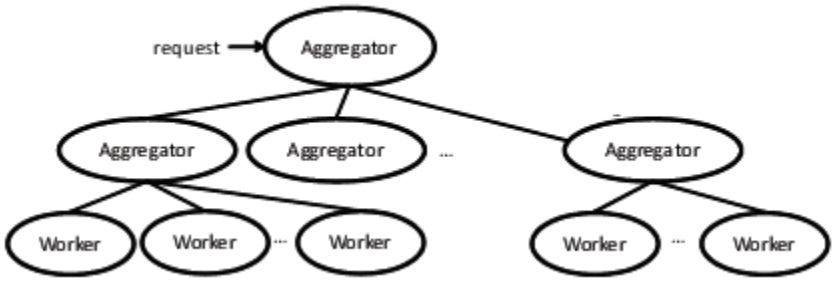
- **Introduction** In this assignment, you have to implement a common application structure in datacenter called Partition/Aggregate. The Partition/Aggregate design pattern shown in Figure 1 is the foundation of many large scale web applications. Requests from higher layers of the application are broken into pieces and farmed out to workers in lower layers. The responses of these workers are aggregated to produce a result. Web search, social network content composition, and advertisement selection are all based around this application design pattern.

  Figure 1

- **Concepts** In first assignment you will create a distributed search engine. You will use the concepts of concurrency, threading, and client/server communication protocols to solve this task. The goal of this assignment is to create a distributed system that can run across different machines. Searching through large amount of data is an "embarrassingly parallel" application—it consists of a set of inexpensive operations on large chunks of data, and there's no data that needs to be shared between different searching nodes. They just receive a work unit allocation, search



through all the files/folders assigned in that unit, and tell the server if any of them was a match. The challenges in this assignment are twofold.

First, the system is designed to run on the wide- area network. The Internet is not a nice place: it can drop, mutilate, or delay your packets. Your remote worker nodes may become unavailable temporarily or permanently. You'll have to deal with packet loss and node and communication failures. Second, since you're harvesting the work of a bunch of "volunteer" computers, the nodes may run at widely disparate speeds. Some may be high-end servers; others may be cheap notebooks or ten-year-old desktops. You'll have to make sure that your server properly balances the load across these nodes so that everybody's busy and you may not accidentally allocate 10 years of work to an ancient 486!

To know workers speed server would have to send ping command to workers. In response to this command worker will inform server about its existence plus the number of computations worker have performed. By this server can maintain the computation power of its workers and hence it can distribute work for next client accordingly.

Design and Implementation

The entire system consists of three programs:

Worker Client

Request Client Server A request_client sends a query to the server, and the server is responsible for dividing the job into parts, allocating those parts to worker_clients and then aggregating results. The clients and server communicate with each other using the sockets API to send UDP packets. The protocol they must implement is detailed in the following sections; the clients and server must be able to interoperate with other clients and servers that correctly implement the protocol. The server must be robust to communication failures (clients never receive a message) and to client failures by eventually assigning uncompleted jobs to other clients. **Note: All messages are to be transmitted using UDP**

Server The server should recognize the two different clients as

they contact it. It should keep track of the clients and which jobs they're currently working on or what job they've requested that the server solve. It should handle timeouts. The server may allocate jobs as it sees fit. It is your job to ensure that the jobs are of reasonable size and that the load is balanced across the worker_clients. The server should do this by having the number of workers assigned to each request be as equal as possible, without pre-empting workers. For example, there are 10 workers, which are all working on one request, and a new request comes in. As the workers finish their jobs, they are assigned to work on the new request, until each request is being

handled by 5 workers. Your code should produce an executable file named "server" and should use the following command line arguments:

./server <port> Example: ./server 2222

For ensuring that the port number of the server process is unique for each student, please use the following formula to compute the port number of the server process. Port = 10000 + (last four digits of your registration number) *20

For example if you registration number is 10080013, the port number that you should try first is: Port = 10000 + (0013)*20=10000+2600=10260.

In case this port number is already used, try the next port number (10261), until you found an unused port.

Furthermore, for simplicity of the structure, server will also be responsible for aggregating results from multiple worker_clients.

Worker_client

The worker_client should be multi-threaded to facilitate communication with the server. One thread should be used to do the actual work of the client (the searching) and a second thread should be used to listen for

messages from the server. The client should be independent and should be able to find out everything it needs to know through the protocol defined below. The client should not remember jobs it's worked on in the past. Your code should produce an executable file named "worker_client" and should use the following command line arguments:

./worker_client <server hostname> <port> Example: ./worker_client 127.0.0.1 10260

Request_client

The request_client does not need to be multi-threaded, but it certainly can be if you like. Its job is to request the query to the server. It is also required to ping the server every 5 seconds to remind the server of its existence. Since we do not know how long it will take the server to find the answer, this approach is more feasible than defining an arbitrary timeout value. Your code should produce an executable file named "request_client" and should use the following command line arguments:

./request_client <server hostname> <port> Example: ./request_client 127.0.0.1 10260 Once connected, the client can send query to server.

Protocol

For this assignment, you will implement a comma separated protocol. The various parts of the message will be aligned on specified bytes, such that there is less variation between messages:

Magic, Client_ID, Command, File_Range_Start, File_Range_End, Query, Results Data Types **Magic:** unsigned int (4 bytes) **Client_ID:** unsigned int (4 bytes)

Command: All commands specified in the next section are represented as number. In protocol command number is an unsigned int (4 bytes)

File_Range_Start: Vary

Key_Range_End: Vary

Query: Vary

MAGIC refers to a magic number, so that we are able to identify whether a message is relevant to our application. Our MAGIC number is 15440.

The Client_ID of worker_clients is the ID of the client randomly generated by the server when the worker sends a REQUEST TO JOIN. When the worker sends a REQUEST TO JOIN, it sets the client id field to 0. When the server responds (with a JOB), the server sets the client id field to a randomly generated number. The worker_client should use that number from that point on.

The Client_ID of request_clients is the ID of the client randomly generated by the server when the request_client sends a search Query. When a request_client sends a query, it sets the client_ID field to 0. When the server responds with an ACK JOB, the server sets the client ID field to a randomly generated number. The command is the command that is being sent.

Commands

The following list of commands does explain what to do in every possible situation. In cases not covered by the following list or elsewhere in this document, do what you think would work best and would make the most sense.

REQUEST_TO_JOIN: The worker_client starts the relationship with the server by sending this command. There is no other info for this message.

Command Code: 1

JOB: When the server wants to assign a job to a worker_client, it sends this command, along with the range and the search. For example: XXXX YYYY HHHHHHHHHHHH" where the XXXXs represents the value

of File_Range_Start and YYYY is the value of File_Range_End, and the

client needs to check all the values in the range [XXXX, YYYY] including the end points. The Hs is the search query

For example: JOB Cricket/003.txt Football/004.txt ‘Manchester United’ Command Code: 2

ACK_JOB: When the worker_client receives a JOB, it should acknowledge it with an ACK JOB with these contents: “XXXX YYYY HHHHH” where the Xs, Ys and Hs are the same as discussed above. The server should also use this command to communicate to the request_client that it received the request. The other info field does not need to contain anything, but the client id field should be filled in (by the server).

Command Code: 3 **PING:** Used for request_clients to ping the server, and for the server to ping worker_clients. Command Code: 0

DONE_NOT_FOUND: When the worker_client completes its job and has not found the any results, it sends a DONE_NOT_FOUND with parameters: “XXXX YYYY”. If the server is not able to find the results, it sends the request_client a DONE_NOT_FOUND with : HHHHH... (only query values are included in the message, no results)

Command Code: 4

DONE_FOUND: When the worker_client completes its job and has found the results or the server wants to tell a request_client the results, it sends a DONE_FOUND + the list of results such that each result is filename and line in which the results are found. **COLORING is important and have to number the results too (Not in screenshot).**

Command Code: 5

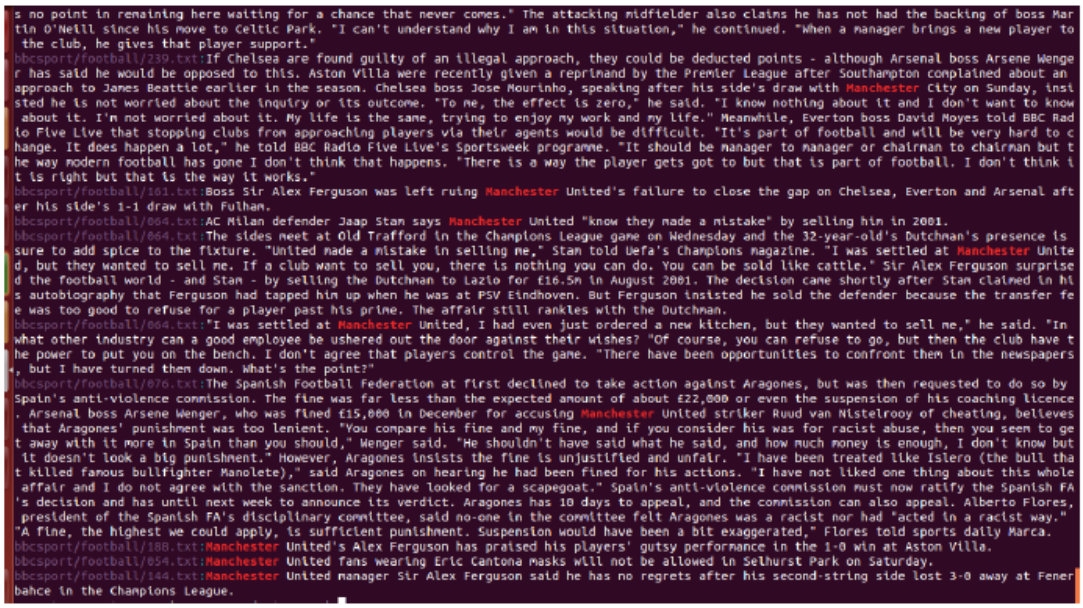


Figure 2

NOT_DONE: When a worker_client has received a PING, but is not done processing its job, it sends this command to the server with parameters: XXXX ZZZZ HHHHHHH, RRRRR...,where “XXXX” is the start of the range the server assigned, ZZZZ is the latest file the client has search, HHHH is the query and RRRR are the results found till the file ZZZZ. This means that the client has so far checked the range [XXXX, ZZZZ]. The reason for providing the latest value “ZZZZ” is that if the client fails and the job is assigned to a new client by the server, the new client does not start the job from the beginning of the range, rather it tarts from the last “ZZZZ” value received by the server from the old client before its failure.

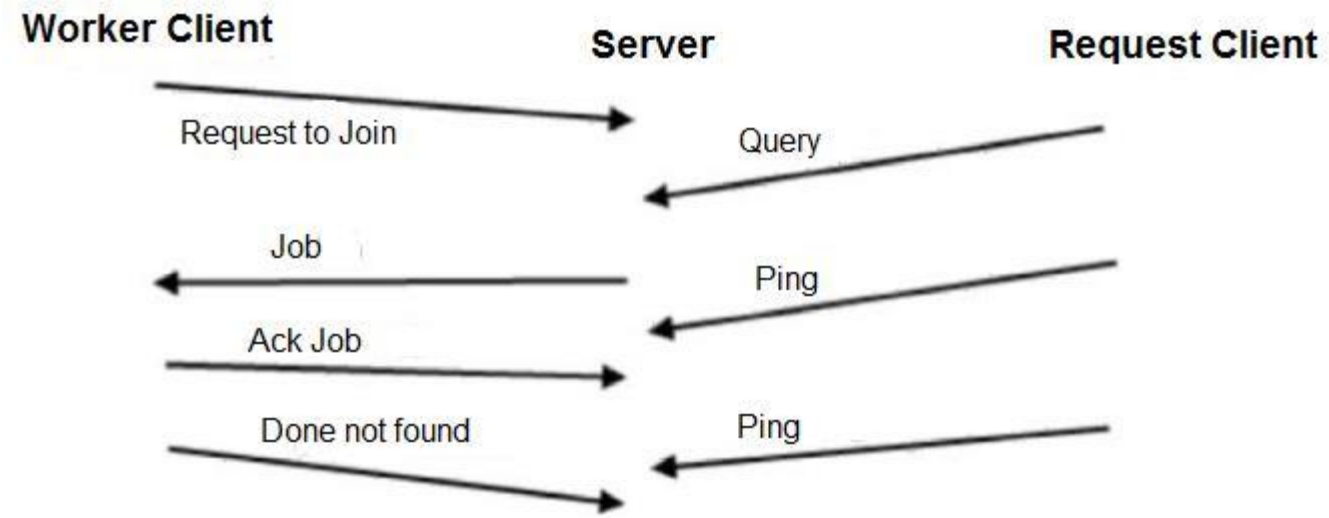
Command Code: 6

CANCEL_JOB: When the Request client sends CANCEL_JOB command to the server along with its Client_ID. The server forwards the CANCEL_JOB command to all the worker clients working on the job associated with the given Request client. Upon receiving the CANCEL_JOB command each worker client cancels the current job and wait for the new request.

QUERY: When a request_client wishes to make a request, it sends this

command to the server with parameters: “HHHHH”.

Command Code: 8



Failure

Figure 3

If a worker client fails to acknowledge the receipt of a job (times out), the server should attempt to send the job twice more. Once it has tried 3 times and the client has not acknowledged the job, the server should remember the job and assign it to the next available client and forget all about the previous client. If the worker client fails to send a message, once it has completed the job (times out), the server should send a PING to the client. The worker should respond with its previous DONE message (whichever variant it might have been). If the worker is currently processing a job, it should respond with NOT_DONE. If the server receives NOT_DONE response, it should reset the number of pings it sent to the worker, and wait for timeout again. If the PING times out, the server should try twice more and then the reassign the job to another worker client and forget about the previous client. The request client is responsible for sending a PING message to server every 5 seconds. The server should monitor these pings and if it doesn’t receive a ping within 15 seconds, it should abort that job. The timeout for all

worker client/server messages is 3 seconds. The means that server after assigning a job to a worker client should wait for 3 seconds to for ACK_JOB. If the server doesn't get the ACK_JOB within 3 seconds, the client has died out and server should send the job to next available client. Once the server receives the ACK JOB, it should wait for 3 seconds to send the PING.

If the server fails, all state should be saved to a file, and when restarted it should be able to resume operation without any problems.

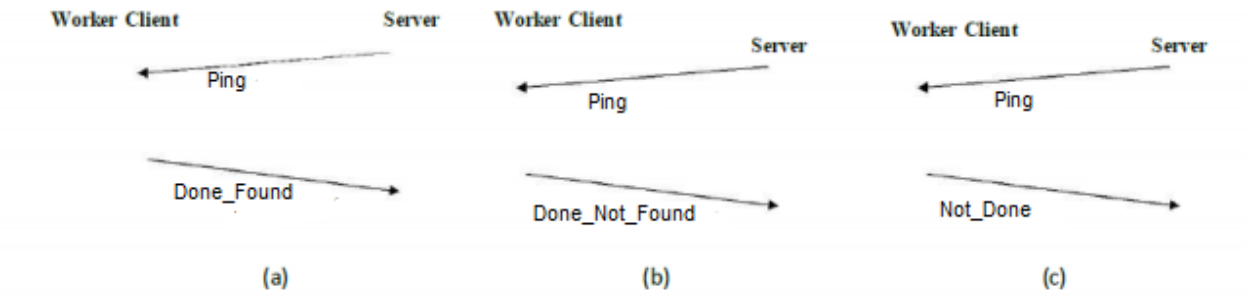


Figure 4. Worker_client's response to server's ping when: (a) the worker_client has completed processing and has found the results; (b) the worker_client has completed processing and has not found the any results; (c) the worker_client has not completed processing.

Other Notes

A significant percentage of the grade of this assignment will be given based on efficiency of the protocol. Optimizations will be given extra credit.

Simple Search Complete: 20 (Includes proper display of results) Job equally distributed among workers: 10 Worker Crash handling: 20 (10 for not crashing, 10 for distributing job among others) New worker Joining: 10 (Re-allocate part of job to new worker) Server Crash Handling: 20 (10 for workers not crashing, 10 for proper recovery of server) Multiple Search Request handling: 20 (Equally distribute jobs among multiple workers)