CS553 : Programming Assignment #3

Report

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1. Design

The goal of this programming assignment is to enable us to gain experience with the Amazon Web Services such as EC2 Cloud, SQS queuing service and DynamoDB. The primary aim of this assignment is to implement a static task provisionner. Our framework is divided into three parts: a client who submits tasks, the front end scheduler which handles the jobs distribution and scheduling and eventually the workers which runs the tasks either locally or remotely.

We are to use both SQS and DynamoDB in order to handle the replication of jobs in the scheduler part of this project. Finally we will measure the performance of our framework for throughput and efficiency according to the number of workers and the duration of the sleep tasks of the workers. Our project is implemented using java language and helped with the AWS APIs.

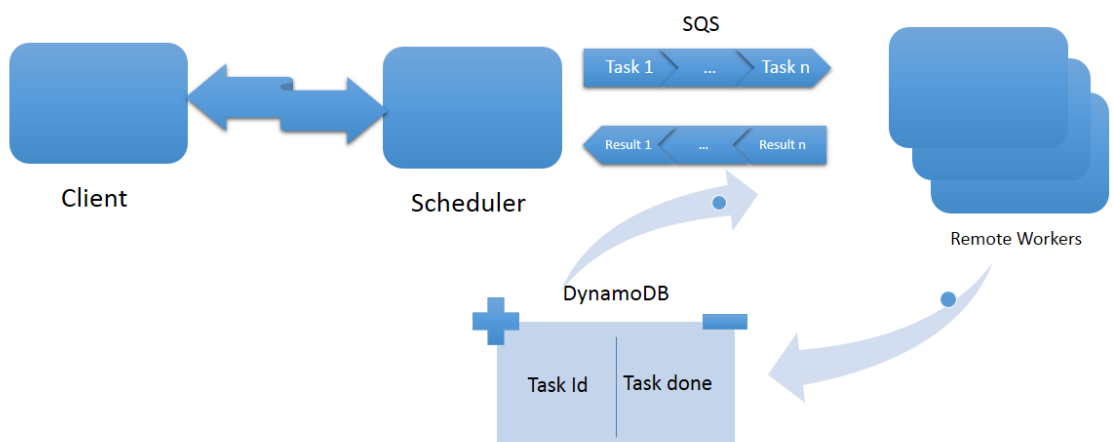


Figure 1: Framework layout

1.1 Components and their functionalities

This project focuses on developing a task execution framework that supports static scheduling. This framework is mainly composed of

- a client,
- a frontend,
- a number of local workers,
- a number of remote workers,
- a static provisioner.

The remaining contents of this section describe the functionalities of each component.

a. Client has three functionalities:

- reading from the workload file and generating the corresponding tasks

- sending all tasks to the frontend through a socket

- spawning another thread to serve a socket, in order to receive the result of each task execution from the frontend. Notice this thread starts at the same time as sending the tasks.

b. Frontend has three functionalities:

- serving a socket to receive the tasks from the client

- sending all tasks to the local workers through a implicit memory queue, or

- sending all tasks to the remote workers through a SQS queue

- spawning another thread to check task completion by polling from the implicit memory queue or SQS queue, and send all the completed tasks back to the client through a socket. Notice this thread starts at the same time as sending the tasks.

c. Local workers are in charge of:

- reading the task description from the received task

- spawn an OS process to execute the description, and check if it succeed

- return the task with the result record

d. Remote workers are in charge of:

- poll the task from the SQS queue
- check the dynamoDB to see if the task is duplicated. If it is duplicated, return to previous step
- reading the task description from the received task
- spawn an OS process to execute the description, and check if it succeed
- send the task back to another SQS queue (Note: the whole procedure is in a while loop.)

e. Static provisioner is in charge of:

- increasing or decreasing the number of worker according to the amount of incoming tasks statically in order to improve efficiency of the system.

1.2 Detailed Implementation of some components

- What language and tools we use for this project?

We use Java language and Eclipse IDE with AWS Toolkit.

- How do we generate the workload file?

We write a program to generate the workload file, corresponding to each benchmark request.

- How is each task represented?

Each task is encapsulated into a serializable object, which contains three attributes: task ID, task description, and result.

When the client generates each task, the task ID is a random string, the task description is the contents read from the workload file, and the result is set to "null".

The result will be rewrite by either local or remote task.

- How does the frontend scheduler detect local worker's completion?

Each local worker thread is encapsulated into a callable class.

An ExecutorCompletionService object is declared at front-end to submit each callable thread. Then, the thread which is in charge of send the result back to client only need to call the take() method of this ExecutorCompletionService object, to get a completed task object.

It is guaranteed that this take() method will return not only a completed task, but also the first completed task so far.

- How does the frontend detect remote worker's completion?

Since the front-end and remote worker communicate through SQS queue, the front end periodically spawn a new thread to poll from the SQS queue, and send them back to client.

However, sometimes the queue may be empty when the front-end poll it. In order to keep the stream between the client and front-end alive, the front-end will send a "fake task" instead.

- How does the remote worker terminate itself?

We have a line commented out during our experiments for convenience, which is:

(new ProcessBuilder("shutdown", "-h", "now")).start();

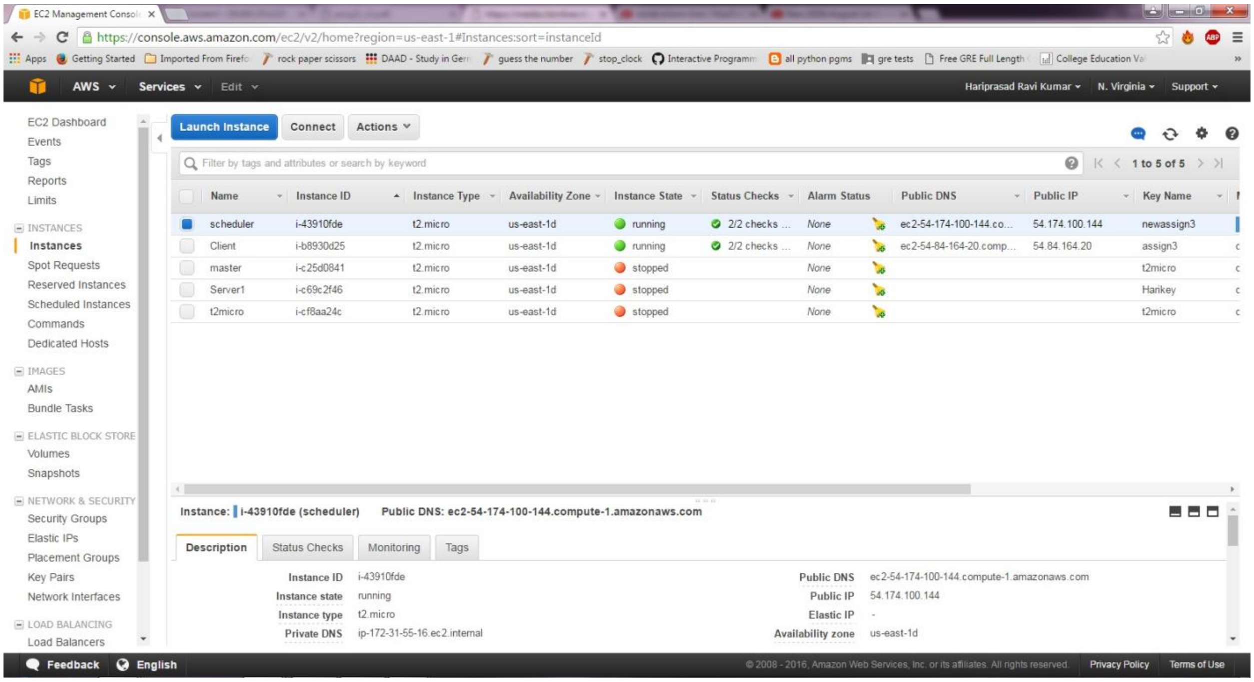
after a duration of idle time (fetch a message from task queue every half-second, until a non-empty message is obtained).

2. Manual

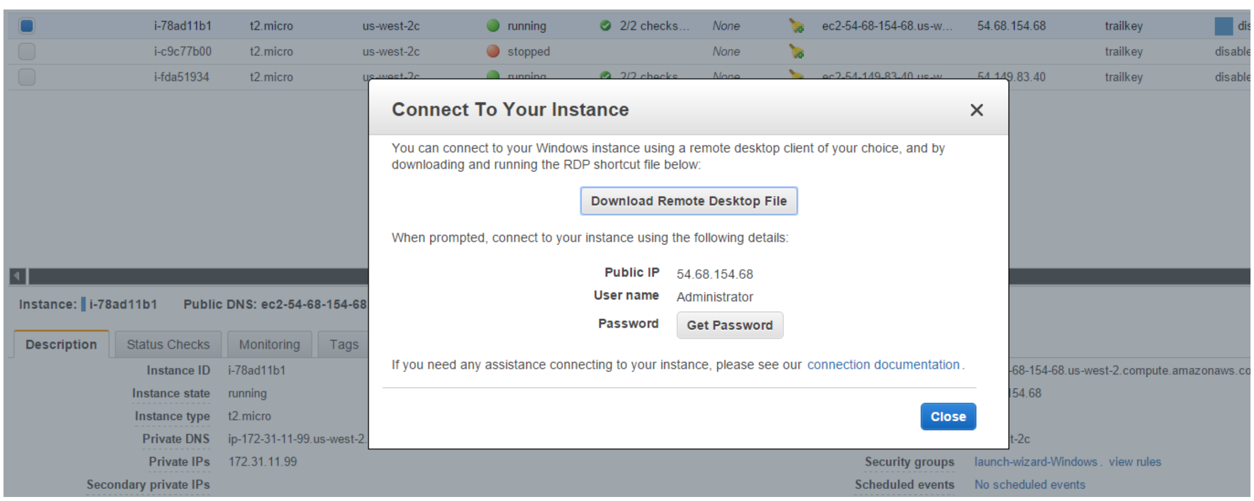
Client:

- Client runs on t2.micro instances of EC2.
- Client reads and takes up the local file and sent it to the server.
- Local file contains the list of task to be executed by server.
- Client runs on cloud instance using the interface, client –s QNAME –w <WORKLOAD_FILE>
- The QNAME is the name of the SQS queue and the name of the DynamoDB instance
- Workload file is the client's local file.
- Each task was separated by a new line and given a unique id for its identification.
- The client reads a file from the local and sends it to the server task by task.
- Client is run using the command "java -cp pgm3.jar Client <<Server Name>>"
- Server name is the name of server to which data is sent to. Localhost is given to say that the server is in the current machine.
- Port number specifies the port on which the server is listening to.
- A hash map is implemented in order to associate a task with ID.

Client Instance:



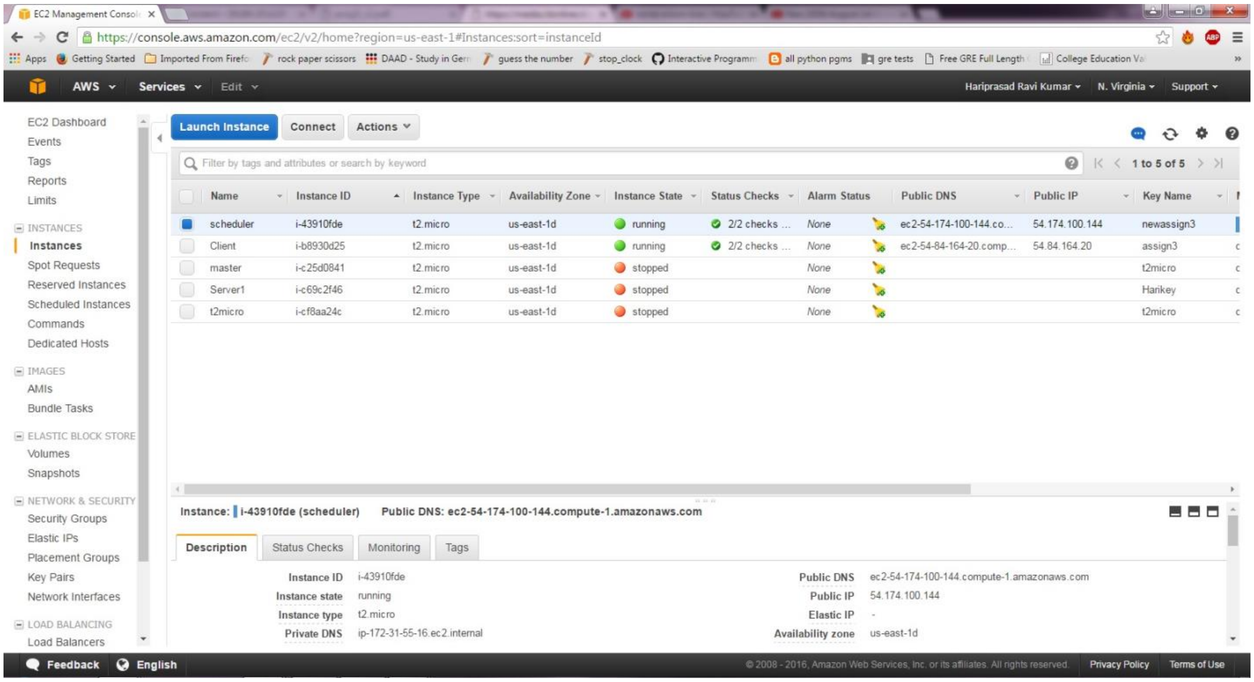
Connecting Client Instance to Remote desktop:



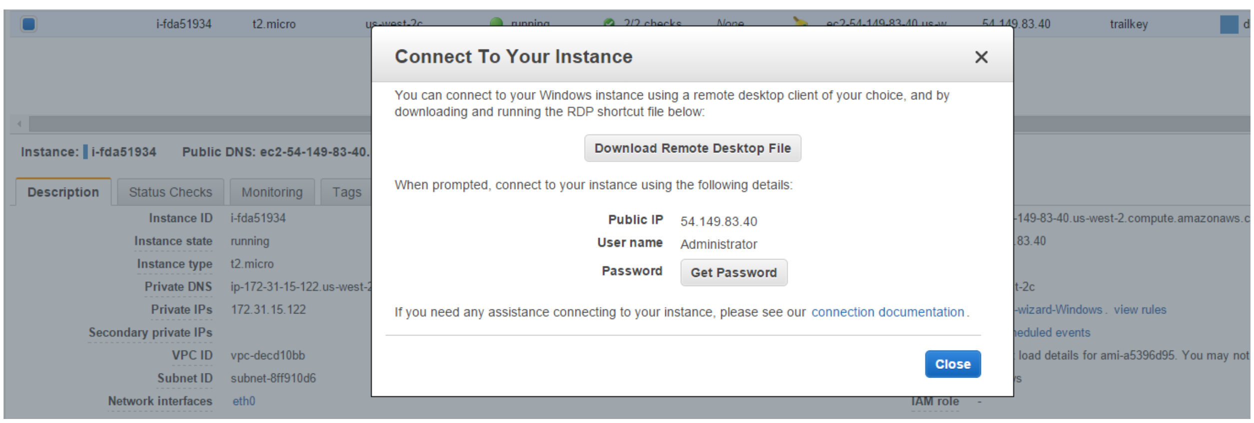
Server:

- Server runs on t2.micro instances of EC2.
- Server listens on its specified port.
- The tasks arrive the server one by one or in batches
- Server runs with the interface, scheduler –s QNAME -lw <NUM> -rw
- lw usage specifies the local worker. Number of threads that it uses can also be specified.
- If rw switch is used, it uses the remote worker.
- Free thread picks a task and executes it.
- The tasks are either sent in batches or one-by-one.
- If the 'lw' switch is used, the tasks are written to a in-memory queue which is implemented using a linked list.
- If the 'rw' switch is used, the tasks are written to the SQS on AWS. The queue is called the 'taskQueue'
- If the switch is 'lw', then number of threads can be specified.
- A thread executor service is run which pops and item from the queue and submits it to a thread pool.
- The thread which is free takes up the task and executes it.

Scheduler Instance:



Connecting to Remote desktop:



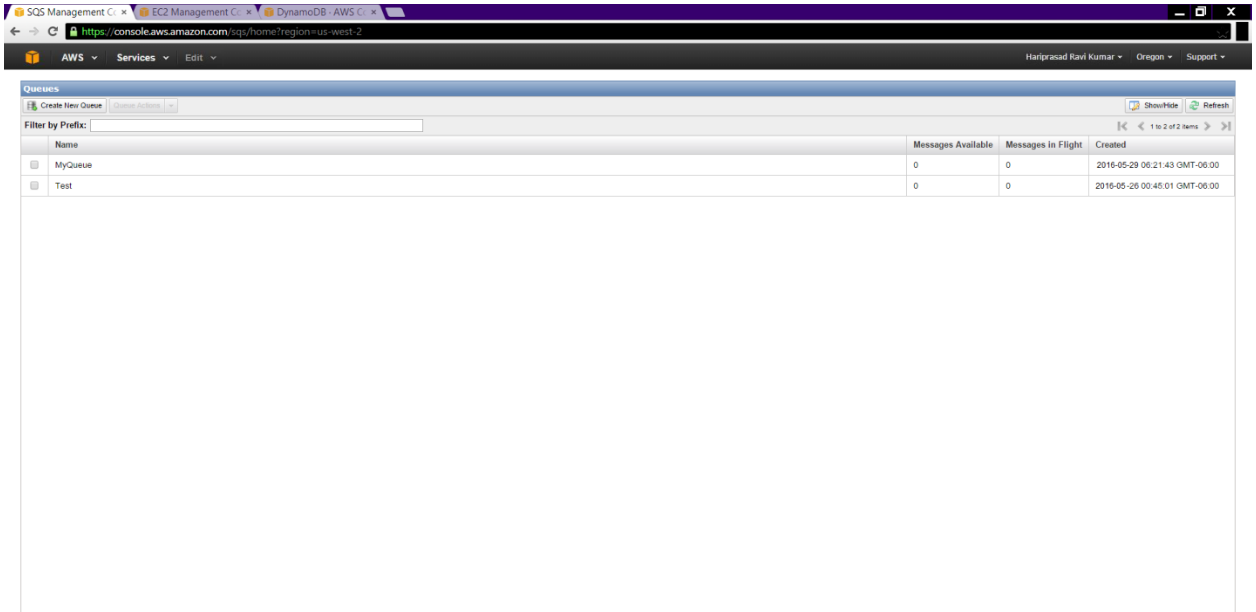
Local Backend Workers:

- The number of threads specified in the scheduler defines the number of local workers.
- A local worker method will take the task provided and sleeps for the specified amount of time.
- As the thread completes running the task, the result is written to another queue. If the thread fails an exception is raised and the return value is written into the result queue.
- Local Worker runs on t2.micro instances of EC2.It uses in-memory queue for storing the task and its results. The number of local workers is specified by the server.
- Local Worker picks up the task and sleeps for the specified amount of time. When the thread completes the task results are written into another queue and success is returned.
- When an exception occurs during thread execution, failure is returned.

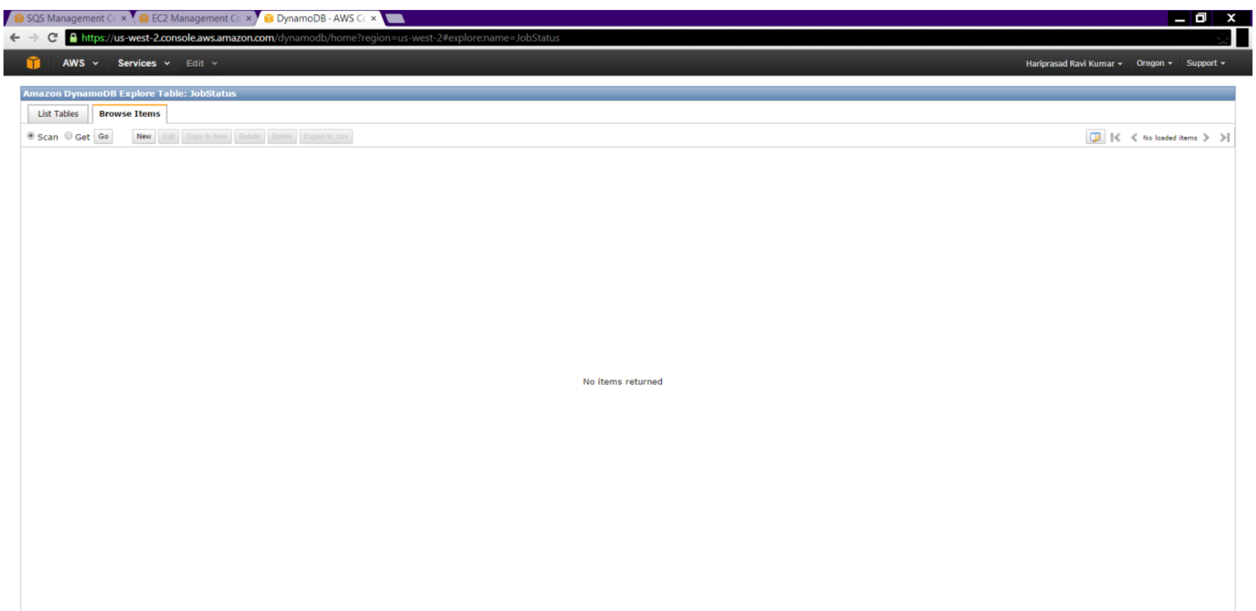
Remote Backend Workers:

- Remote Backend Workers runs on t2.micro instances of EC2.
- If rw switch is used then the tasks are written into SQS queue on AWS. The remote worker polls the queue at regular interval.
- If there exists a task it is picked up and executed.
- If there is no task, it is polled after specific time. If the queue is idle for long time, the worker is terminated along with VM. When the 'rw' switch is used, the tasks are written into SQS queue on AWS.
- A custom AMI is created holding the jar file and a crontab file. The crontab file runs the command on the system boot. The remote worker polls the SQS queue. If there is a task, it is retrieved and executed.
- If there are no tasks, it polls after a few minutes. If it is idle for the long time, the remote worker is terminated.

SQS



Dynamo DB:



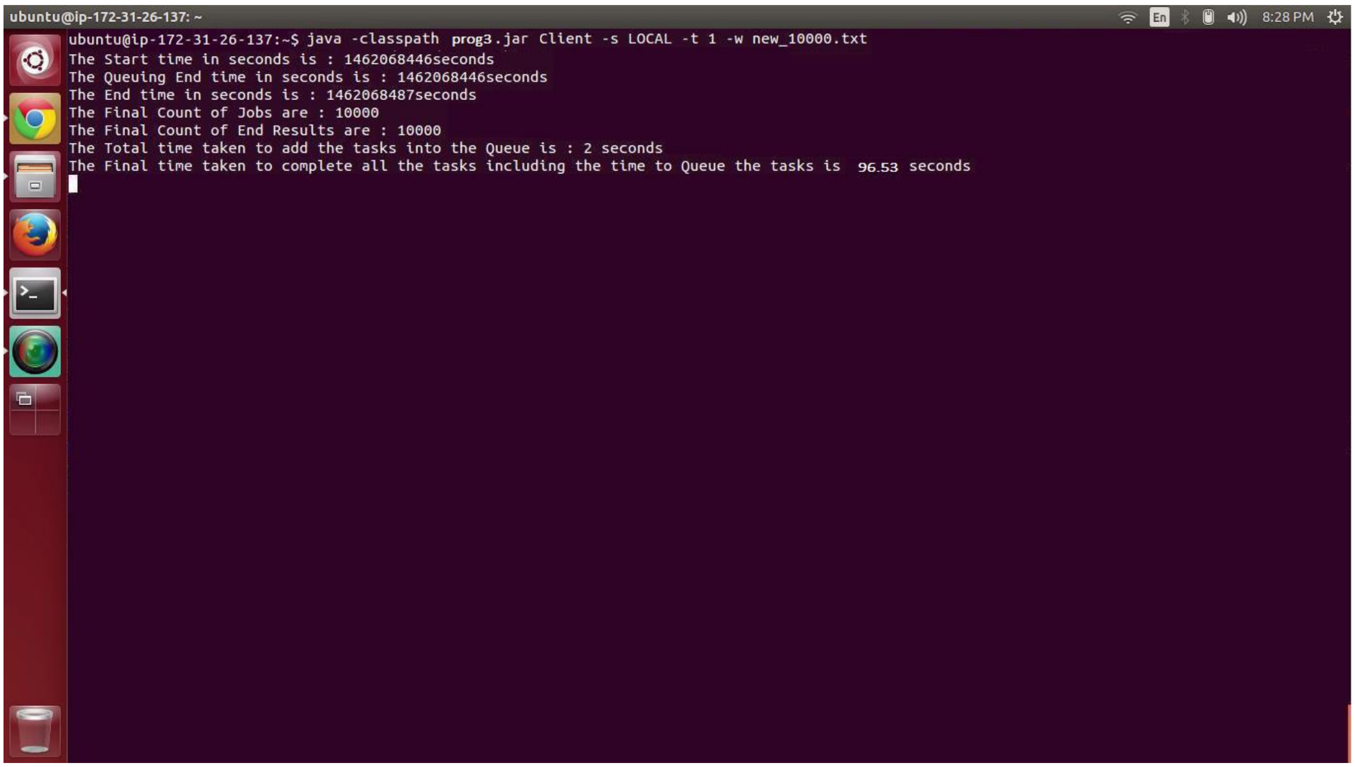
3. Performance Evaluation

3.1 Throughput Evaluation

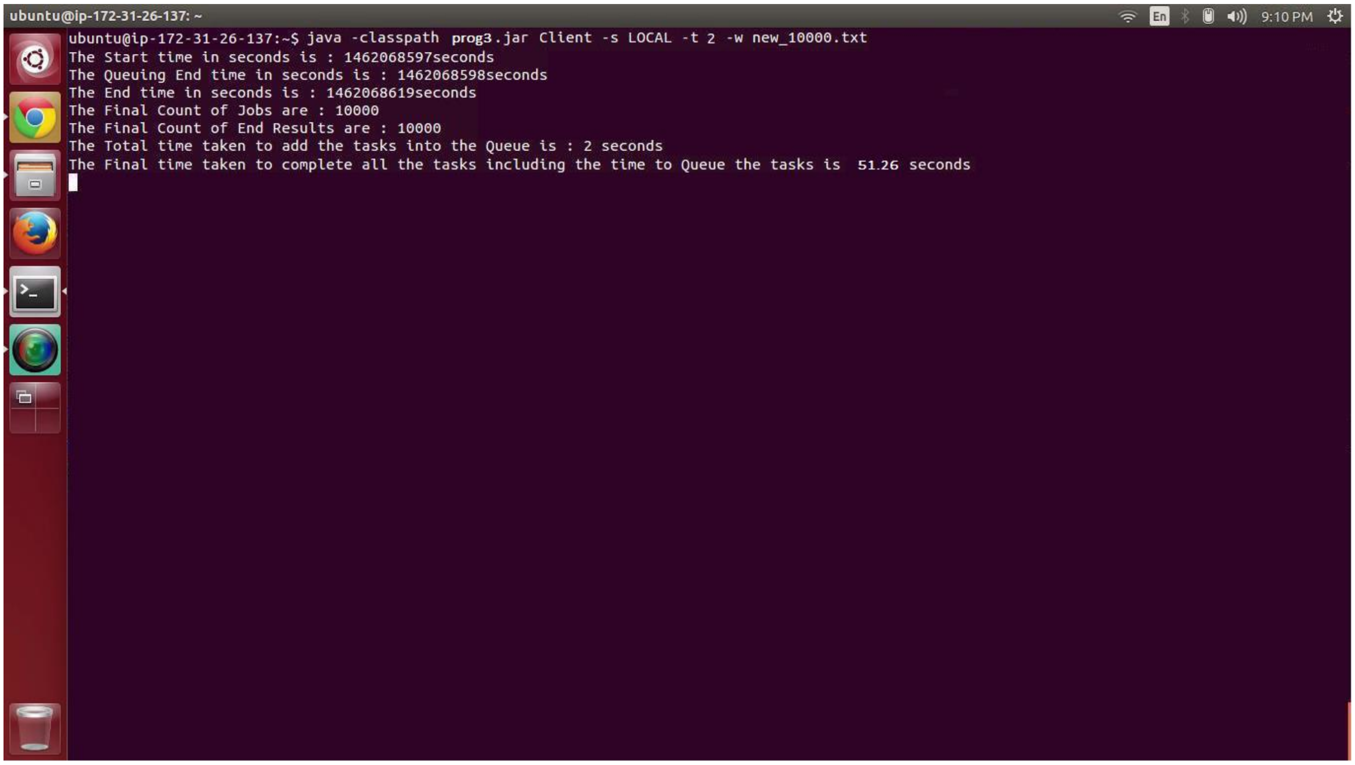
The throughput is calculated by 10000 / execution_time. For each experiment, a workload file contains 10k “sleep 0” is passed to the client. The client records the time first task object is sent to front-end, and the time it received the result of the last task.

Local:

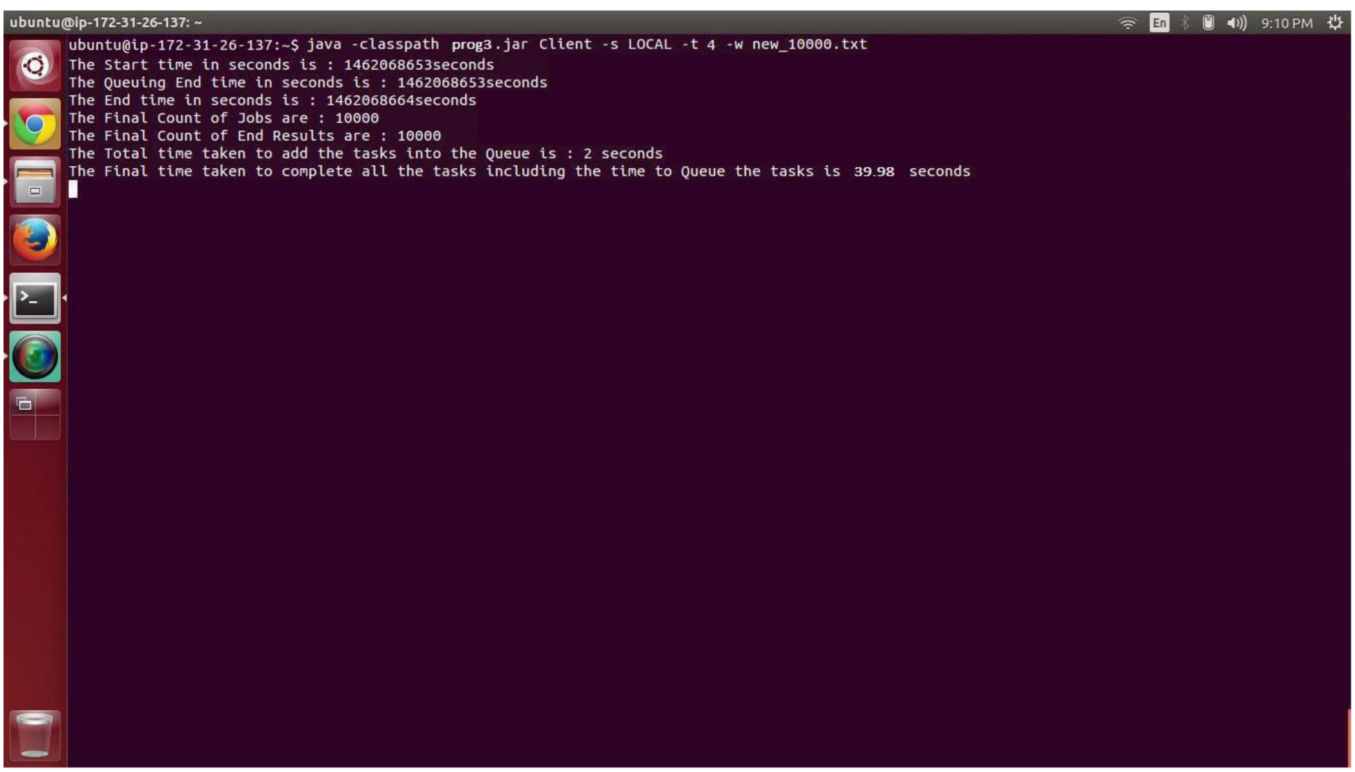
1 worker



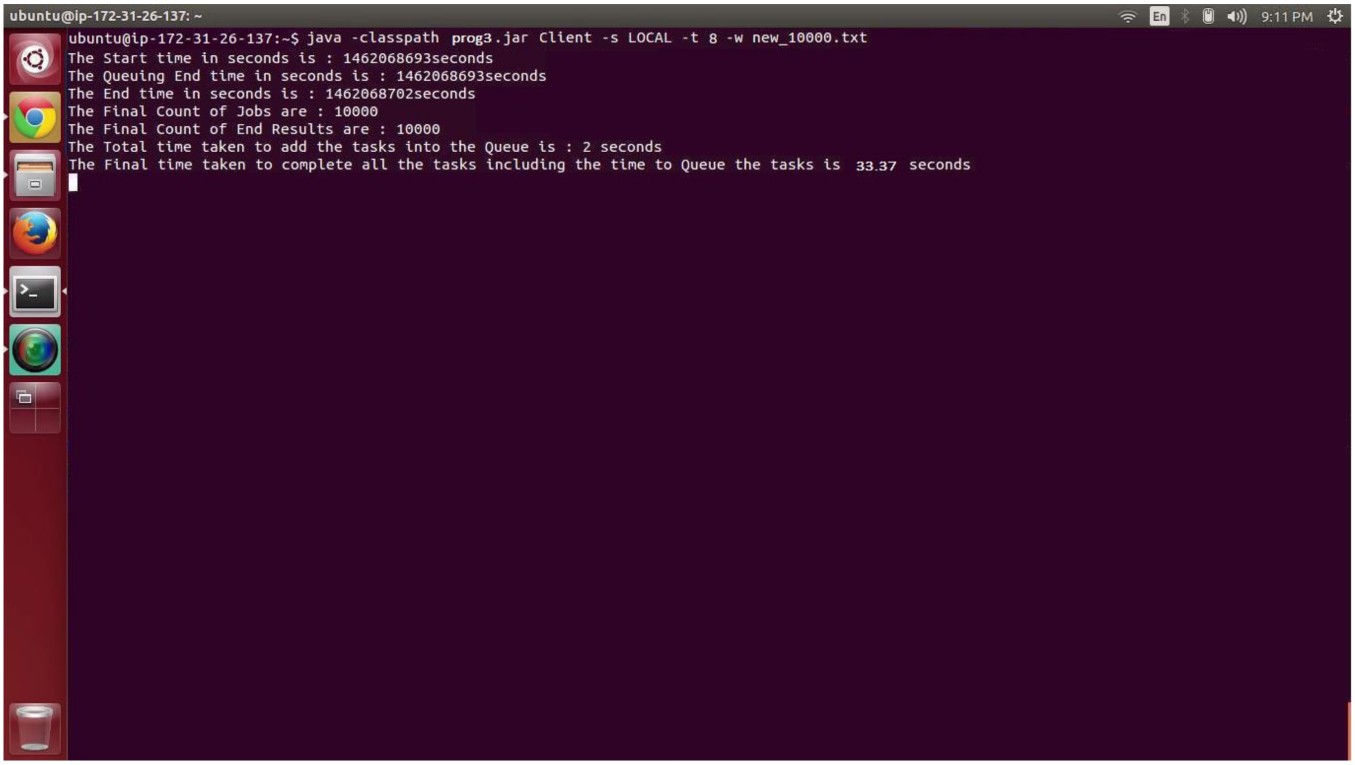
2 workers



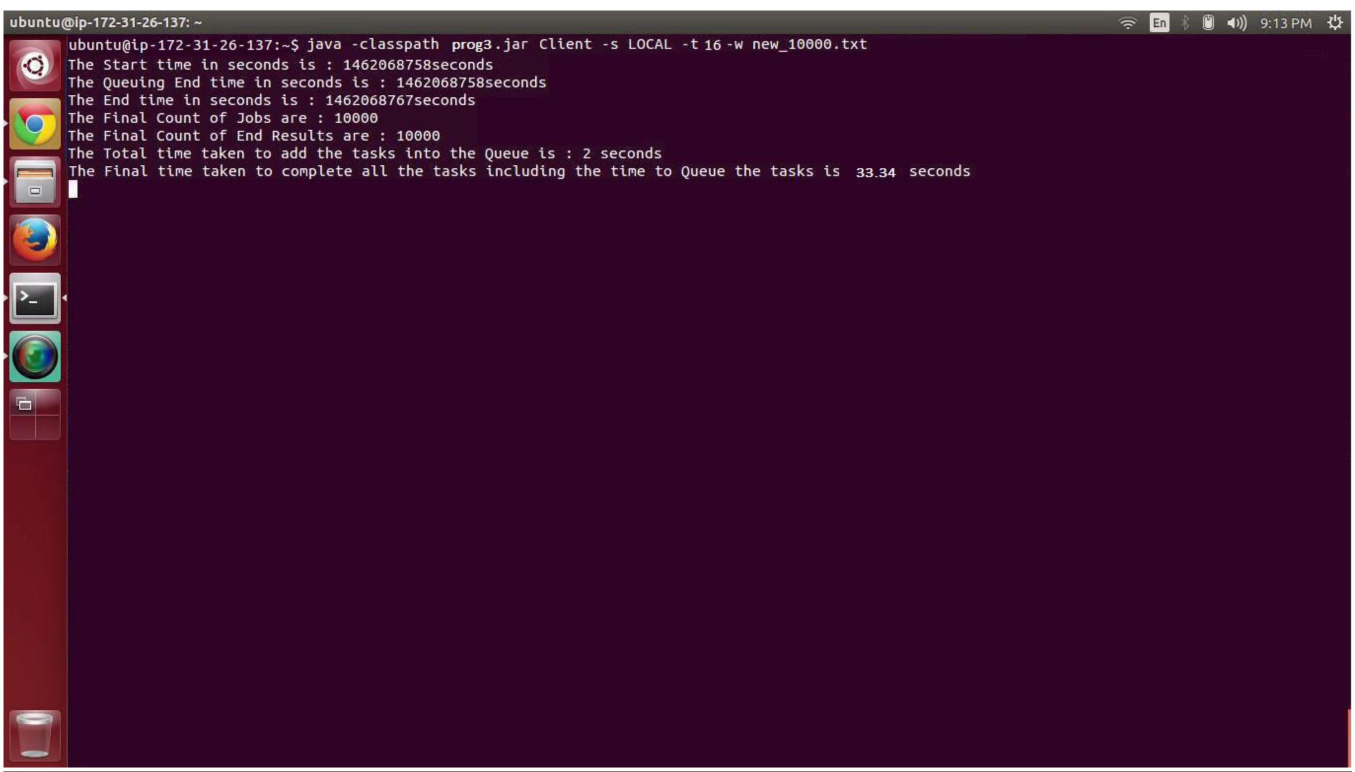
4 workers



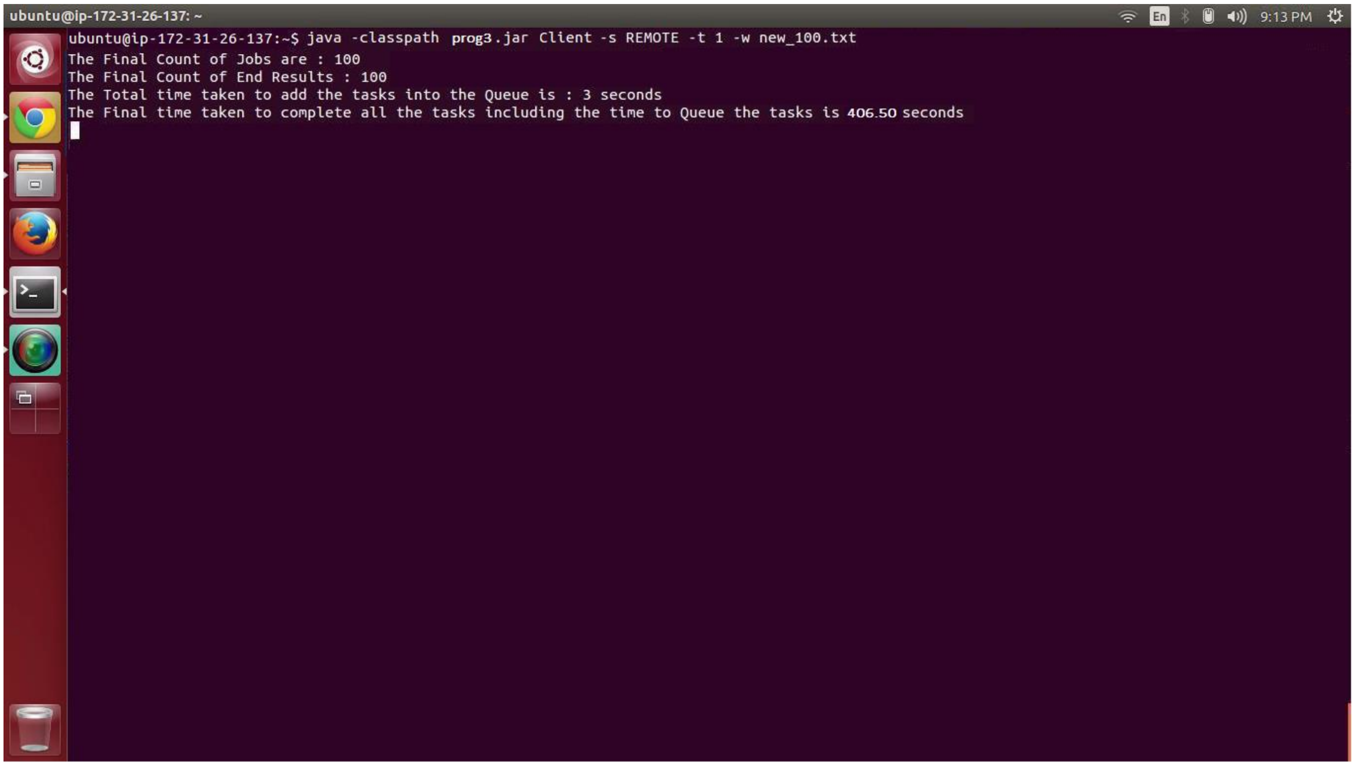
8 workers

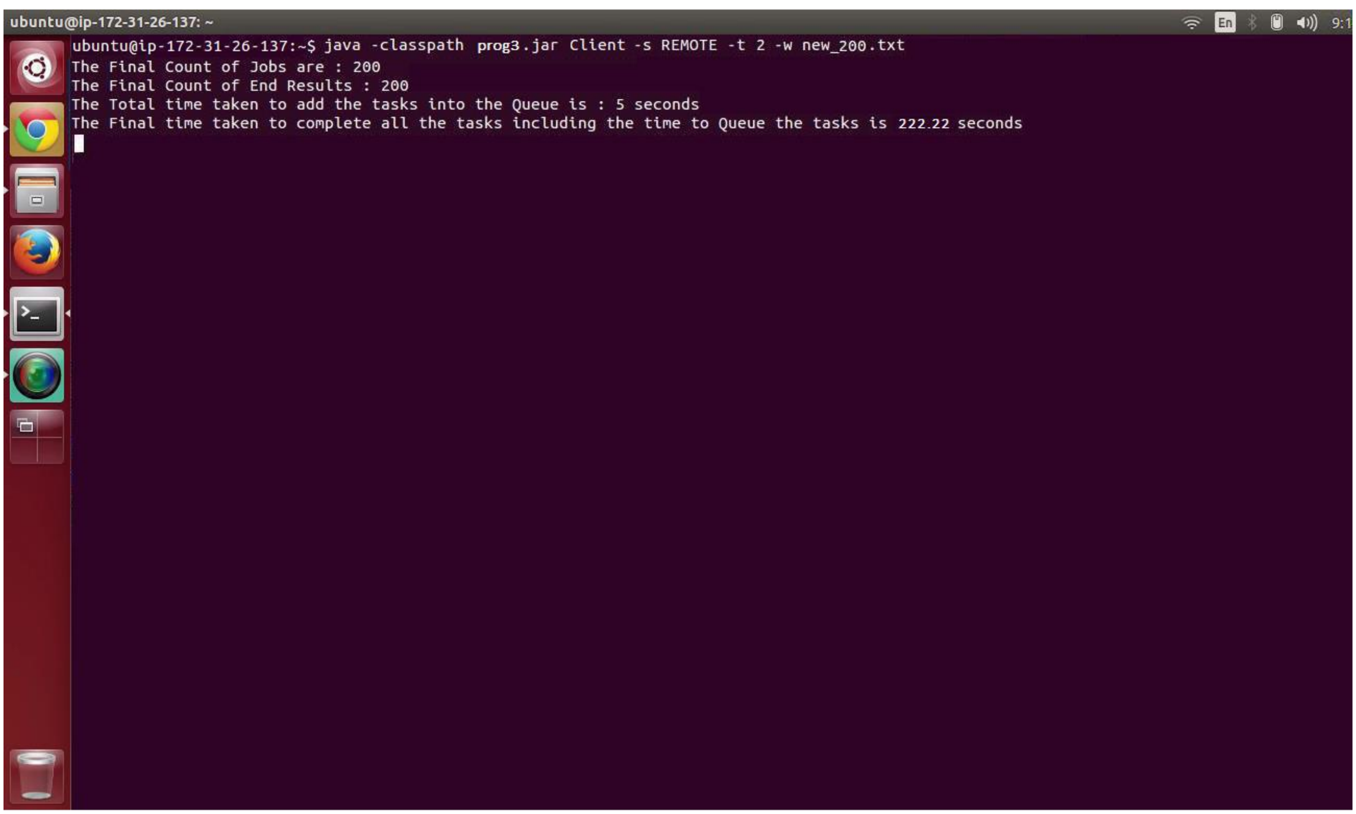


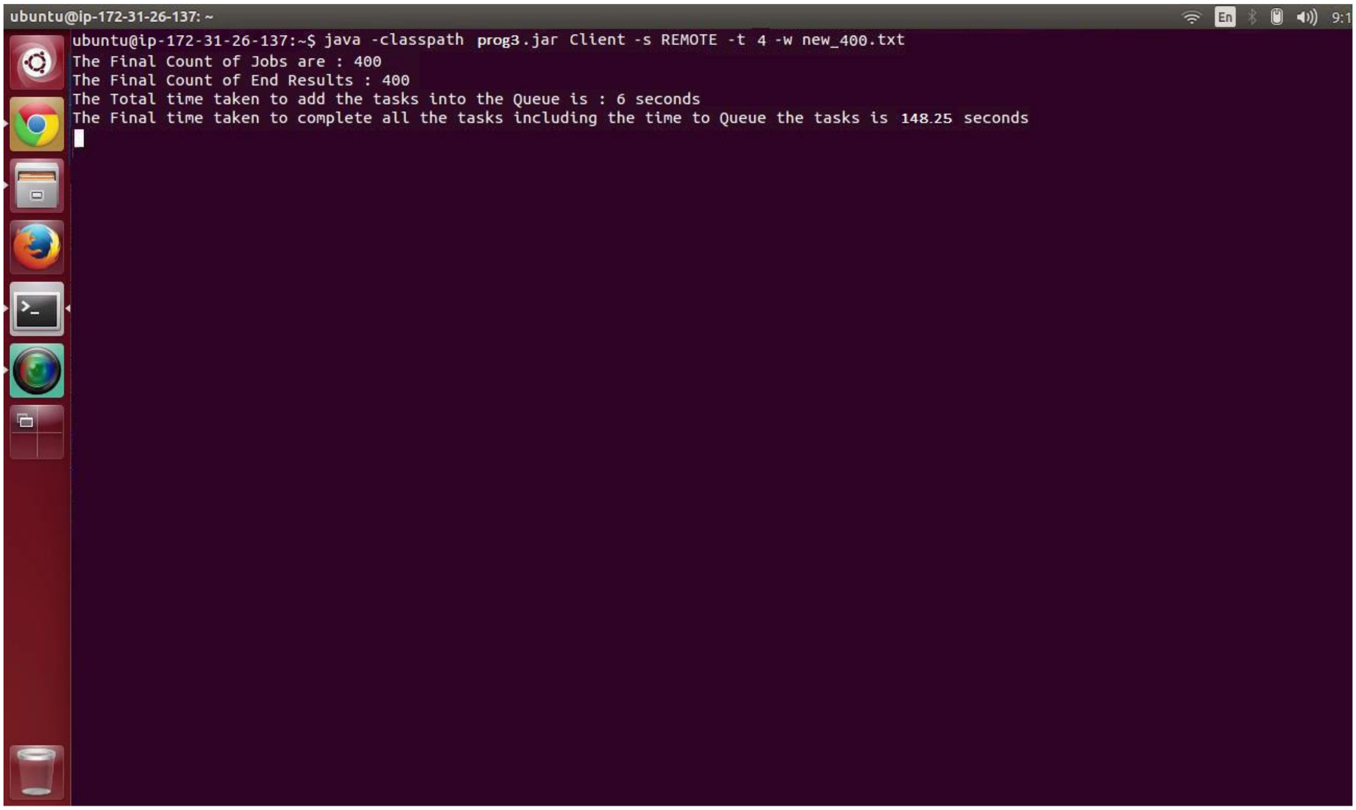
16 workers

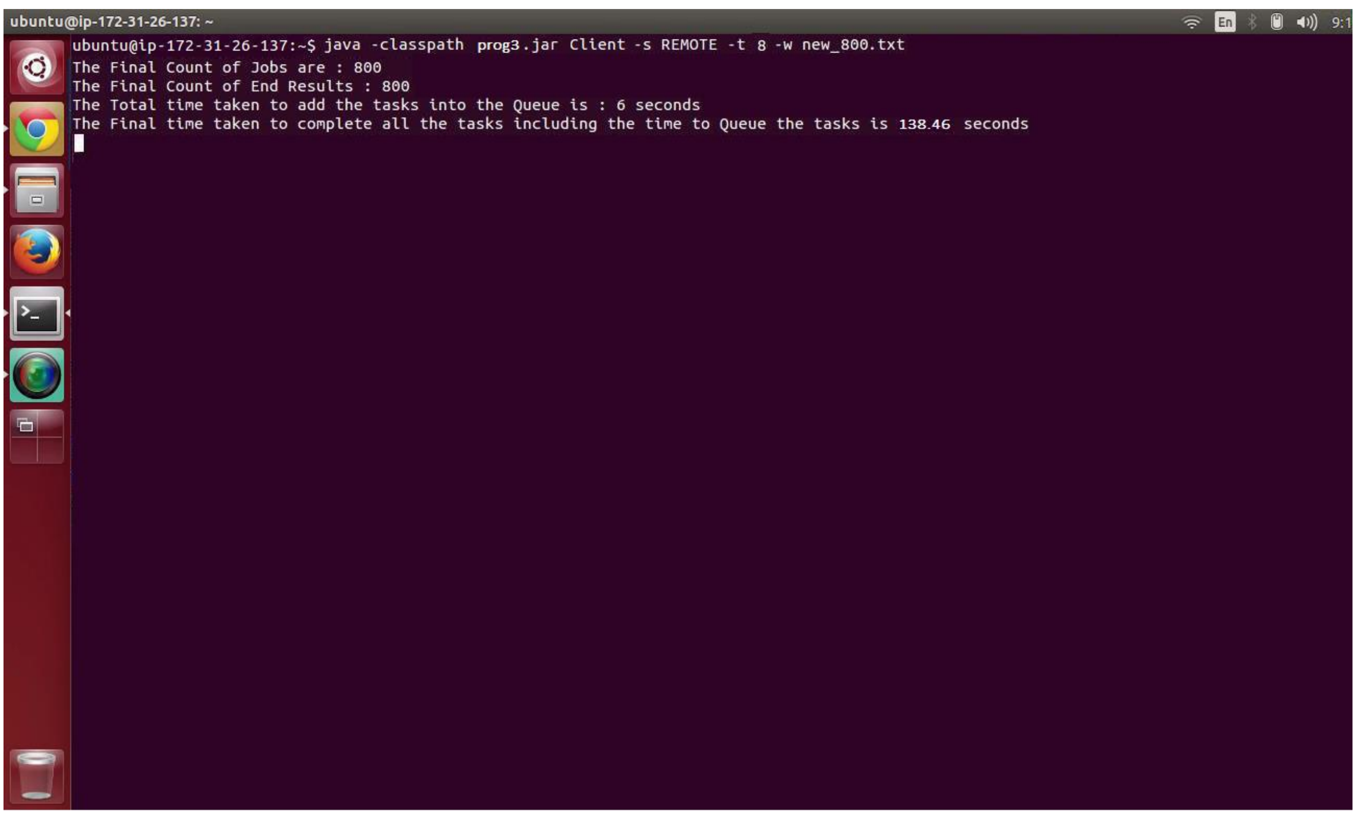


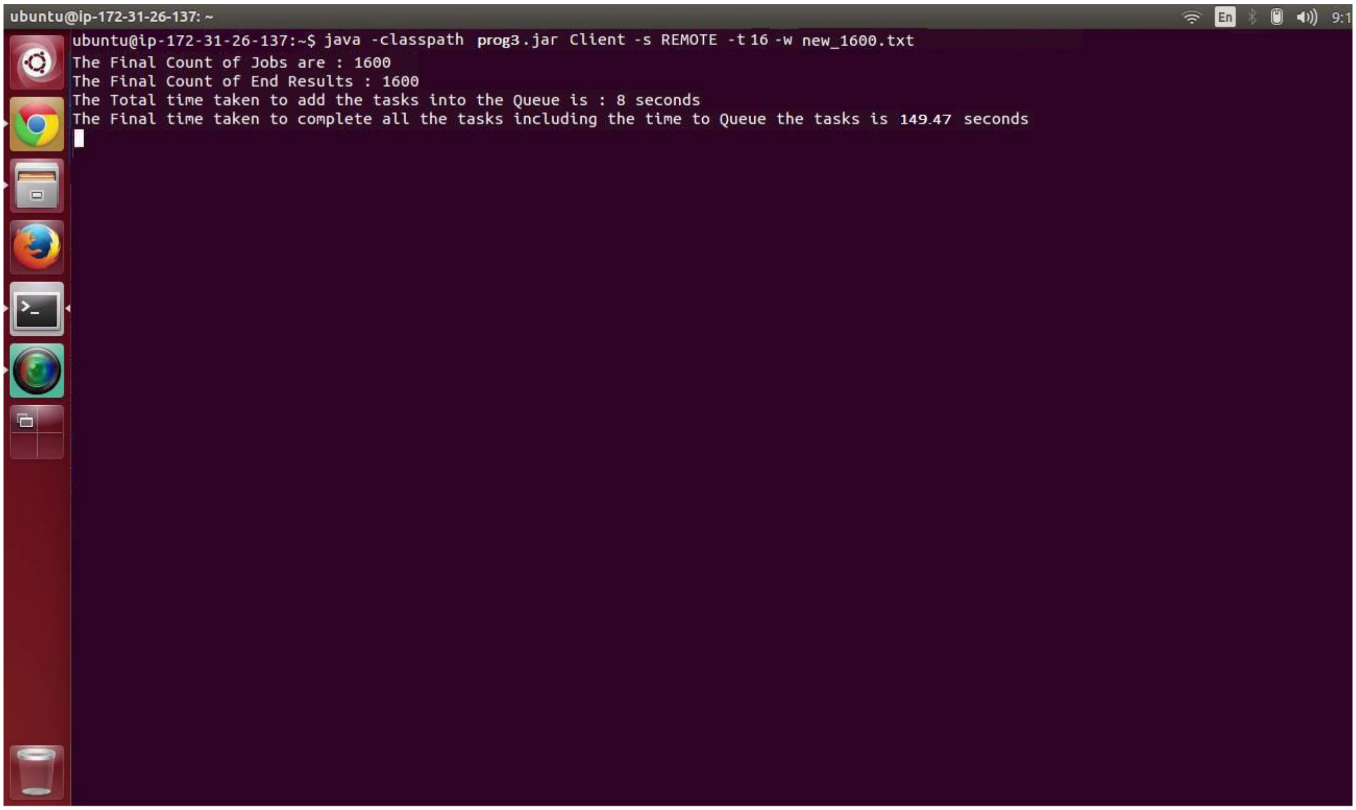
Remote:


ubuntu@ip-172-31-26-137: ~
9:13 PM
ubuntu@ip-172-31-26-137:~$ java -classpath prog3.jar Client -s REMOTE -t 1 -w new_100.txt
The Final Count of Jobs are : 100
The Final Count of End Results : 100
The Total time taken to add the tasks into the Queue is : 3 seconds
The Final time taken to complete all the tasks including the time to Queue the tasks is 406.50 seconds


ubuntu@ip-172-31-26-137: ~
ubuntu@ip-172-31-26-137:~$ java -classpath prog3.jar Client -s REMOTE -t 2 -w new_200.txt
The Final Count of Jobs are : 200
The Final Count of End Results : 200
The Total time taken to add the tasks into the Queue is : 5 seconds
The Final time taken to complete all the tasks including the time to Queue the tasks is 222.22 seconds

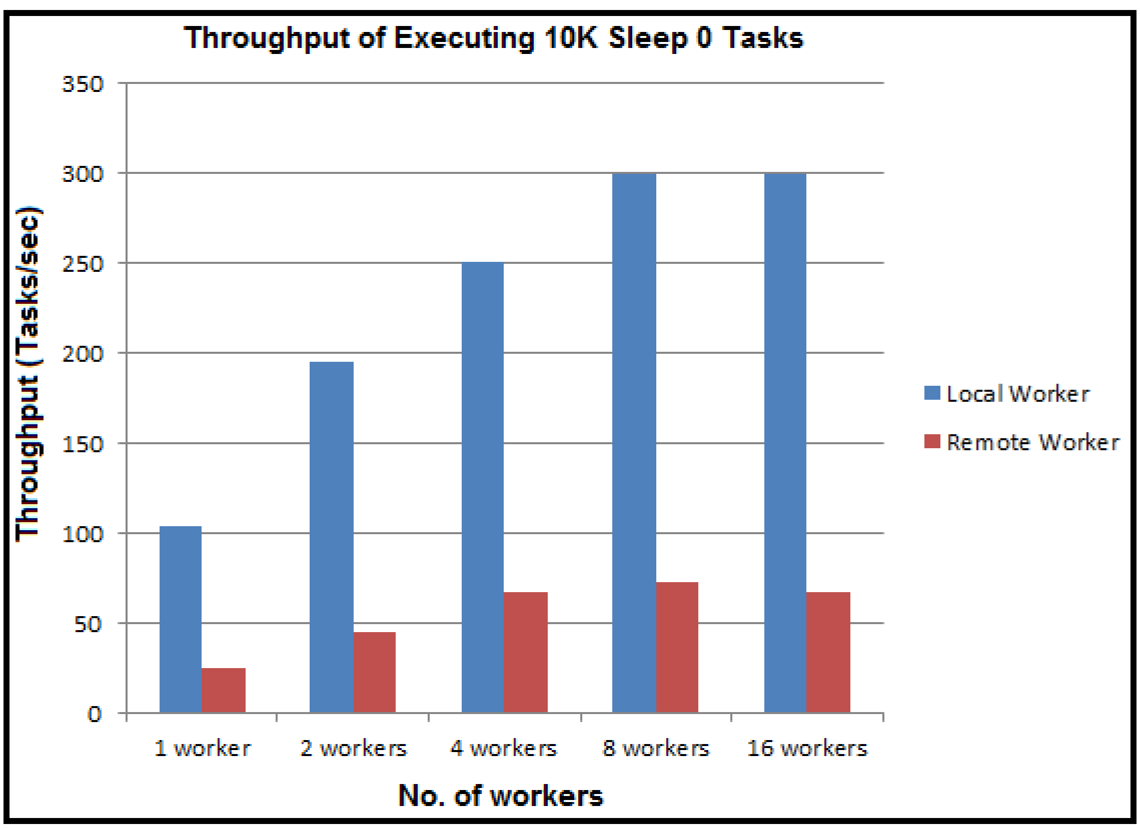

ubuntu@ip-172-31-26-137: ~
ubuntu@ip-172-31-26-137:~$ java -classpath prog3.jar Client -s REMOTE -t 4 -w new_400.txt
The Final Count of Jobs are : 400
The Final Count of End Results : 400
The Total time taken to add the tasks into the Queue is : 6 seconds
The Final time taken to complete all the tasks including the time to Queue the tasks is 148.25 seconds


ubuntu@ip-172-31-26-137: ~
ubuntu@ip-172-31-26-137:~$ java -classpath prog3.jar Client -s REMOTE -t 8 -w new_800.txt
The Final Count of Jobs are : 800
The Final Count of End Results : 800
The Total time taken to add the tasks into the Queue is : 6 seconds
The Final time taken to complete all the tasks including the time to Queue the tasks is 138.46 seconds



<u>Throughput:</u>

	1 worker	2 workers	4 workers	8 workers	16 workers
Local Worker	103.59	195.07	250.12	299.59	299.89
Remote Worker	24.6	45	67.45	72.22	66.9

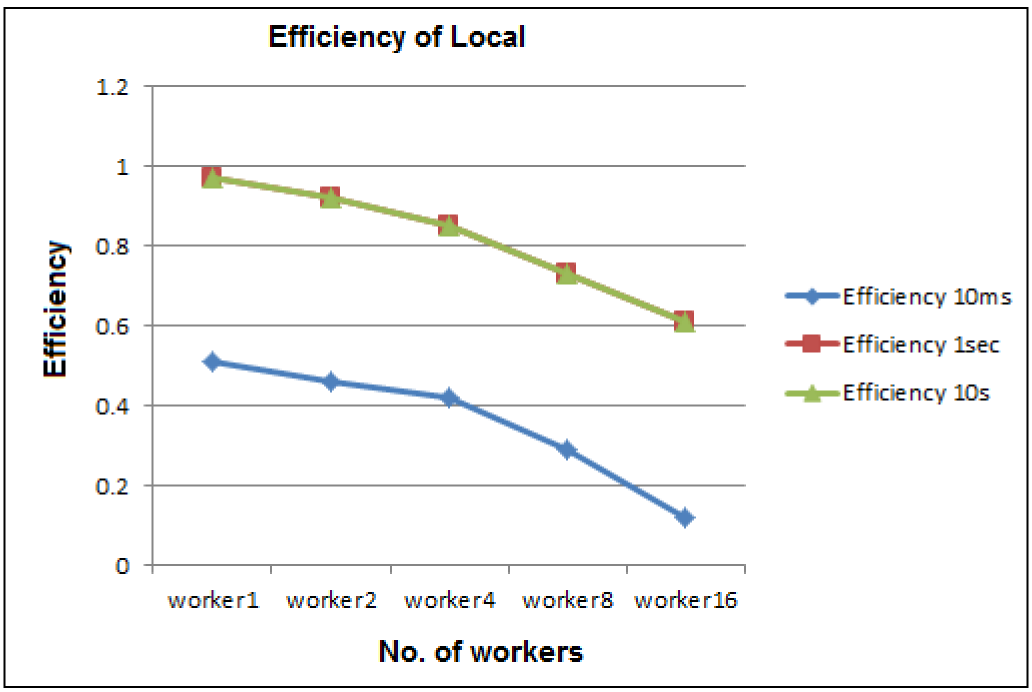


Both local worker and remote worker scale from 1-worker to 2-worker ideally. Their throughput improvements brought by more parallelism both stop working at 8-worker setting. For remote worker experiments, by observing dynamics of queue length at AWS SQS monitor, we find that starting at 8-worker setting, our frontend can no longer keep up with the pace the multiple workers are generating; e.g., 0 task in task queue, but more than a thousand results in result queue. Hence, the parallelism capacity of AWS services is impressive, and the throughput in our system is bottlenecked at frontend.

3.2 Efficiency Evaluation

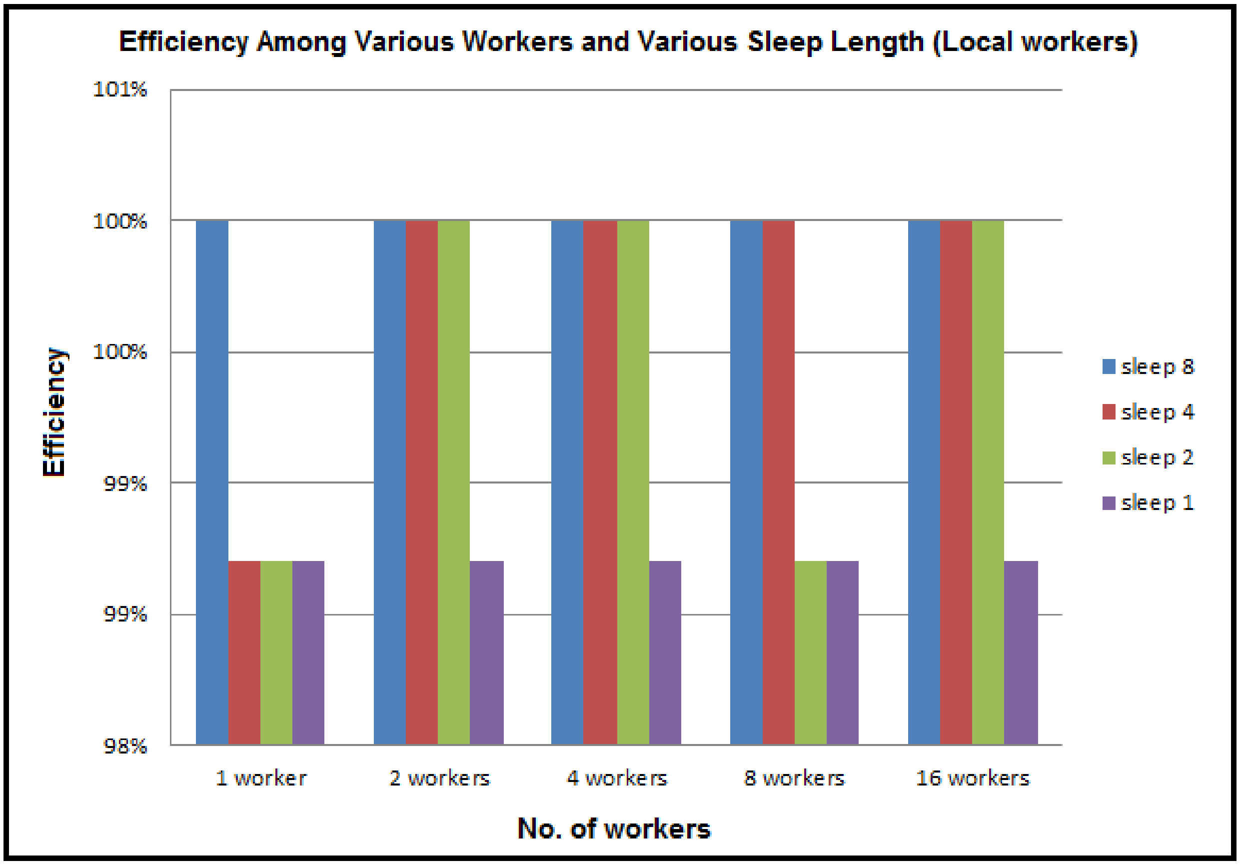
3.2.1 Local workers

	worker1	worker2	worker4	worker8	worker16
Efficiency 10ms	0.51	0.46	0.42	0.29	0.12
Efficiency 1sec	0.97	0.92	0.85	0.73	0.61
Efficiency 10s	0.97	0.92	0.85	0.73	0.61



The efficiency is calculated by 80 / execution_time. For each experiment, a workload file is generated in a way such that every worker will have the average sleep time to be 80 seconds. The client records the time first task object is sent to front-end, and the time it received the result of the last task.

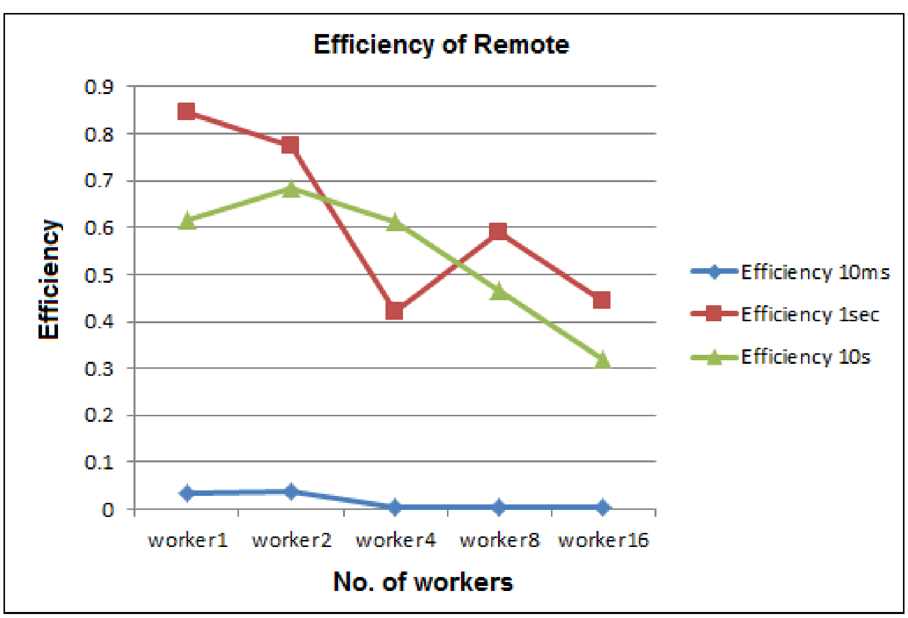
	1 worker	2 workers	4 workers	8 workers	16 workers
sleep 8	100%	100%	100%	100%	100%
sleep 4	98.70%	100%	100%	100%	100%
sleep 2	98.70%	100%	100%	98.70%	100%
sleep 1	98.70%	98.70%	98.70%	98.70%	98.70%



Running local workers show great efficiency in all experiments. sleep 1 experiments do show lower efficiency due to much more overheads with the same amount of real work.

3.2.1 Remote workers

	worker1	worker2	worker4	worker8	worker16
Efficiency 10ms	0.03421	0.03808	0.0057	0.00386	0.00254
Efficiency 1sec	0.84316	0.77367	0.41952	0.58834	0.44491
Efficiency 10s	0.61613	0.68436	0.6117	0.46555	0.31925



Let's first take a detailed look at a simplest case where there is only 1 worker, and 1 task, which is sleep 1:

- a task is read from disk at the client's machine, wrapped into a task object, and sent to the frontend over a TCP connection;

- the frontend then wrap the received task object into a SQS message, and sends it off to the task queue;

- 1 worker fetches messages in every half-second while idle, until a non-empty message is retrieved. Once the message is retrieved, worker first sends its task id off to task table (using DynamoDB) for consistency check. If the task id is proved to be valid, worker passes the task to local process to execute; if invalid, ignore and idle;

- Local process sleeps for 1 second, and informs worker the success of the run;

- Worker wraps updated task object (with result) in a SQS message, and sends it off to result queue, from which frontend fetches once every 10ms;

- When the frontend retrieves a nonempty message from result queue, it immediately carves out the task object within, and sends it back to client over a TCP connection;
- The client reads the resulting *task* object from TCP connection and displays it content on screen; and the user is notified that the task has been finished.

The entire process above consists of 8 transfers between 6 entities:

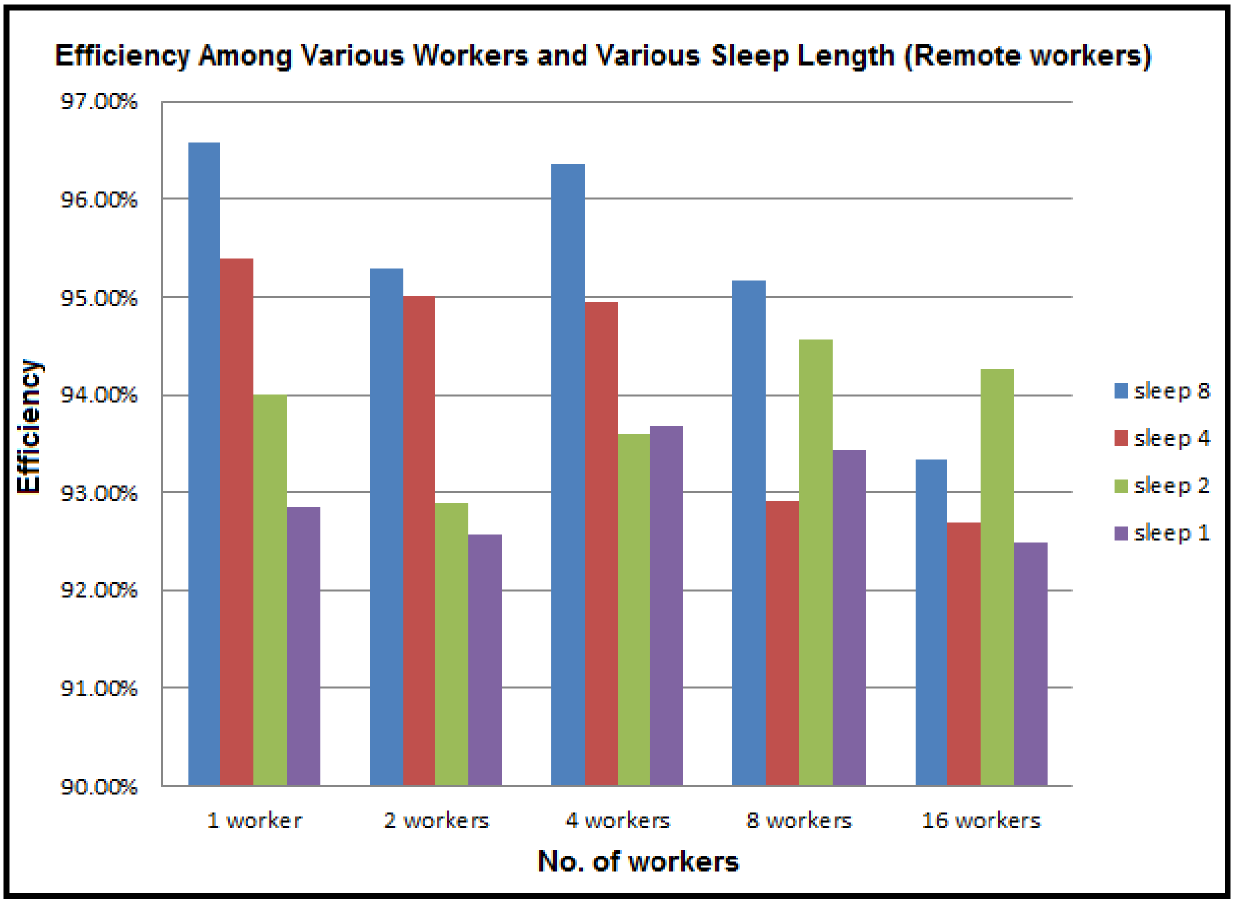
- client *to* frontend *to* task queue *to* worker *to* task table *back to* worker *to* result queue *back to* frontend *back to* client.

Denote the overhead in this process as Δ*t* seconds, for 1worker experiments, we have their total run time (in seconds) presented as follows:

- 8 sec, 10 tasks: $(8 + \Delta t) \times 10 = 80 + 10\Delta t$;
- 4 sec, 20 tasks: $(4 + \Delta t) \times 20 = 80 + 20\Delta t$;
- 2 sec, 40 tasks: $(2 + \Delta t) \times 40 = 80 + 40\Delta t$;
- 1 sec, 80 tasks: $(1 + \Delta t) \times 80 = 80 + 80\Delta t$.

After running the 4 × 5 Experiments, each with 3 runs, and get average run time, we can plot the following chart:

	1 worker	2 workers	4 workers	8 workers	16 workers
sleep 8	96.57%	95.28%	96.36%	95.17%	93.33%
sleep 4	95.40%	95.00%	94.94%	92.92%	92.69%
sleep 2	94.00%	92.90%	93.60%	94.57%	94.26%
sleep 1	92.85%	92.57%	93.67%	93.43%	92.49%



Aside from these finals results in chart, we have 2 major observations during experiments:

- in all experiments, frontend feeds task queue much faster than workers consume;
- in all experiments, client receives many “fake” results (utilized as heartbeat in order to keep TCP connections alive) from frontend, which means that the frontend retrieves results much faster than workers produces.

According to the two observations, we conclude that frontend overheads Δt_{front}

doesn't play big role in total overheads. And the total run time is largely dominated by 80 sec sleep time plus backend overheads.

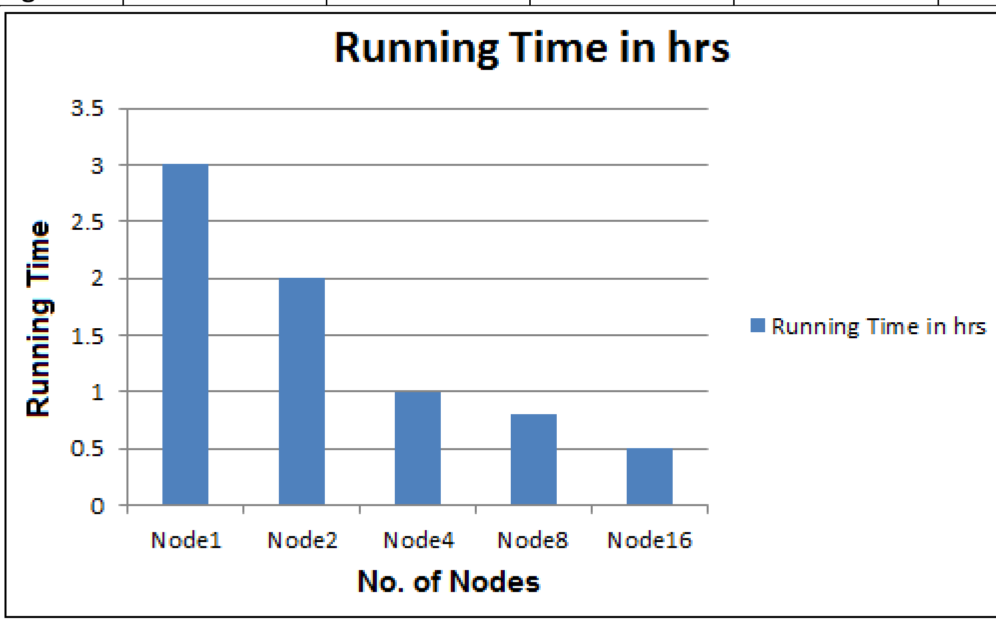
The chart confirms this, to certain degree. Experiment results within one cluster show a trend that efficiency decreases as sleep time shrinks (or, the total run time increases as sleep time shrinks). While experiment results across clusters for a given sleep time show a degree of evenness, suggesting that the elimination of front-end overheads in our analysis above is reasonable, and demonstrates scalability of AWS SQS service and DynamoDB service.

3.2. Animoto Clone:

- It runs on m1.small instances of EC2.
- Real time web applications (conversion of pictures to video) are done instead of sleeping application.
- Pictures from various web sites are collected and converted to video.
- Video is written to S3 and its location is specified to the user.

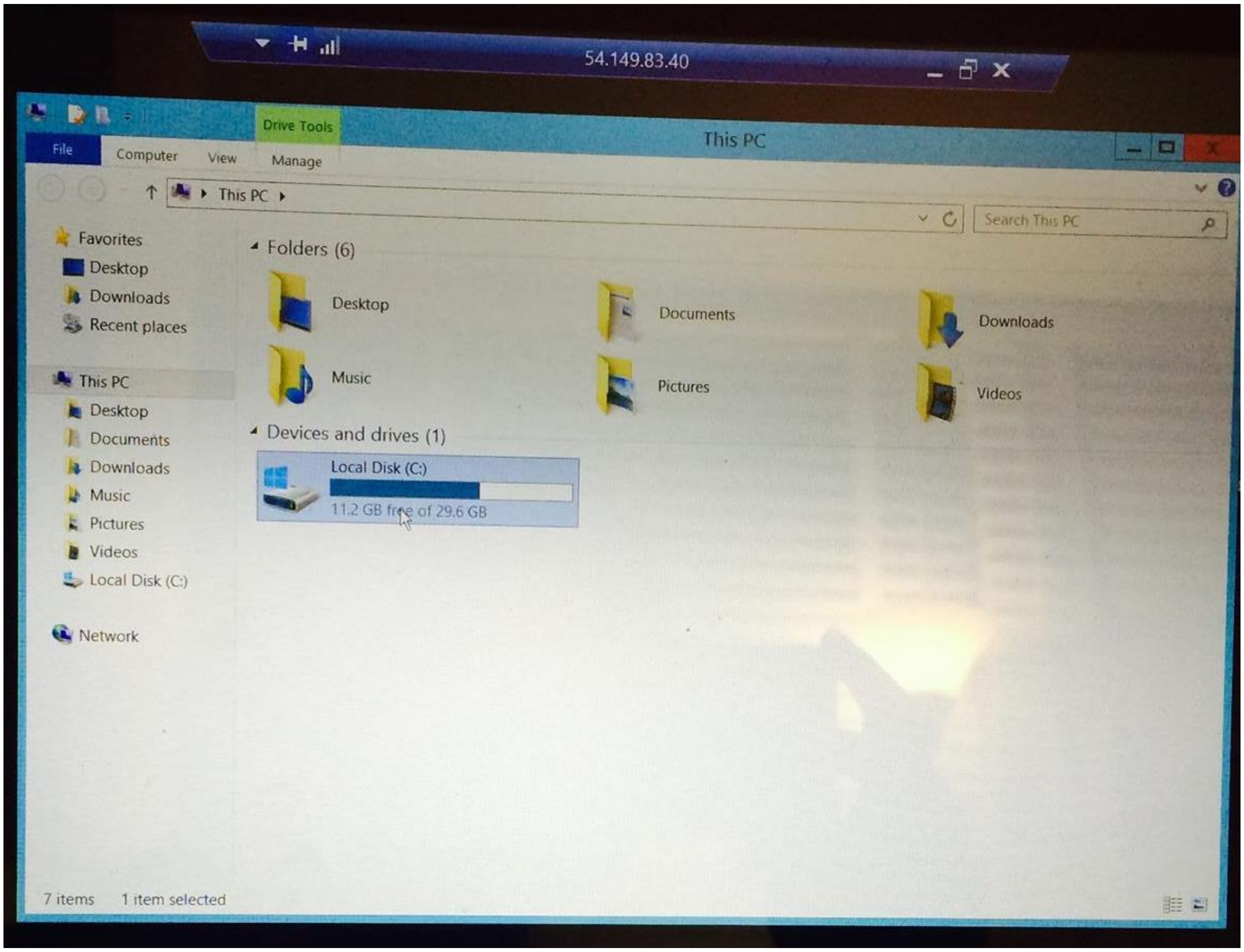
Fixed workload of 160 jobs were used and each job consists of 60pictures (1920*1080 resolution). The running time for 1,2,4,8 and 16 nodes were observed and plotted as follows

Number of nodes	1	2	4	8	16
Running time	3 h	2 h	1h	0.8 h	0.5 h

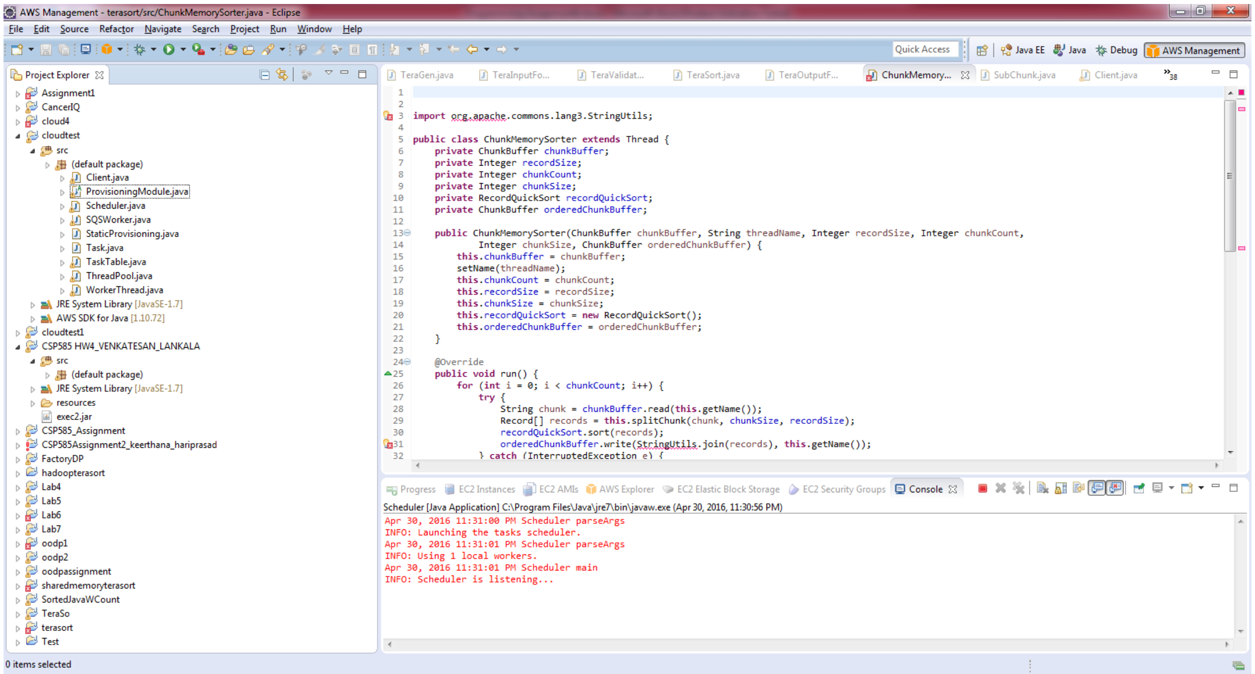


Steps:-

1. Will create Instances 'CLIENT' and 'SCHEDULER' in AWS (aws.amazon.com)
2. SQS have no messages this point, but during running it will contain the messages consists of JOB fromclient.
3. DynamoDB now it contains 0 rows, at runtime time it will contain the job status like success.
4. Scheduler will connect and download remote desktop IP and start that remote IP

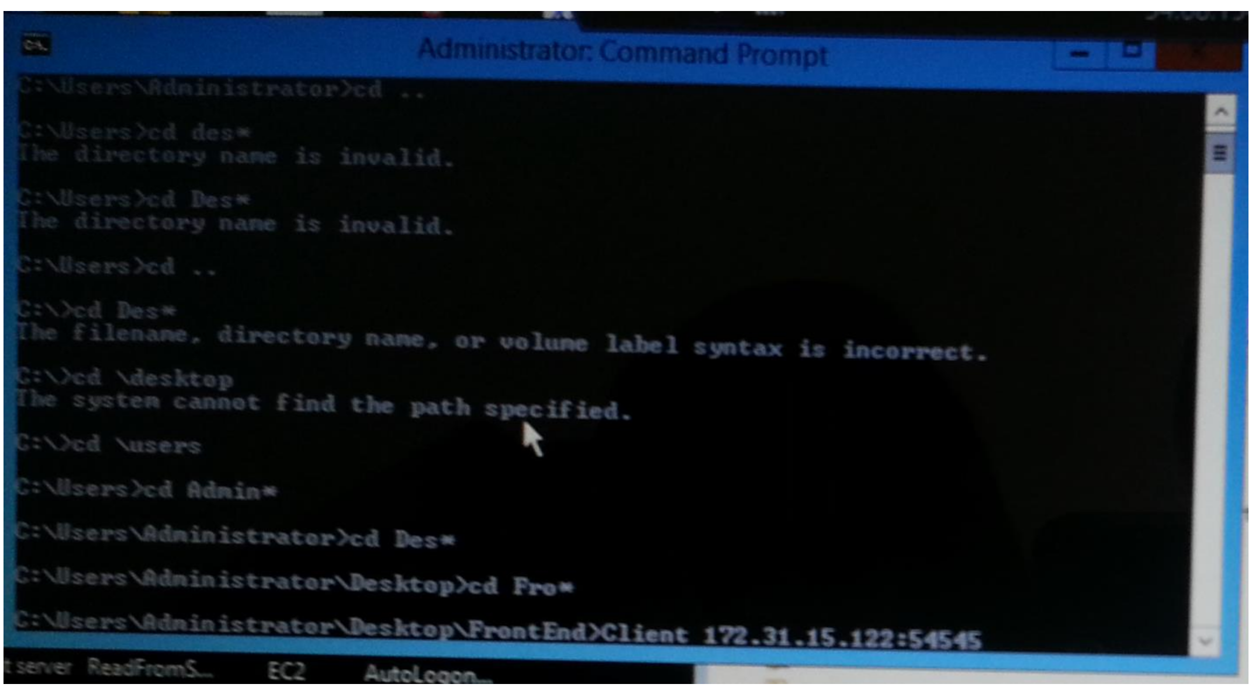


5. In Remote Desktop go to Local Desktop-> workout-> main->Scheduler.java
6. Build the Scheduler java, and Run it to make the ports listen.

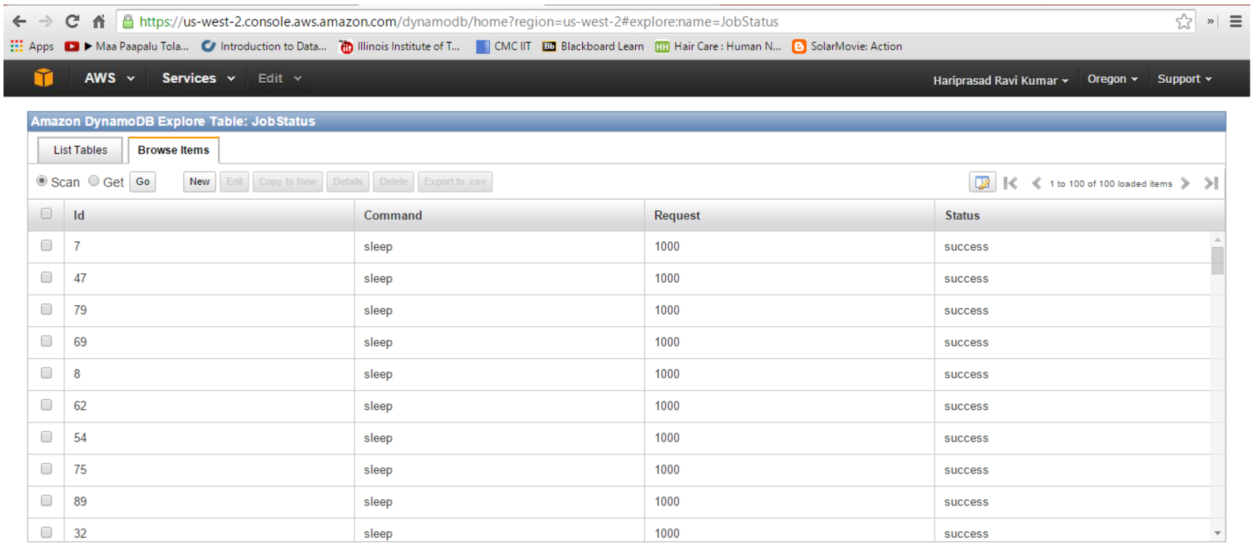


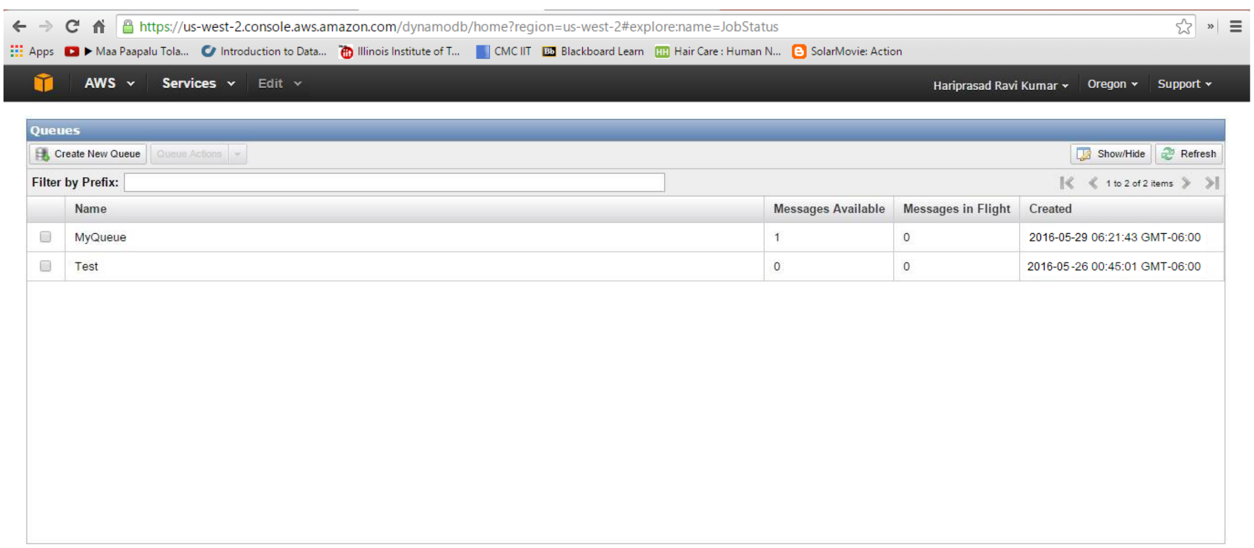
7. Build the Image Scheduler, Run it.

8. Connecting Client Instance to Remote Desktop.
In remote desktop run in the command prompt,
Cd desktop
Cd Frontend
Client 172.31.15.122:54545 workload



After Running Front End DynamoDB and SQS:





References:-

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2. http://aws.amazon.com/sqs/
3. http://aws.amazon.com/s3/
4. http://aws.amazon.com/dynamodb/
5. http://www.ffmpeg.org/faq.html#How-do-I-encode-single-pictures-into-movies_003f
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