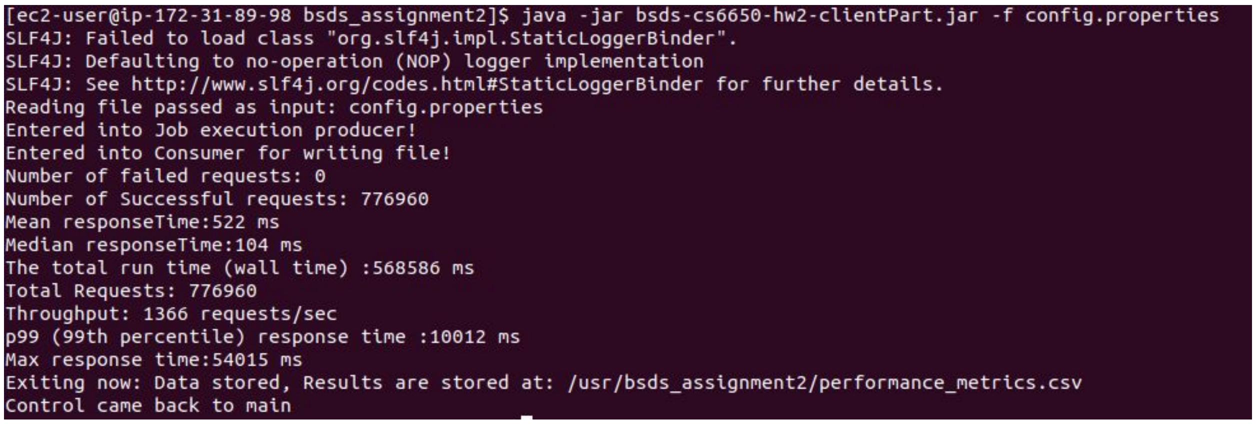
ASSIGNMENT 2

(CS 6650 - Building Scalable Distributed Systems)

Rahul Pandey
Github:
https://github.com/rahulpandeycs/bsds6650-Course-fall2020/tree/master/Assignment%202

Extra Credit part(Bonus):

Successful run with 512 as MAXthreads:



```
[ec2-user@ip-172-31-89-98 bsds_assignment2]$ java -jar bsds-cs6650-hw2-clientPart.jar -f config.properties
SLF4J: Failed to load class "org.slf4j.impl.StaticLoggerBinder".
SLF4J: Defaulting to no-operation (NOP) logger implementation
SLF4J: See http://www.slf4j.org/codes.html#StaticLoggerBinder for further details.
Reading file passed as input: config.properties
Entered into Job execution producer!
Entered into Consumer for writing file!
Number of failed requests: 0
Number of Successful requests: 776960
Mean responseTime:522 ms
Median responseTime:104 ms
The total run time (wall time) :568586 ms
Total Requests: 776960
Throughput: 1366 requests/sec
p99 (99th percentile) response time :10012 ms
Max response time:54015 ms
Exiting now: Data stored, Results are stored at: /usr/bsds_assignment2/performance_metrics.csv
Control came back to main
```

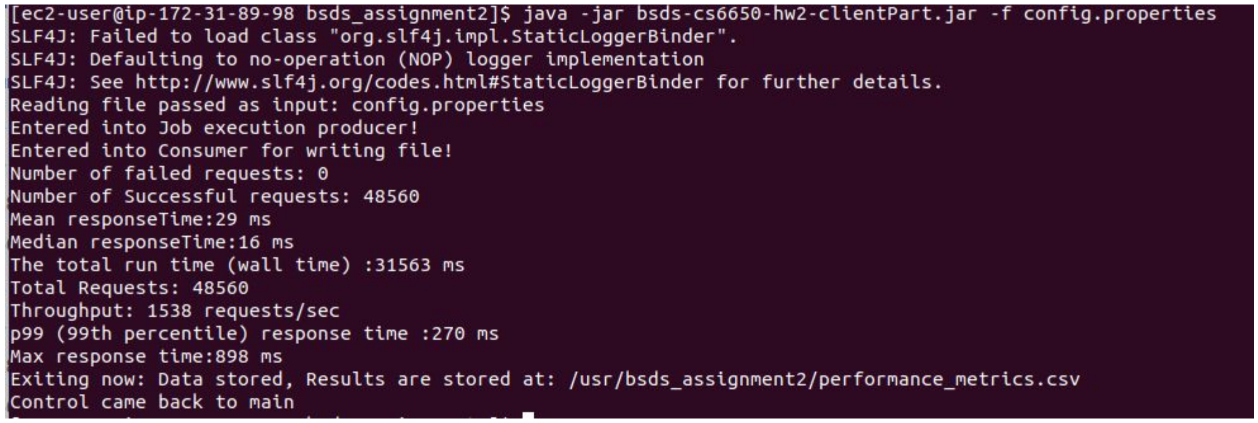
Running logs:

https://github.com/rahulpandeycs/bsds6650-Course-fall2020/tree/master/Assignment%202/RunLogs

Single server tests:(Free 1 Ec2 Tier, Single RDS Instance with Free tier plan)

32 Threads

ScreenShot:



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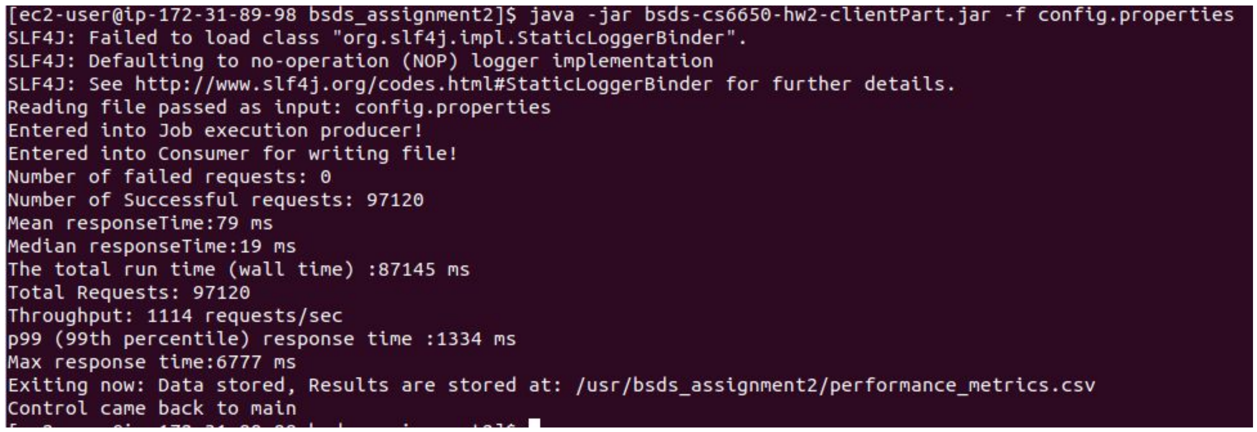
SLF4J: See http://www.slf4j.org/codes.html#StaticLoggerBinder for further details.
Reading file passed as input: config.properties
Entered into Job execution producer!
Entered into Consumer for writing file!
Number of failed requests: 0
Number of Successful requests: 48560
Mean responseTime:29 ms
Median responseTime:16 ms
The total run time (wall time) :31563 ms
Total Requests: 48560
Throughput: 1538 requests/sec
p99 (99th percentile) response time :270 ms
Max response time:898 ms
Exiting now: Data stored, Results are stored at: /usr/bsds_assignment2/performance_metrics.csv
Control came back to main
```

GeneratedCSv:
https://github.com/rahulpandeycs/bsds6650-Course-fall2020/blob/master/Assignment%202/RunLogs/32Threads/SingleInstancePerformance.csv

64 Threads

ScreenShot:



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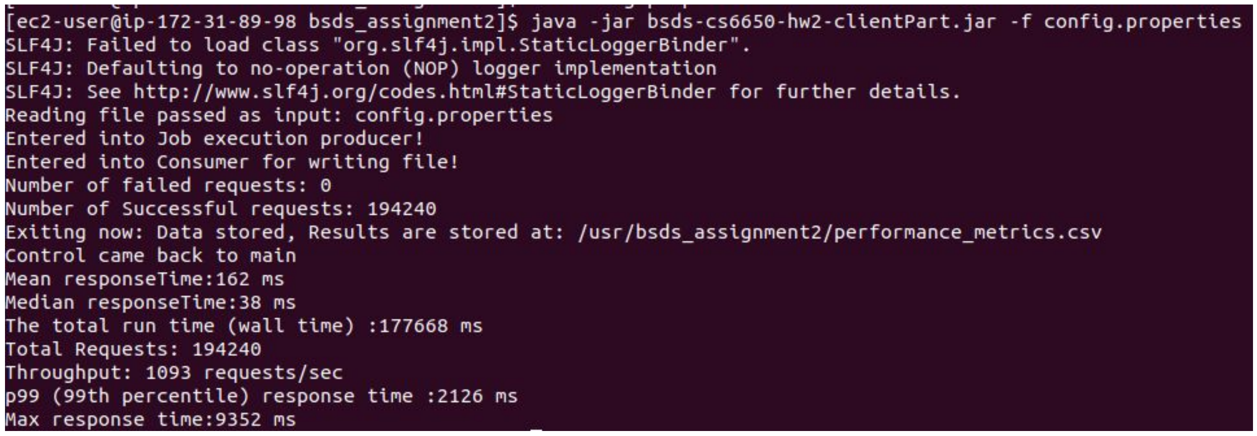
SLF4J: Defaulting to no-operation (NOP) logger implementation
SLF4J: See http://www.slf4j.org/codes.html#StaticLoggerBinder for further details.
Reading file passed as input: config.properties
Entered into Job execution producer!
Entered into Consumer for writing file!
Number of failed requests: 0
Number of Successful requests: 97120
Mean responseTime:79 ms
Median responseTime:19 ms
The total run time (wall time) :87145 ms
Total Requests: 97120
Throughput: 1114 requests/sec
p99 (99th percentile) response time :1334 ms
Max response time:6777 ms
Exiting now: Data stored, Results are stored at: /usr/bsds_assignment2/performance_metrics.csv
Control came back to main
```

GeneratedCSv:
https://github.com/rahulpandeycs/bsds6650-Course-fall2020/blob/master/Assignment%202/RunLogs/64Threads/SingleInstancePerformance.csv

128 Threads

ScreenShot:



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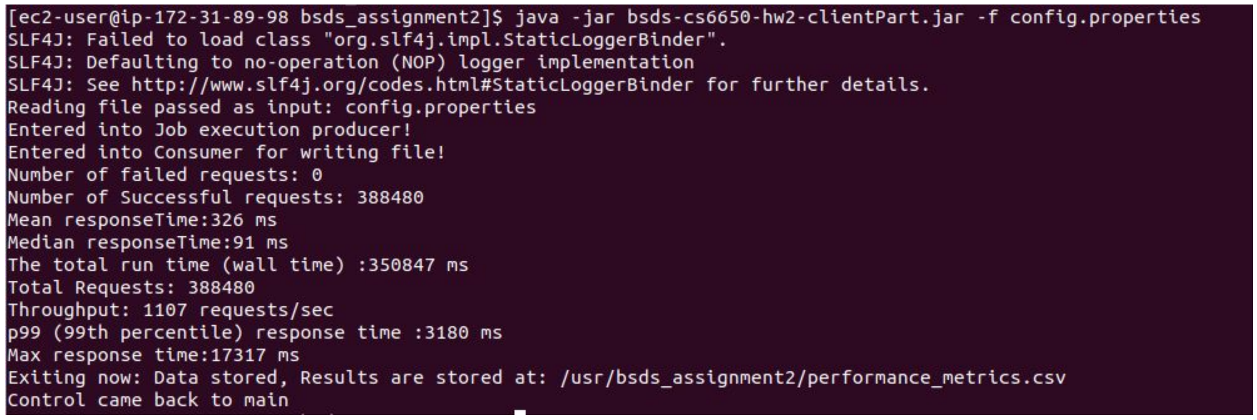
SLF4J: Defaulting to no-operation (NOP) logger implementation
SLF4J: See http://www.slf4j.org/codes.html#StaticLoggerBinder for further details.
Reading file passed as input: config.properties
Entered into Job execution producer!
Entered into Consumer for writing file!
Number of failed requests: 0
Number of Successful requests: 194240
Exiting now: Data stored, Results are stored at: /usr/bsds_assignment2/performance_metrics.csv
Control came back to main
Mean responseTime:162 ms
Median responseTime:38 ms
The total run time (wall time) :177668 ms
Total Requests: 194240
Throughput: 1093 requests/sec
p99 (99th percentile) response time :2126 ms
Max response time:9352 ms
```

GeneratedCSv:
https://github.com/rahulpandeycs/bsds6650-Course-fall2020/blob/master/Assignment%202/RunLogs/128 Threads/SingleInstancePerformance.csv

256Threads

ScreenShot:



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SLF4J: Defaulting to no-operation (NOP) logger implementation
SLF4J: See http://www.slf4j.org/codes.html#StaticLoggerBinder for further details.
Reading file passed as input: config.properties
Entered into Job execution producer!
Entered into Consumer for writing file!
Number of failed requests: 0
Number of Successful requests: 388480
Mean responseTime:326 ms
Median responseTime:91 ms
The total run time (wall time) :350847 ms
Total Requests: 388480
Throughput: 1107 requests/sec
p99 (99th percentile) response time :3180 ms
Max response time:17317 ms
Exiting now: Data stored, Results are stored at: /usr/bsds_assignment2/performance_metrics.csv
Control came back to main
```

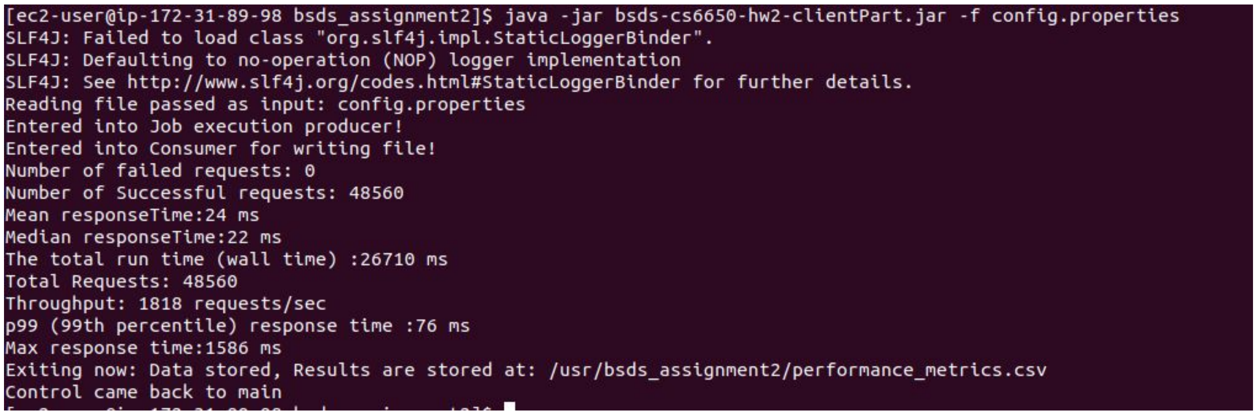
GeneratedCSv:

https://github.com/rahulpandeycs/bsds6650-Course-fall2020/blob/master/Assignment%202/RunLogs/256 Threads/SingleInstancePerformance.csv

Load Balanced tests: (Free 4 Ec2 Tier, Single RDS Instance with Free tier plan)

32 Threads

ScreenShot:



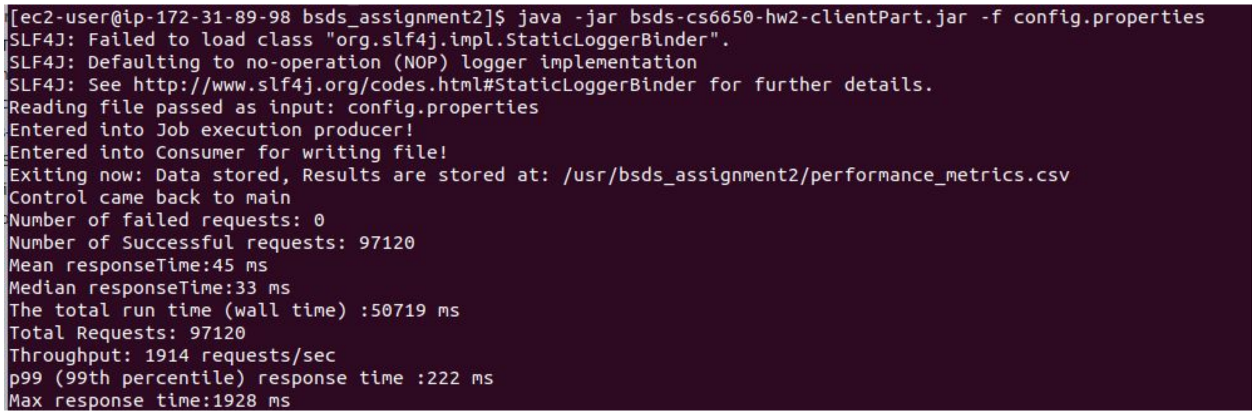
```
[ec2-user@ip-172-31-89-98 bsds_assignment2]$ java -jar bsds-cs6650-hw2-clientPart.jar -f config.properties
SLF4J: Failed to load class "org.slf4j.impl.StaticLoggerBinder".
SLF4J: Defaulting to no-operation (NOP) logger implementation
SLF4J: See http://www.slf4j.org/codes.html#StaticLoggerBinder for further details.
Reading file passed as input: config.properties
Entered into Job execution producer!
Entered into Consumer for writing file!
Number of failed requests: 0
Number of Successful requests: 48560
Mean responseTime:24 ms
Median responseTime:22 ms
The total run time (wall time) :26710 ms
Total Requests: 48560
Throughput: 1818 requests/sec
p99 (99th percentile) response time :76 ms
Max response time:1586 ms
Exiting now: Data stored, Results are stored at: /usr/bsds_assignment2/performance_metrics.csv
Control came back to main
```

GeneratedCSv:

https://github.com/rahulpandeycs/bsds6650-Course-fall2020/blob/master/Assignment%202/RunLogs/32Threads/loadBalancerPerformace.csv

64 Threads

ScreenShot:

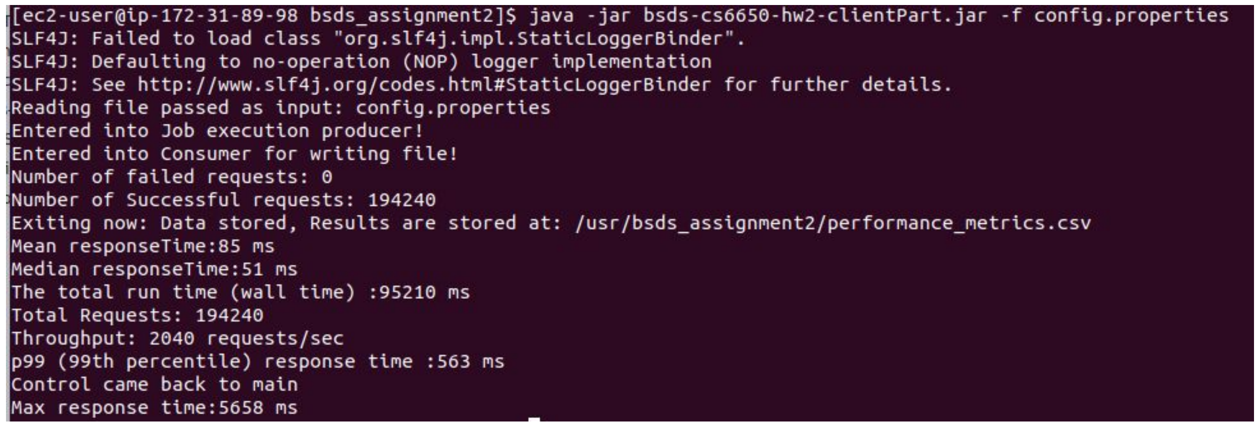


```
[ec2-user@ip-172-31-89-98 bsds_assignment2]$ java -jar bsds-cs6650-hw2-clientPart.jar -f config.properties
SLF4J: Failed to load class "org.slf4j.impl.StaticLoggerBinder".
SLF4J: Defaulting to no-operation (NOP) logger implementation
SLF4J: See http://www.slf4j.org/codes.html#StaticLoggerBinder for further details.
Reading file passed as input: config.properties
Entered into Job execution producer!
Entered into Consumer for writing file!
Exiting now: Data stored, Results are stored at: /usr/bsds_assignment2/performance_metrics.csv
Control came back to main
Number of failed requests: 0
Number of Successful requests: 97120
Mean responseTime:45 ms
Median responseTime:33 ms
The total run time (wall time) :50719 ms
Total Requests: 97120
Throughput: 1914 requests/sec
p99 (99th percentile) response time :222 ms
Max response time:1928 ms
```

GeneratedCSv:
https://github.com/rahulpandeycs/bsds6650-Course-fall2020/blob/master/Assignment%202/RunLogs/64Threads/loadBalancerPerformace.csv

128 Threads

ScreenShot:

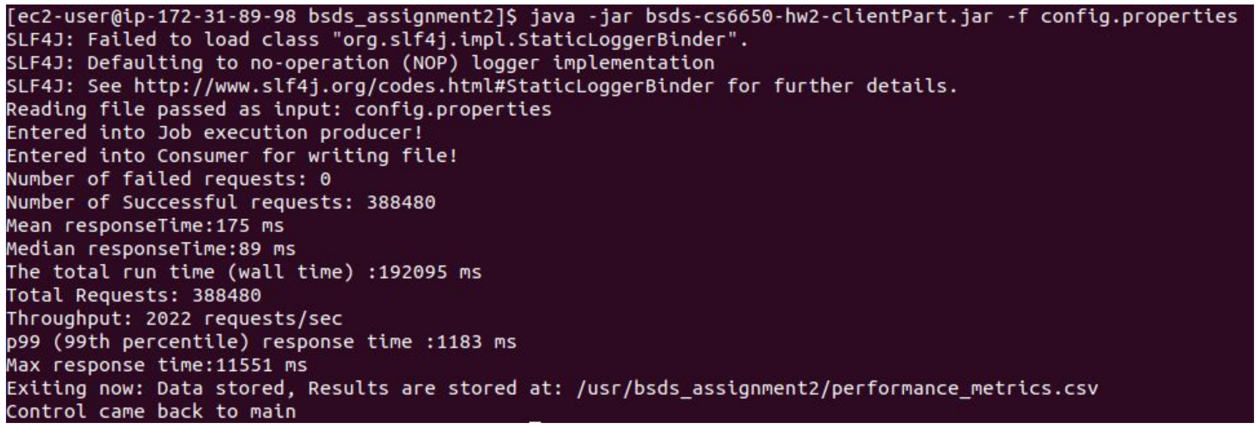


```
[ec2-user@ip-172-31-89-98 bsds_assignment2]$ java -jar bsds-cs6650-hw2-clientPart.jar -f config.properties
SLF4J: Failed to load class "org.slf4j.impl.StaticLoggerBinder".
SLF4J: Defaulting to no-operation (NOP) logger implementation
SLF4J: See http://www.slf4j.org/codes.html#StaticLoggerBinder for further details.
Reading file passed as input: config.properties
Entered into Job execution producer!
Entered into Consumer for writing file!
Number of failed requests: 0
Number of Successful requests: 194240
Exiting now: Data stored, Results are stored at: /usr/bsds_assignment2/performance_metrics.csv
Mean responseTime:85 ms
Median responseTime:51 ms
The total run time (wall time) :95210 ms
Total Requests: 194240
Throughput: 2040 requests/sec
p99 (99th percentile) response time :563 ms
Control came back to main
Max response time:5658 ms
```

GeneratedCSv:
https://github.com/rahulpandeycs/bsds6650-Course-fall2020/blob/master/Assignment%202/RunLogs/128Threads/loadBalancerPerformace.csv

256 Threads

ScreenShot:



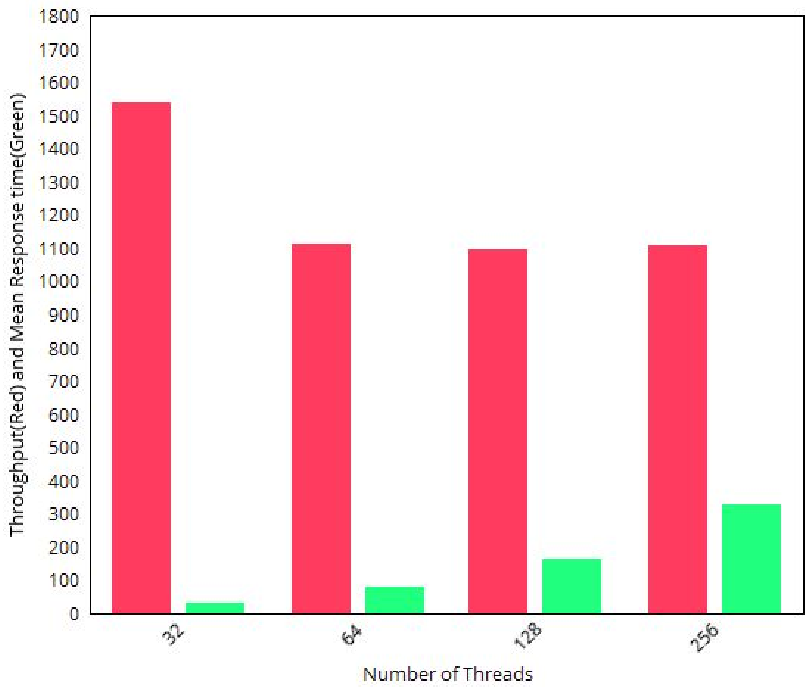
```
[ec2-user@ip-172-31-89-98 bsds_assignment2]$ java -jar bsds-cs6650-hw2-clientPart.jar -f config.properties
SLF4J: Failed to load class "org.slf4j.impl.StaticLoggerBinder".
SLF4J: Defaulting to no-operation (NOP) logger implementation
SLF4J: See http://www.slf4j.org/codes.html#StaticLoggerBinder for further details.
Reading file passed as input: config.properties
Entered into Job execution producer!
Entered into Consumer for writing file!
Number of failed requests: 0
Number of Successful requests: 388480
Mean responseTime:175 ms
Median responseTime:89 ms
The total run time (wall time) :192095 ms
Total Requests: 388480
Throughput: 2022 requests/sec
p99 (99th percentile) response time :1183 ms
Max response time:11551 ms
Exiting now: Data stored, Results are stored at: /usr/bsds_assignment2/performance_metrics.csv
Control came back to main
```

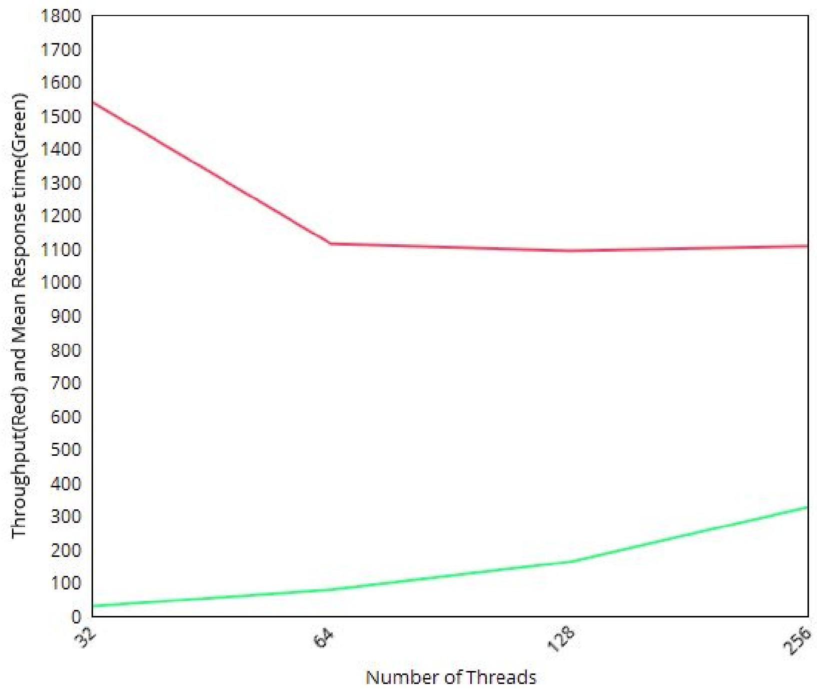
GeneratedCSv:

https://github.com/rahulpandeycs/bsds6650-Course-fall2020/blob/master/Assignment%202/RunLogs/256Threads/loadBalancerPerformace.csv

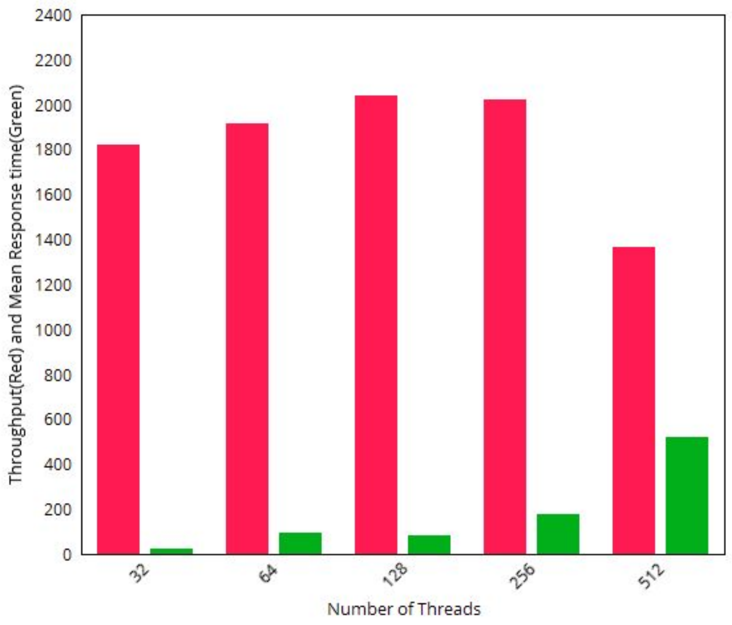
Throughput and mean response by the number of threads:

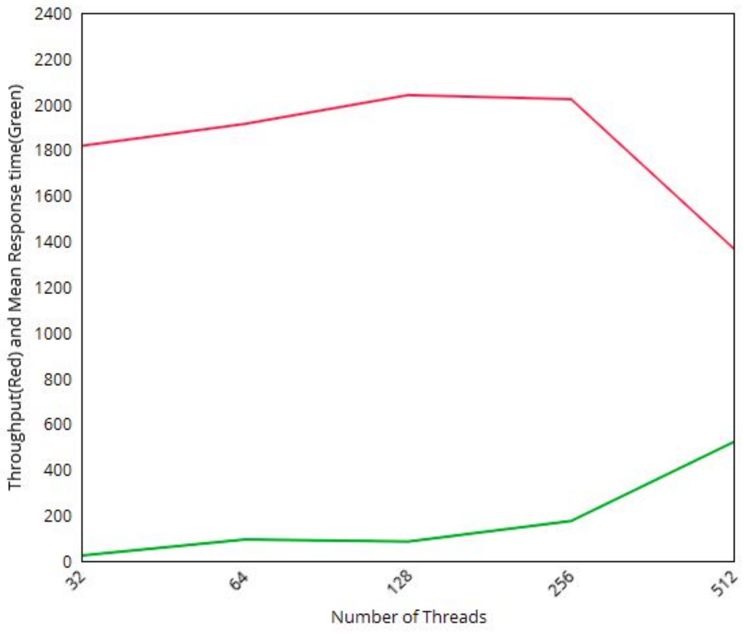
Single Instances tests:





Load Balanced tests:





<u>UML diagrams</u>: (Also included with detailed section below)

<u>Server:</u>
https://github.com/rahulpandeycs/bsds6650-Course-fall2020/tree/master/Assignment%202/CS6650-hw2-Server/UML

<u>Client:</u>
https://github.com/rahulpandeycs/bsds6650-Course-fall2020/tree/master/Assignment%202/bsds-cs6650-hw2-clientPart/UML

<u>Executable Jars</u>:

https://github.com/rahulpandeycs/bsds6650-Course-fall2020/tree/master/Assignment%202/ExeculatebleJars

Running the application:
The application is divided into 3 Parts:

- The Server
- The Client Part
- The load balancer

The server needs to be hosted and kept running either on Cloud (e.g AWS) or Localhost. The client will then need to modify the **resources/config.properties** to point to its address and execute calls.

A sample view of contents of config.properties looks like:

1. maximum number of threads to run (maxThreads - max 256)
2. number of skier to generate lift rides for (numSkiers - default 50000), This is effectively the skier's ID (skierID)
3. number of ski lifts (numLifts - range 5-60, default 40)
4. the ski day number - default to 1
5. the resort name which is the resortID - default to "SilverMt"
6. IP/port address of the server

Config.properties

```
cmd.maxThreads=32
cmd.numSkiers=20000
cmd.numLifts=60
cmd.skiDay=1
cmd.resortId=SilverMt
#Local
```

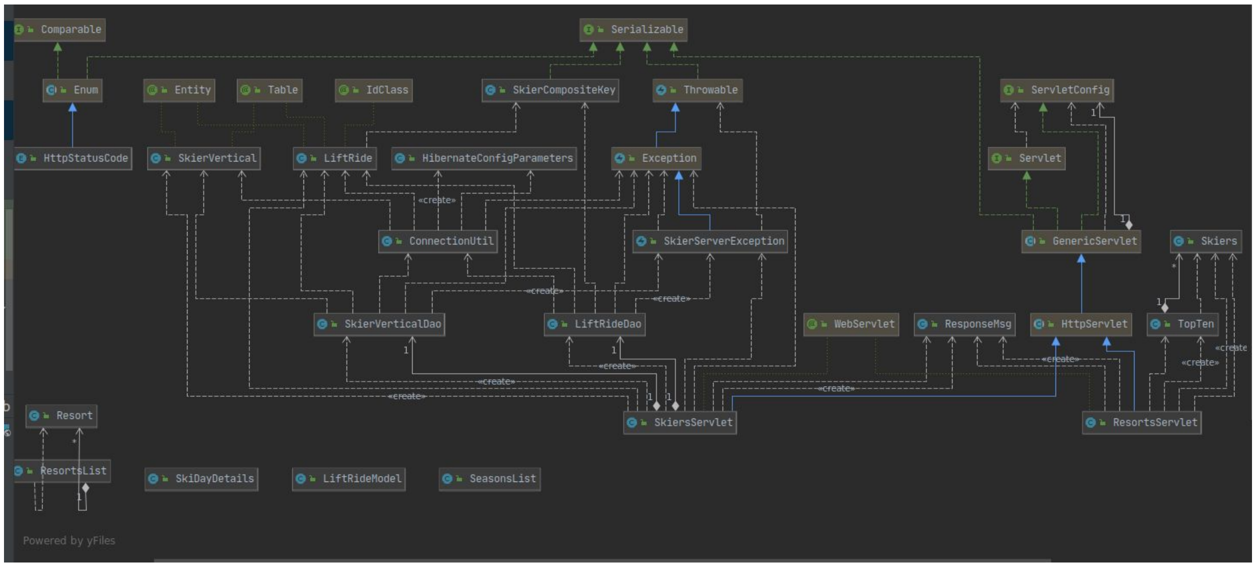
cmd.addressPort=http://bsdscs6650-1923097914.us-east-1.elb.amazonaws.com:8080/CS6650-hw2-Server-deploy
To run the application, the client needs to be packaged as .jar with configured config.properties. Then run as below:

Client part: (Jar included in folder executable_jar)

```
java -jar bsds-cs6650-hw2-clientPart.jar -f config.properties
```

Note: If no config.properties is provided it reads default config.properties

The Server design description



The server exposes below API using Java Servlets:

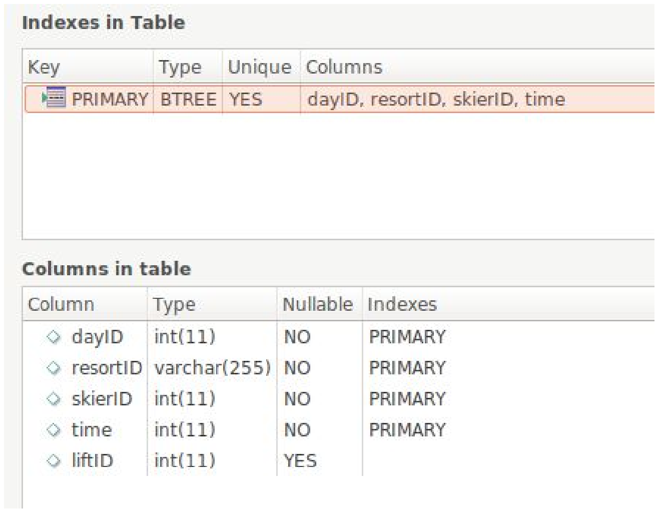
Skiers

POST/skiers/liftrides

GET/skiers/{resortID}/days/{dayID}/skiers/{skierID}

GET/skiers/{skierID}/vertical

The Database Design



Indexes in Table

Key	Type	Unique	Columns
PRIMARY	BTREE	YES	dayID, resortID, skierID, time

Columns in table

Column	Type	Nullable	Indexes
dayID	int(11)	NO	PRIMARY
resortID	varchar(255)	NO	PRIMARY
skierID	int(11)	NO	PRIMARY
time	int(11)	NO	PRIMARY
liftID	int(11)	YES	

The database is designed to keep in mind the responsiveness of the read and write API's. Several refactorings were performed to choose the primary keys so that the database doesn't incur locks during high load. Also it has been made sure that queries run faster so as to get higher throughput.

Validations on server:

The input to the doGet and doPost method is first validated to make sure they are in format:

POST/skiers/liftrides
GET/skiers/{resortID}/days/{dayID}/skiers/{skierID}
GET/skiers/{skierID}/vertical

The data inside the url i.e *{resortID}, {dayID}, {skierID}* is also validated to make sure they are of proper types. The data input to the skiers post method is validated to make sure it is of type liftRide. After validation and proper check the data is processed using Dao layer and response is returned in application/json format.

The Exception class SkierServerException is created to provide custom exceptions.

JDBC Connection and pooling:

The application has support for both **dbcp** and **hibernate** for connection to database. The current implementation is defaulted to **hibernate-c3p0.** The connection also uses the pooling feature and makes sure the max number of connections to the database is **15** at a time.

The application class ConnectionUtil provides the session via getSessionFactory() method. This session is used by the dao layer classes to establish connections for each query. The ConnectionUtil class ensures singleton creation of sessions.

The Dao Layer:

The database access layer (Dao) provides different methods to perform CRUD operations on respective databases. It uses ConnectionUtil class to establish the connection and then perform various operations like Read, update and create on the database.

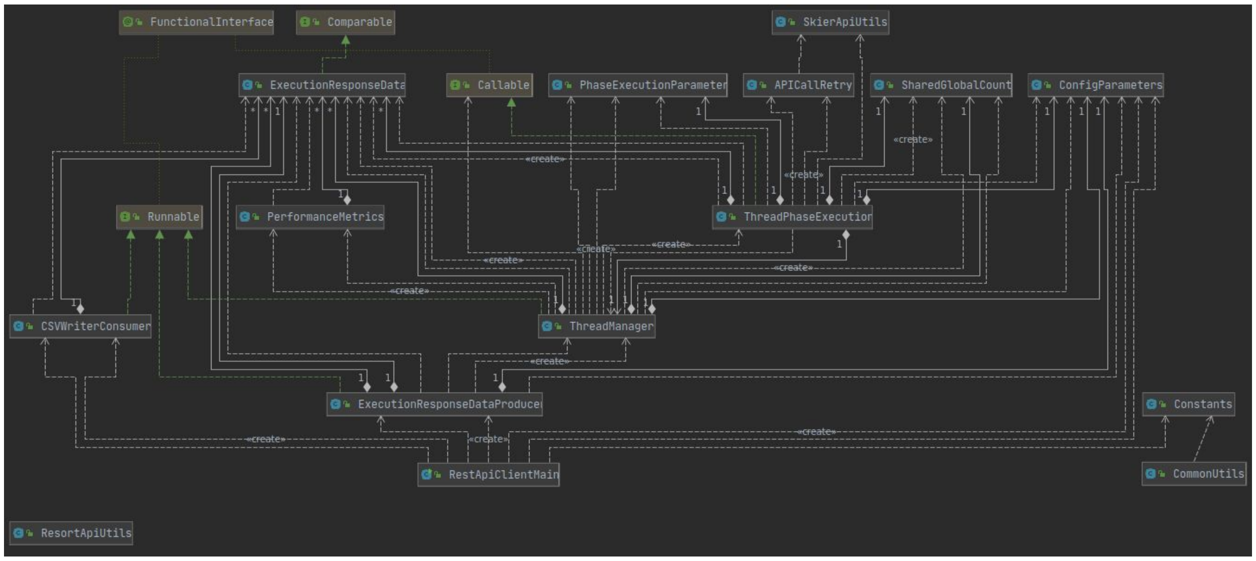
Example:

```
try (Session session = ConnectionUtil.getSessionFactory(LiftRide.class).openSession()) {
    transaction = session.beginTransaction();
    liftRide = session.get(LiftRide.class, ride);
    transaction.commit();
}
```
The server is connected to Single RDS instance with 1 Gb memory.

Unit tests:

The junit tests are written to ensure that the server works properly and delivers desired results. The units test mock the servlets and use mockito to perform testing and various assertions.

The Client Part



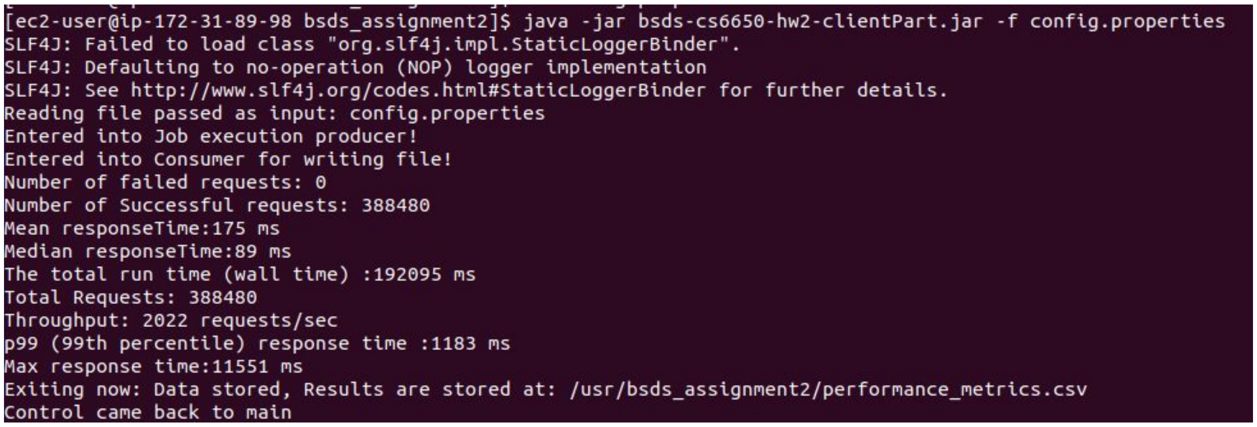
The Startup phase

The Client has been designed as a multi threaded client. The client execution starts with execution of the jar file and clients main class *RestApiClientMain* is called. The main class parses the input config.properties into a properties file and initializes *ConfigParameters* class.

The control is then passed to *ThreadManager* class which is executed in a separate thread then main. The threadManager takes care of threads phase execution by calling *ThreadPhaseExectution* class with their respective configuration as initialized in *PhaseExecutionParameter* Class.

The respective phases are then executed and after 10% of each phase is elapsed the next phase is started,this is taken care of by using CountDownLatch and initializing it to 10% of the total number of threads for a respective previous phase. As results need to be returned for each executed thread, Callable is used instead of runnable as in client part 1. The results are stored in list of *ExecutionResponseData* class, this list is then passed to *PerformanceMetrics* class which takes care of generating mean, median and various other performance metrics.

The execution then terminates with results printed to the console and CSV is generated from run results as stored in List of *ExecutionResponseData* Class. A sample output will look like:



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Total Requests: 388480
Throughput: 2022 requests/sec
p99 (99th percentile) response time :1183 ms
Max response time:11551 ms
Exiting now: Data stored, Results are stored at: /usr/bsds_assignment2/performance_metrics.csv
Control came back to main
```

The Executor Framework:

The executor framework has been used to create a fixed thread pool as:

ExecutorService WORKER_THREAD_POOL = Executors.newFixedThreadPool(parameters.getMaxThreads() / 4 + parameters.getMaxThreads() + parameters.getMaxThreads() / 4);

Phase threads are then passed to the thread pool for execution using method **submitToThreadPhaseExecution**(ExecutorService threadPool, PhaseExecutionParameter phaseExecutionParameter, double countDownThreshold**)** and submitted to thread pool as shown below.

//Creating a thread execution callable based on input to **submitToThreadPhaseExecution**
Callable<List<ExecutionResponseData>> phaseThread = new ThreadPhaseExecution(parameters, phaseExecutionParameter, this, latch);

//Submitting the phase execution thread to threadpool
Future<List<ExecutionResponseData>> futureExecutionResponseData = threadPool.submit(phaseThread);

//Adding results to blocking queue to write to the file later
blockingQueue.add(futureExecutionResponseData);

Each of these future calls are then later retrieved in the thread manager to build up the performance metrics and write data to CSV using LinkedBlocking queue.

The API retry on request failure:

The application has been designed to be fault tolerant and make sure it retries enough number of times before marking a request as fail.

It is expected that the call to the server will fail with unknown reasons considering several factors. Hence, each api call has been configured to retry at least 5 number of times before repeating the actual failure. The class APICallRetry has been created to cater to the API call failures and the calling class needs to create its class and call its respective methods to handle retry.

The blocking queue to prevent memory overhead:

It was observed that the memory could become a bottleneck as the number of API calls grow and size of the data structure being used to calculate metrics will exceed the available memory, hence keeping it in mind the data structure to store api execution results is changed to **blocking queue**. The LinkedBlockingDeque implementation is used to input api execution data at one end (Producer) and another thread pool consumer “CSVWriterConsumer” is created that will keep pulling out data from the other end of the queue and keep appending it to the local CSV file.

The Load Balancer:

It is observed the application throughput and mean response time was not enough to meet the end user needs. Hence an application level load balancer is introduced to route the traffic to 4 instances of the server. More than 100% improvement in the throughput and mean response time was observed. The single RDS instance is used and AWS Load balancer service is used to implement load balancer.