CS262 Engineering Notebook

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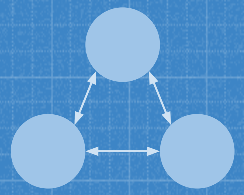
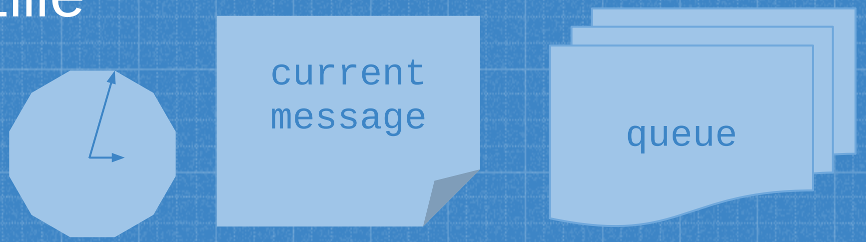
Programming Assignment 2

Understanding the Assignment and Specs

- We will be simulating three machines who can send messages to each other

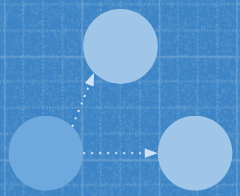


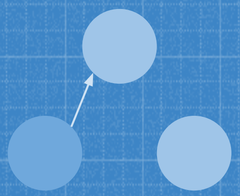
- We are simulating different machine speeds because each machine has a clock that limits the number of commands it can perform in real time

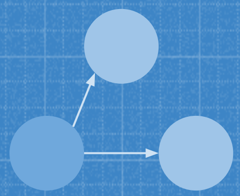


Thanks, Professor Waldo!

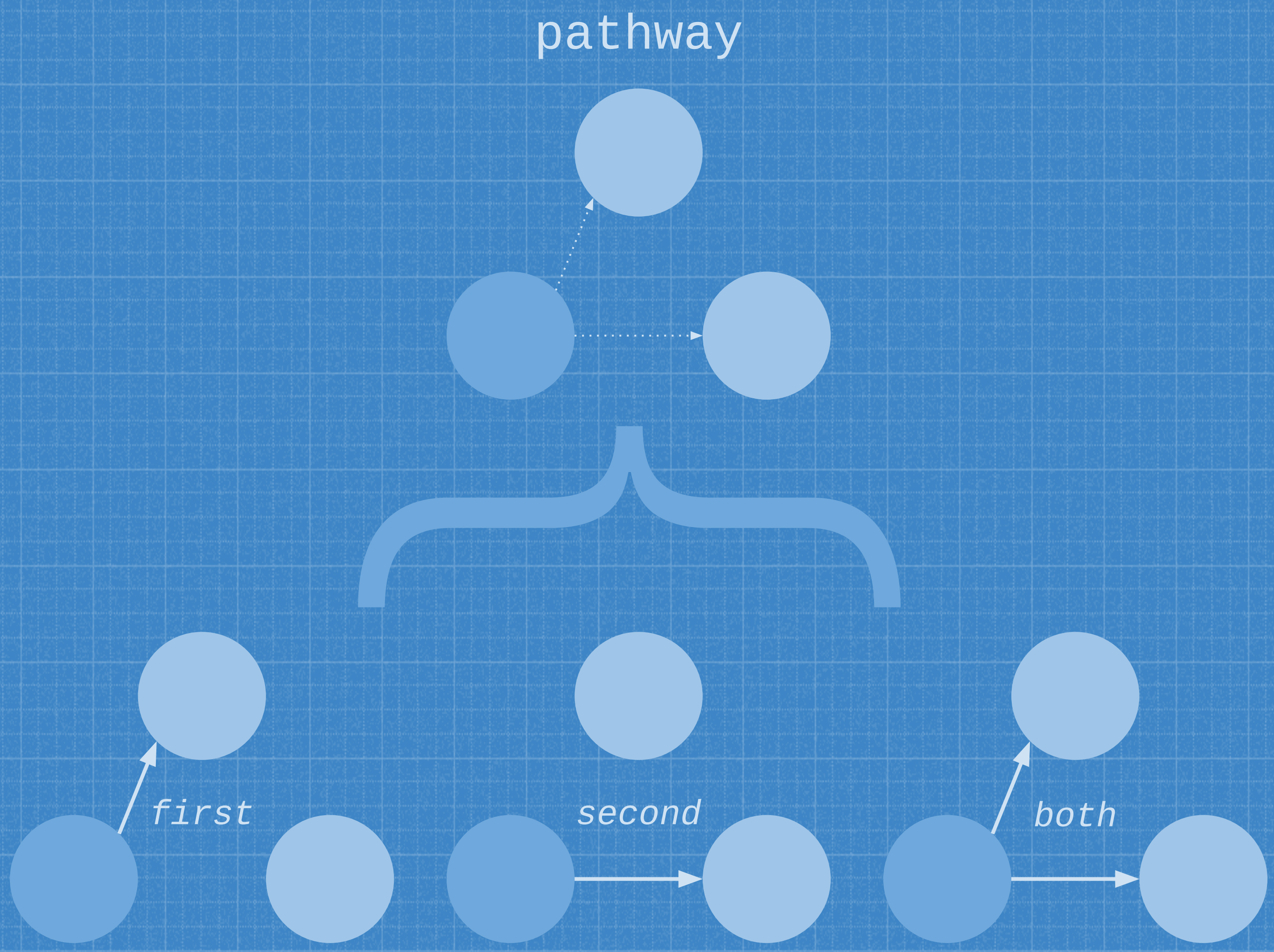
Professor Waldo’s code served as a fantastic framework for our project. What we learned is that there are six options of what can happen: each node can send a message to its first or its second neighbor (2 choices), and there are 3 nodes (2*3 total choices).







If we break down the “pathway” diagram in the previous slide, **three “options” emerge**, which we coded in clockSimMore.py:



Each Machine

- Maintain a queue of pending events and an internal clock
- Write events to a machine-specific log
- Bind to a socket, reserved for this machine, and listen for incoming
- messages, which are added to the queue.
- Execute (at most) a pre-specified number of the certain instructions; write to a log

Steps for a Processor

1. The processor will have a randomly-generated speed
2. We need to establish a connection
3. The processor will execute as many actions as it can based on its given speed and whether there are messages in the queue (as per the specifications)

- If we're sending, we can either send to the first neighbor, second neighbor, or both (we literally define the functionality for "both" as first, then second)

Design Choice: Breaking the Problem Down

When we really abstracted the message sending, we were able to define “first” and “second,” then use these definitions to define “both.”

This abstraction saved us time and hopefully made our code a lot simpler + easier to understand!

From the professor’s code, we were able to expand to 2- and 3-way messages.

Lamport’s Timestamp Algorithm

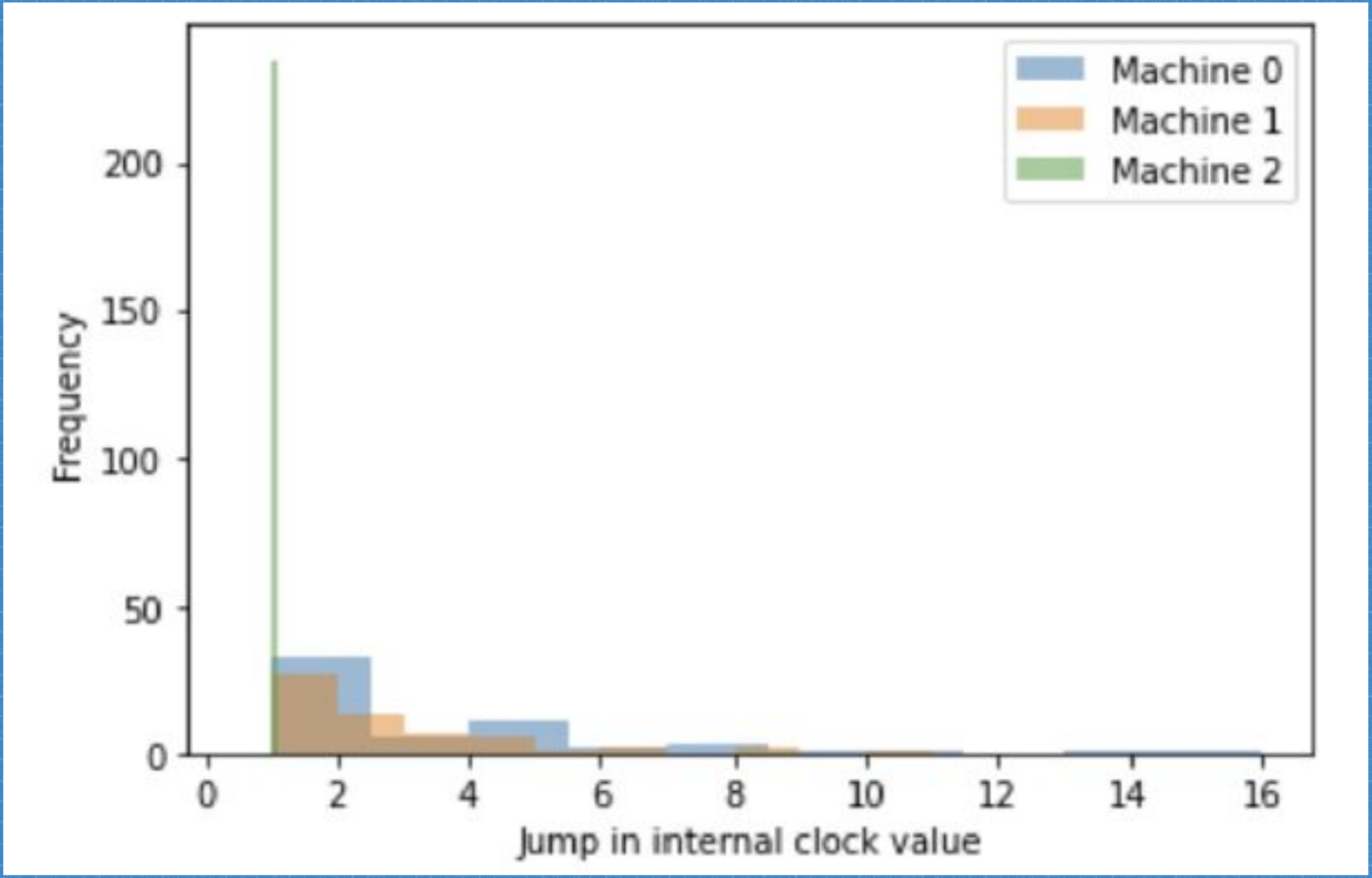
To maintain the internal logical clocks, we used Lamport's timestamp algorithm. We chose this algorithm because it is simple (each machine just maintains a single clock value), but still allows us to infer some information about the ordering of events from the logs. We update the internal clocks according to the following rules: The clock is incremented before executing any instruction (listed above). Any messages sent by a machine include the clock value of that machine.

Lamport’s Timestamp Algorithm (cont.)

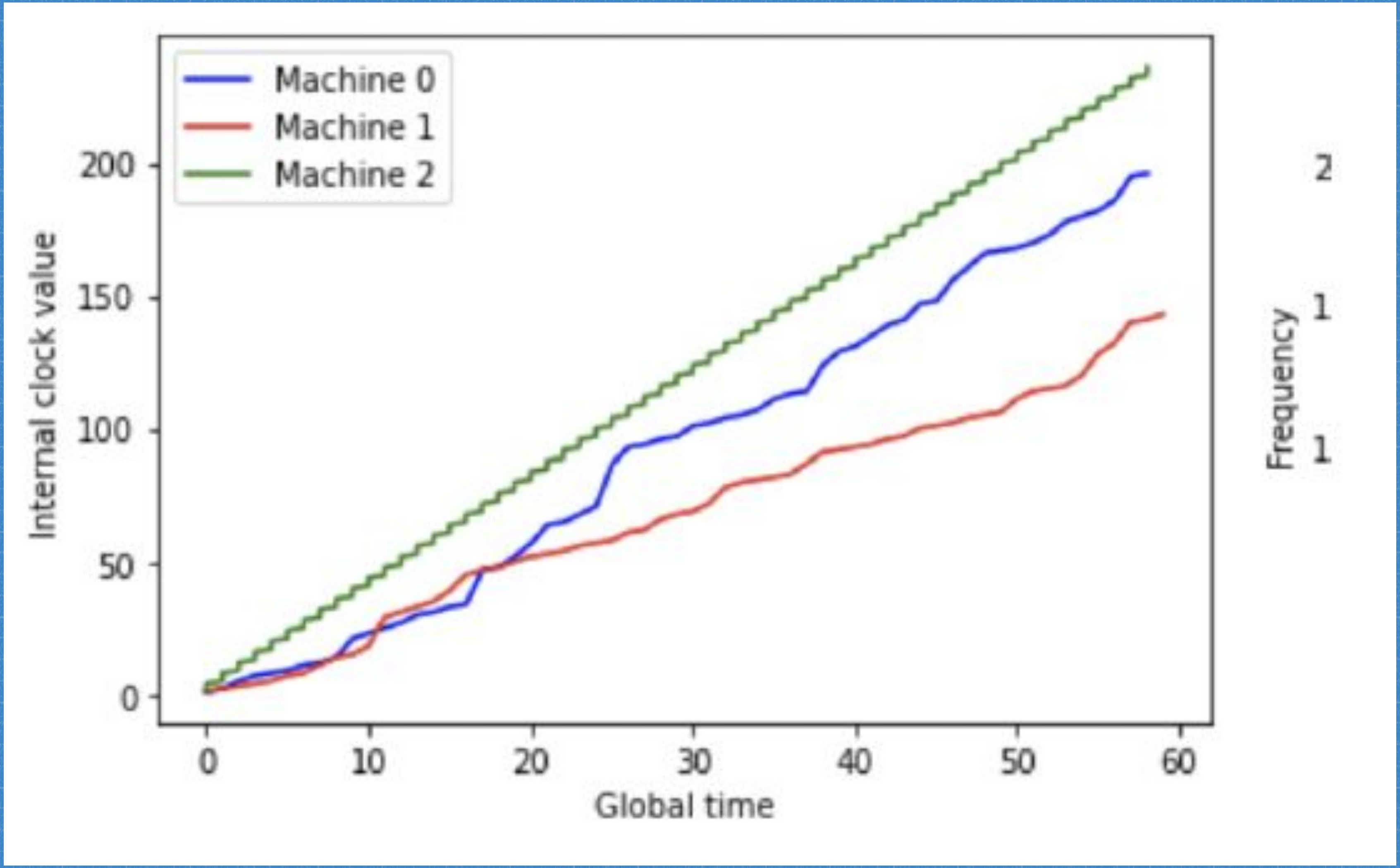
Having received a message from another machine, which includes a clock value, the clock value on the current machine is updated to be the maximum of itself and the received clock value.

We also decided to run the virtual machine as a separate Process, using Python's multiprocessing package. To model the fact that separate machines do not share memory, we used Processes instead of Threads (which do share memory).

Data Analysis



Data Analysis (cont.)



Data Analysis Findings

- Smaller variation in clock cycles naturally resulted in less drift and smaller jumps in clock values. As expected, queue sizes will still be large if there is also a smaller probability of an event being internal.
- Smaller probability of an event being internal significantly exacerbated the effects described above. Namely, we observed significantly larger jumps in values of logical clock values, larger queue sizes and larger drift, for slower machines. This makes sense; smaller probability of internal events means more messages are sent.

Unit Testing

```
def assertConfig(config):
    '''Check that an input config is valid.'''

    # Validate host address using a regex.
    # https://www.geeksforgeeks.org/python-
    # program-to-validate-an-ip-address/.
    ipRegex = "^((25[0-5]|2[0-4][0-9]|1[0-9]
        [0-9][1-9]?[0-9])\.){3}"
    ipRegex += "(25[0-5]|2[0-4][0-9]|1[0-9]
        [0-9]|[1-9]?[0-9])$"
    assert(type(config[0]) == str)
    assert(re.match(ipRegex, config[0]))

    # Check that port is in valid range, and
    # that tick size is at least 1.
    assert(type(config[1]) == int)
    assert(config[1] >= 0 and
      config[1] <= 65535)
    assert(type(config[1]) == int)
    assert(config[2] >= 1)
```

Unit Testing (cont.)

Because of our design choices, our implementation of clocks does not contain any input or output methods but rather runs several workers through different processes and threads that don’t necessarily return any values. These processes modify data structures and print to the LOG txt files. We completed unit testing by using assertions within each method, ensuring that messages were sent and received in a valid format.

Programming Assignment 1

Monday, February 6th: Specifications

1. **<u>Users can create, log into, and delete accounts</u>**
    a. What happens if a user tries to delete an account before their message has delivered?
    b. If a user isn’t currently logged in, their message should be queued; deliver their message as soon as they log in
    c. Confused by “deliver undelivered messages to a particular user”
    d. Could use a SQL database for this, but based on the scope of the assignment, we decided that it makes more sense to use a dictionary to store account usernames and passwords (limitation: passwords are not secure this way because they are stored on an accessible txt file!)

Monday, February 6th: Specifications (cont.)

2. **Build a wire protocol**
    a. One file that defines the functionality of a server
    b. One file that defines the functionality of a client
    c. Need to build a client, server that use these functionalities
    d. Support multiple clients; don't need to support multiple servers
    e. Write a README with detailed instructions on how to use these files as server and client wanting to chat
3. **gRPC implementation**
    a. Use gRPC to instead build the wire protocol, then compare over various factors: 1) complexity, 2) performance, 3) size of buffers, etc.

Tuesday, February 7th: Preliminary Research

- Message — python-can 4.0.0 documentation
- Documentation | gRPC
- Welcome to gRPC Python’s documentation!
- Can someone explain what a wire-level protocol is? - Stack Overflow
- About: Wire protocol
- WebSocket: Simultaneous Bi-Directional Client-Server Communication | by Gabbie Piraino | Medium
- Socket in Computer Network - GeeksforGeeks

Wednesday, February 8th: C++ Implementation Attempt

We first thought to implement with C++ because we were both fairly familiar with the language and wanted to use its range of packages.

After looking into a Python implementation, we realized that Python was far more efficient, elegant, and easy to code in (even though C++ compiles faster and is generally more comprehensive.)

The next slide shows the common pseudocode between our C++ and Python implementations:

Wednesday, February 8th: Pseudocode Behind the Approach (CLIENT-SIDE)

1. Establish the host and port
2. Create the socket and connect
3. Create a message that stores the client’s input
4. Until the message reads ‘bye’, signaling the end of the conversation, use the socket to send the message to the server. Be able to receive and print the server’s response. Then, take in a new message.
5. Repeat step 4 as needed
6. Close the program

Wednesday, February 8th: Pseudocode to Code Ideas (CLIENT-SIDE)

1. Establish the host and port
2. Create the socket and connect
3. Create a message that stores the client’s input
4. while (message != “bye”)
   a. Use the socket to send the message to the server
   b. Receive and print the server’s response
   c. Take in a new message
5. Close the program

Wednesday, February 8th: Pseudocode Behind the Approach (SERVER-SIDE)

1. Establish the host and port
2. Create the socket, bind the host and port
3. Listen for and connect to new connections
4. Receive and decode the client’s message; return an error if this is undesired data
5. Create a message that stores the server’s input
6. Encode and send this message to the client
7. As long as you’re receiving data, keep doing steps 4 through 6
8. Close the program

Wednesday, February 8th: Pseudocode to Code Ideas (SERVER-SIDE)

1. Establish the host and port
2. Create the socket, bind the host and port
3. Listen for and connect to new connections
4. while True:
    a. Receive and decode the client’s message; error message + break if undesired data
    b. Create a message that stores the server’s input
    c. Encode and send this message to the client
5. Close the program

Thursday, February 10th: Testing it Out

We tested the C++ code we generated from the pseudocode on one computer. We realized that, using this design, we created a requirement for a certain order in our communication: unless exactly one message is being sent alternately from client to server (A->B, B->A, repeat), our code does not work.

We would like to create an approach that does not restrict the messaging patterns of server and client. At this point in time, we also had not switched over to using Python.

Thursday, February 10th: Testing it Out (cont.)

We were also unsure of how to handle putting both client and server on one host. For now, we designed code in which the client and server are on the same computer.

We had yet to test this with two different computers and also felt very lost as to how to implement gRPC. For instance, it took a while to figure out how to auto-generate the Python code via the terminal after writing our proto file.

Monday, February 13th: Buggy Python Implementation

We finally switched over to Python and saw immediate improvements. For instance, because of Python’s functionality that can support “.connect,” for example, our earlier steps in the pseudocode became much simpler:

- Creating a client socket:
  - `client_socket = socket.socket()`
- Connecting the client socket:
  - `client_socket.connect((host, port))`
- Taking input:
  - `message = input(" -> ")`

Tuesday, February 14th: Remaining Todo List

1. Fix the Python implementation of the wire protocol
2. Create code that supports specification pertaining to accounts
3. Start on gRPC implementation
4. Upkeep design notebook
5. Compare the two approaches; record findings in design notebook

Wednesday, February 15th: Implementing Login User Flows

We created functionality for users to register and log in. We record the username and hashed password in a txt file to be referenced when a user is trying to log in again. We still need to figure out account deletion as well as link this login flow to our client.py.

We are a little stuck as to how to create an “inbox” for queued messages that we can show the user once they log in. We also do not know what to do if a user logs off before their message can send.

Figuring out the Delete Functionality

We first tried to create an option from the main menu for a user to delete their account but then realized this would be a security issue if a user can delete an account before logging in. We played around and initially put the code into client.py because client.py would only be called from login.py once the user is logged in.

We then copied the contents of client.py into login.py, but we realized that having this content in one file could create dependency issues.

We also wanted users to be able to delete their account at any time as long as they are signed in, so we decided to add the Delete functionality by detecting when a user types “/delete account” in to the terminal. After a confirmation prompt, the account information will be deleted from the .txt file.

Deletion was tricky to figure out– we realized that there isn’t a great way to simply remove a specific line from a .txt file in Python. So, we used a temp file to create the updated accounts information list, then renamed the accounts information list to the name of the temp file.

We also decided not to auto-delete an account after multiple failed login attempts and instead just direct the user to create a new account. We tried to put ourselves into the user’s shoes to design the most helpful user flow.

Friday, February 17th: Starting Proto

gRPC was initially a nightmare to figure out. Getting familiar with package installation and M1 Mac problem solving was a big barrier to entry for getting started on Part 2. After researching multiple client/server gRPC approaches, we saw many different and complicated ways to display a chat stream. It took a couple days for us to understand the technical concepts enough to realize that the chat proto line is actually very simple: to send a message, you take in a message stream and output a message stream (the messages can even be of the same struct!).

- `rpc Chatter (stream Reply) returns (stream Reply);`

We worked on first building an MVP, then adding extra functionality and complexity. The first version of our gRPC was a chat with no accounts and no login that kept crashing.

It was difficult to figure out what logic went in what file– did a given function belong in client.py or in the gRPC code, for instance? We tried adding functions and modifying the auto-generated code to no avail, eventually realizing that we didn't need to touch those two files and instead would need robust client and server Python files.

Because so many files share common names and functions, we had a lot of inconsistency based errors in our initial gRPC code where we didn't update an aspect of the code in each relevant file or were using inconsistent naming conventions across files. Taking a step back, simplifying, and first focusing on the MVP was really helpful– we started over around three times and became quicker at building up the basic functionality from scratch.

We wanted to explore other uses for gRPC beyond bidirectional communication, so on Saturday and Sunday, we worked on creating Unary, Server-Side, and Client-Side implementations.

Friday, February 17th: Trustable, Working Part 1

We also finally connected functionality between client.py and login.py, also testing and refining our Delete function, to get a nice, acceptable version of Part 1!

We added functions to display a user list as well as search for a user using the first letter of their username.

If we have time, we’d love to continue making our code more efficient, add more comments and README documentation, and possibly introduce fun colors into the CLI interface to improve the user experience.

Friday, February 17th: Remaining Todo List

1. Allow for multiple clients in Part 1 (want to switch to more of a node implementation where the server is merely the connector between two separate clients)
2. Figure out database implementation for ‘inbox’ (message queueing) functionality
3. Create and use unit tests for our code
4. Compare the two approaches; record findings in design notebook
5. Write README, commenting, general cleanup

Brainstorming for Inbox Database Implementation

- Switch over to SQL so we can use joins and eloquently store a larger amount of data
- Create a ‘message array’ for each user that is printed out when a user logs in
- Create a txt file for each user in which messages to that user are tagged with the receiver username and appended to the text file → delete new messages from txt file when receiver username is logged in (they’ve been read) → print out txt file when a user logs in on their next session because only their unread messages will remain
- Use console logs to record messages and print them if necessary

Saturday, February 18th: We added a gRPC Easter Egg…

try to find it!

Saturday, February 18th: Global User Functionality

1. Consolidated client.py and login.py in Part 1 into just a client.py file; fixed any possible dependency issues that could come with this change
2. Redesigned Part 1 using a ‘node’ approach in which two independent clients can log in with username/password and message each other
    a. This new design will help us because, previously, the server wasn’t logged in as an account while chatting with the client.
    b. Now that we have accounts for each chatter, we can assign a receiver to each message so that we know where to send queued messages
3. Created threads so conversations can happen independently

Saturday, February 18th: Nice-to-Haves for Part 1

1. Ability to still send messages if the other user you were chatting with logs off
2. A prettier CLI look and feel
3. A working message queue system
4. More messaging freedom than the one-for-one chat system we have (where each user trades off sending one message at a time, in an alternating order)
5. Functionality if a user wants to change their password or forgets it

Sunday, February 19th: Auth System

1. Improved reimplementation of server.py (originally changed to handle multiple clients and support threads)
2. Implemented functionality for /logout; created a system to tell whether an existing user were authorized
3. Reimplemented Delete() to account for changes made to server.py
4. Implemented inboxes and wrote unittests
5. Wrote a robust and detailed README.md with instructions for users

COMPARING PART1 and PART2 APPROACHES

PART1

- Message response time is noticeably slower
- Coding experience was a lot more conventional– played to our existing experience
- Buffer size was larger
- More room to be creative with the client/server setup (for instance, we switched from a traditional model to a 'node' model)

PART2

- Very big learning curve at first that honestly made this method less efficient
- However, once we understood how to implement functionality, our bonus three functions were very quick to make
- Buffer size was smaller because of tight packing of protocol buffers
- Code is less complex, but also less familiar to the average coder