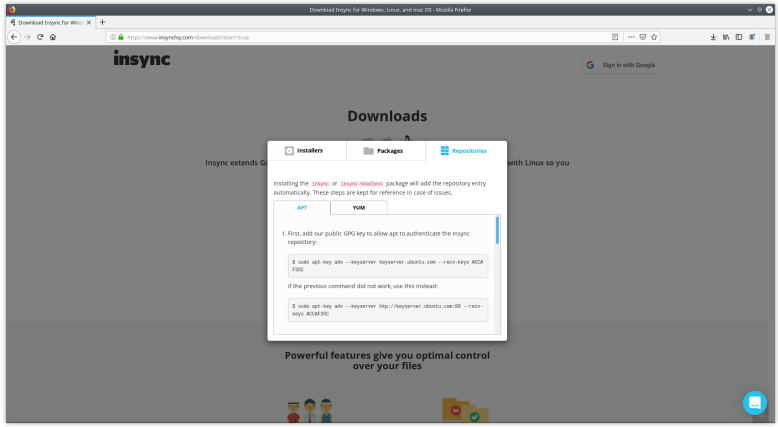

Figure B.3: Install Instructions on InSync Website.

Following the instructions on the InSync website as illustrated in Figure B.3, the following commands were executed in order to install InSync and sync a folder from Google Drive to a folder on the Linux machine's local drive. [InS]

```
root@hanen:/mnt# sudo apt-key adv --keyserver keyserver.ubuntu.com
--recv-keys ACCAF35C
Executing: /tmp/apt-key-gpghome.8tQidnAcU1/gpg.1.sh
--keyserver keyserver.ubuntu.com --recv-keys ACCAF35C
gpg: key A684470CACCAF35C: public key "Insynchq Inc
<services@insynchq.com>" imported
gpg: Total number processed: 1
gpg:               imported: 1
root@hanen:/mnt# lsb_release -a
No LSB modules are available.
Distributor ID: Ubuntu
Description:    Ubuntu 18.10
Release:        18.10
Codename:       cosmic
root@hanen:/mnt# echo "deb http://apt.insynchq.com/ubuntu cosmic
non-free contrib" >> /etc/apt/sources.list.d/insync.list
root@hanen:/mnt# sudo apt-get update
Hit:1 http://security.ubuntu.com/ubuntu cosmic-security InRelease
```

```
Hit:2 http://packages.microsoft.com/repos/vscode stable InRelease
Hit:3 http://us.archive.ubuntu.com/ubuntu cosmic InRelease
Ign:4 http://packages.cloud.google.com/apt gcsfuse-cosmic InRelease
Hit:5 http://ppa.launchpad.net/alessandro-strada/ppa/ubuntu cosmic
InRelease
Hit:6 http://us.archive.ubuntu.com/ubuntu cosmic-updates InRelease
Err:7 http://packages.cloud.google.com/apt gcsfuse-cosmic Release
  404  Not Found [IP: 172.217.14.174 80]
Hit:8 http://us.archive.ubuntu.com/ubuntu cosmic-backports InRelease
Get:9 http://apt.insynchq.com/ubuntu cosmic InRelease [5,557 B]
Hit:10 http://ppa.launchpad.net/avsm/ppa/ubuntu cosmic InRelease
Get:11 http://apt.insynchq.com/ubuntu cosmic/non-free amd64
Packages [776 B]
Get:12 http://apt.insynchq.com/ubuntu cosmic/non-free i386
Packages [619 B]
Get:13 http://apt.insynchq.com/ubuntu cosmic/contrib i386
Packages [1,253 B]
Get:14 http://apt.insynchq.com/ubuntu cosmic/contrib amd64
Packages [1,579 B]
Reading package lists... Done
E: The repository 'http://packages.cloud.google.com/apt gcsfuse-cosmic
Release' does not have a Release file.
N: Updating from such a repository can't be done securely, and is
therefore disabled by default.
N: See apt-secure(8) manpage for repository creation and user
configuration details.
root@hanen:/mnt# sudo apt-get install insync
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no
longer required:
  libncursesw5 libtinfo5
Use 'sudo apt autoremove' to remove them.
The following NEW packages will be installed:
  insync
0 upgraded, 1 newly installed, 0 to remove and 10 not upgraded.
Need to get 144 MB of archives.
After this operation, 400 MB of additional disk space will be used.
Get:1 http://apt.insynchq.com/ubuntu cosmic/non-free amd64 insync
amd64 1.5.7.37371-artful [144 MB]
Fetched 144 MB in 39s (3,678 kB/s)
Selecting previously unselected package insync.
(Reading database ... 230974 files and directories currently
```

```
installed.)
Preparing to unpack .../insync_1.5.7.37371-artful_amd64.deb ...
Unpacking insync (1.5.7.37371-artful) ...
Processing triggers for mime-support (3.60ubuntu1) ...
Setting up insync (1.5.7.37371-artful) ...
Insync installation has finished. You may now start it.
Insync doesn't seem to be running. Start it first.

fs.inotify.max_user_watches = 1048576
Processing triggers for man-db (2.8.4-2) ...
Processing triggers for shared-mime-info (1.10-1) ...
Processing triggers for hicolor-icon-theme (0.17-2) ...
```

Once the install is complete, the InSync pop-ups appear guiding the user through the setup process. The welcome screen appears giving the user the chance to add a Google account for syncing as illustrated in Figure B.4. Once that button is clicked, a browser appears allowing the user to choose which account to sync followed by a screen requesting access to that account as illustrated in Figure B.5. Once access is granted, a screen appears letting the user know that the handshake is complete as illustrated in Figure B.6. InSync, then, creates a folder for the newly connected drive as illustrated in Figure B.7. If the user confirms this action, the following screen lets the user begin syncing either all or select folders as illustrated in Figure B.8.

As a result, the following appears in the terminal.

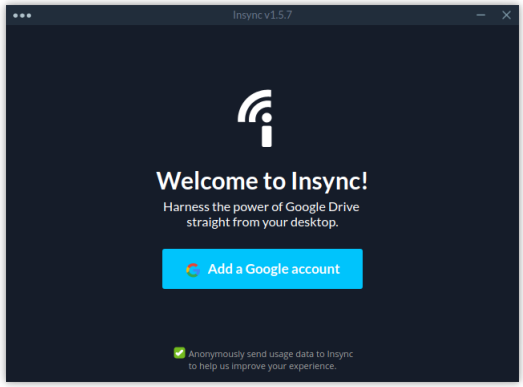

Figure B.4: InSync Welcome Screen.

```
root@hanen:~/hanen.alkhafaji@gmail.com# ls
2019-Hanen-CS-6970
```

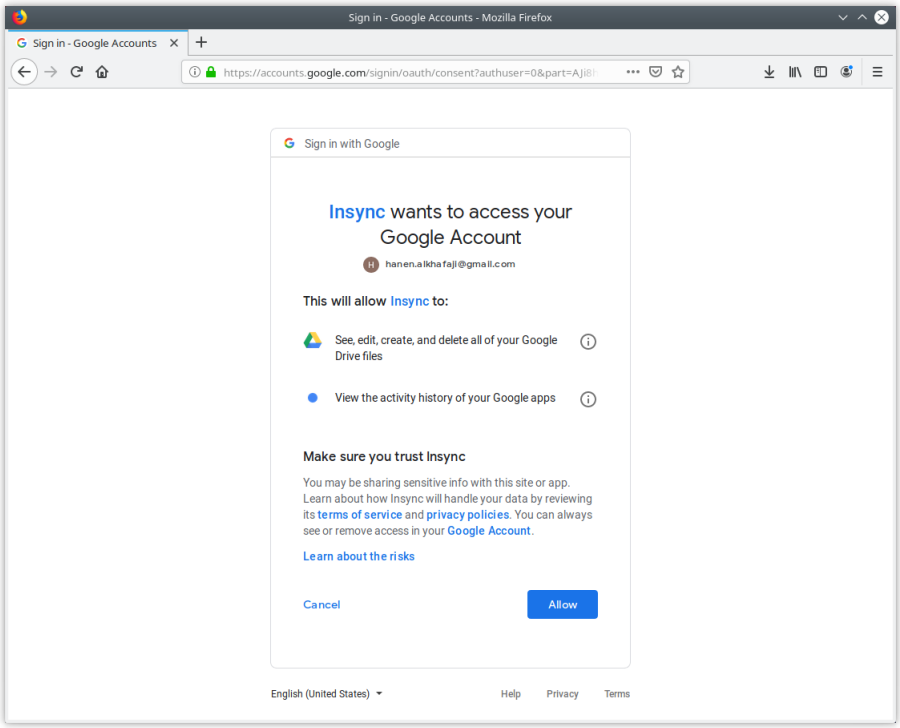

Figure B.5: InSync Requests Access.

B.5 X-Plore

B.6 Write FileSystem with FUSE

B.7 ES File Explorer

B.8 Mounting using SSHFS

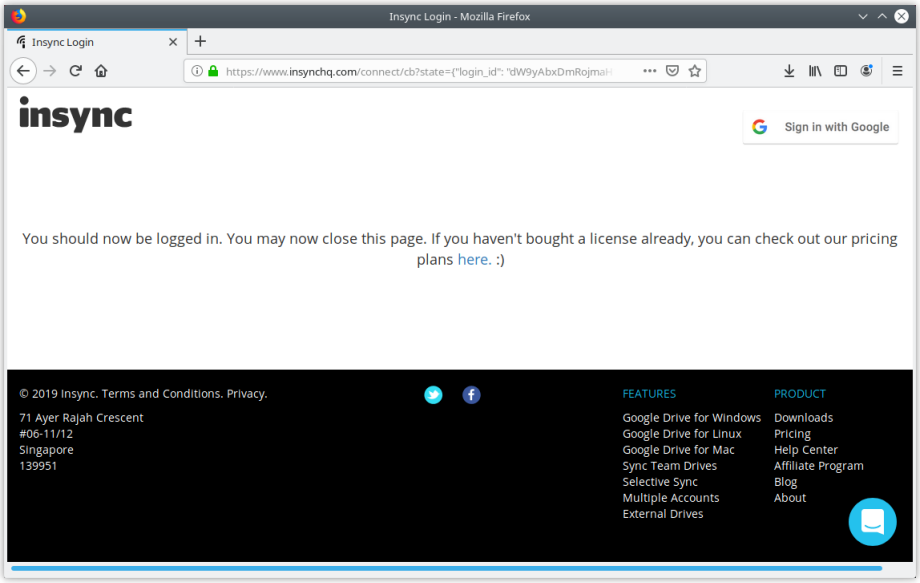

Figure B.6: InSync Installation Complete.

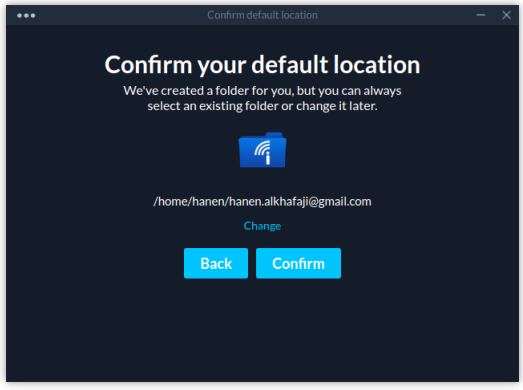

Figure B.7: InSync created folder for syncing Google Drive.

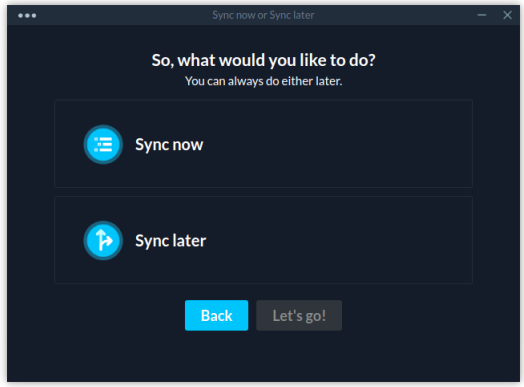

Figure B.8: InSync is ready to sync folders.

APPENDIX C

Meeting Minutes

C.1 5/14/2019

This initial meeting of the summer involved discussions and decisions around which project I should tackle for the independent study course. Dr. Mateti presented two topics we had discussed in meetings prior to this initial one. These two topics were selected after we had discussed other options and narrowed them down to a project dealing with Cloud Computing and a project dealing with Cloud Storage. Both projects would involve Android. The Cloud Computing topic would be one in which I would research different cloud computing approaches. The Cloud Storage topic would involve implementing a solution for mounting different cloud storage folders onto an Android device at the operating system level. There are many apps available that will do this very thing on the application level, where a user interacts with their cloud storage through the application itself, but cannot access that mounted storage from any other app on the device. Dr. Mateti showed me some apps like that on his phone which included ES File Explorer and X-plore. The goal would be mounting the storage at the OS level so that the user can access it from any app as if it were simply just another folder on their Android file system.

I decided to select the topic of Cloud Storage, because I really wanted to implement something this summer and this sounded both interesting and personally useful. Once I selected the topic I wanted to focus on, Dr. Mateti elaborated further on expectations and next steps. We will meet in his office at 6pm on Tuesdays or Thursdays on an as-needed basis. In the meantime, I will be uploading my meeting minutes and technical document drafts to a shared Google Drive folder that Dr. Mateti has been given access. I will, also, be organizing the tasks needed to accomplish this project using an application called Trello. Dr. Mateti has been given access to this board on Trello. The technical document will be around 50 pages once it is complete and will use Software Engineering principles. I was tasked to explore open source options for mounting Google Cloud and/or Firebase. Other things to read about and look into included Fuse and SSHFS. The plan will be to implement any solution on a Linux PC first. Then, when it is working to our satisfaction, it will be ported over to Android.

Dr. Mateti also provided me with an Android tablet to be used for this course. I will be bringing back the other tablet I borrowed in our next meeting.

C.2 6/4/2019

Dr. Mateti and I met to primarily discuss the development plan for my project for the summer. The goal for the summer is to be able to demonstrate mounting Google Drive at the operating system level on an Android device. The secondary goal is to try the same for another cloud storage provider, but we will determine later if we have time for that.

On KDE, I need to install GDrive (KIO). There is an authentication error that appears that can be resolved by going into System Settings and adding an Online Account for Google Drive. There was also another error that could be resolved by going into Personal Settings and enabling the KDE Wallet. If all else fails, remove the account under System Settings and add it back.

Dr. Mateti provided some helpful hints on using Latex such as for using a typewriter script to distinguish a certain chunk of text from the remaining report. `\begin{verbatim}` terminal output `\end{verbatim}` was another helpful tip.

Dr. Mateti also provided me with a usb input cable that I will use to create a DIY OTG cable, so that I can plug a USB into my tablet. I will plug the USB into my tablet and mount it using the code I develop.

Some action items that Dr. Mateti sent me away with were:

1. Put together a Development Plan document.
2. Revisit the init lab from the Android Security and Internals course from last semester.
3. Browse the OCamlFUSE code and determine comfort level with using it. Do lab report.
4. Rclone might be able to do mounting at the OS level and can handle more cloud storage providers. Do lab report. Include SLOC count of source code.
5. Odrive. Do lab report.
6. InSync. Try the free trial. Do lab report. Do lab report on mounting a USB drive.

C.3 6/11/2019

Dr. Mateti provided me with a tablet that has already been rooted. This will help me make progress without the risk of bricking the device like I did before. Dr. Mateti reviewed his feedback to my OCamlFUSE lab report. He shared a Latex format he

would like me to use for my final report. He asked me to mount a usb drive using an OTG cable. He, also, asked that I make some changes to an existing OCaml project. The plan is to focus on these two items. The feedback given by Dr. Mateti was uploaded on Google Drive. I will need to upload the Latex files he provided and fill things in based on his suggestions.

C.4 7/30/2019

I met with Dr. Mateti to discuss wrapping up the semester and this project. Due to the issues we have run into with OPam to build the OCamlFUSE solution, we have decided to turn our attention to RClone instead. I need to include a section in this report about Android internals and what current applications do with regard to syncing cloud storage. I need to, also, demonstrate RClone on Android to mount four different cloud storage providers. I need to explain in the conclusion what I've learned, what I did, why FUSE, why OCaml, and what future work needs to be done if time were not limited. I need to explain what went wrong with OCamlFUSE like issues with the OPam.

APPENDIX D

Schedule and Activities

- May 14: Decide on project topic
- May 14: On Campus Meeting
- May 17: Read about Fuse
- May 21: Read about SSHFS
- May 21: Install and Try ES File Explorer
- May 23: Install and Try X-plore
- May 23: Draft 1
- June 2: Learned LaTeX and Converted Report
- June 3: Project Scope Document
- June 4: On Campus Meeting
- June 6: Draft 2
- June 8: OCamlFUSE Mount on Linux
- June 11: Dr. Mateti provides rooted Nexus 7 tablet
- June 11: On Campus Meeting
- June 13: Cloud Storage Mounts in Android
- June 17: Lab Report: OCamlFUSE
- June 18: Make Changes to Sample Code
- June 20: Draft 3
- June 21: Create Outline to Guide Project

- June 23: Mount USB
- July 24: Draft 4
- August 5: Final Technical Report

APPENDIX E

Acronyms

OPam package manager for ocaml

OCaml functional programming language

FUSE filesystem in user space

OTG on the go

USB universal serial bus

ADB android debug bridge

APK android package

Bibliography

[Alk] Hanen Alkhafaji. *AndroidMountCloudStorage*. URL: https://github.com/hanenalkhafaji/AndroidMountCloudStorage.

[Cra] Nick Craig-Wood. *rclone on Android with Termux*. URL: https://github.com/ncw/rclone/wiki/rclone-on-Android-with-Termux.

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