#Ping Me

A Fast and Elegant Messaging System

Project Group 11

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CMPE-273 Enterprise Distributed Systems – Fall 2019

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EXECUTIVE SUMMARY

A fault tolerant Messaging System that utilizes Kafka (A message streaming platform) to queue messages, replacing the unreliable traditional message brokers. The Application allows a user to Sign up, Sign in, add channels (group like), post and send messages directly to other users and channels.

Reasons that make this Application Fault Tolerant -

1. Kafka queues the messages so even if the Consumer (Backend Spring Boot) server is down and as long as the producer (The client side react frontend) is up, messages can still be posted which will be saved to the database once the backend server comes up. The front end Application which acts as the Kafka producer has been replicated in sets of three served by an Elastic load balancer ensuring its high availability.

2. The database has been replicated in sets of three (The Application makes use of Cassandra, an AP System). Hence even if a database server is down, the system will still be able to store messages.

3. The Application has been deployed on cloud (AWS). Each server, the Backend, the front end servers as well as the Database instances have been replicated and are being served from behind with and ELB (Elastic Load Balancer) which handles load by forwarding requests fairly among the associated instances.

4. Since Cassandra sacrifices consistency for Availability, Eventual consistency is attained by the system once the network partition has been overcome.

BACKGROUND

This Application is motivated by one of the system outages that Slack (An already existing messaging application) went through.

A resource conflict (two or more jobs tried to acquire the same system resource) lead to a major slowing of the system execution. This lead to the Redis Memory exceeding the maximum limit. Since there was no free memory left, no jobs could be enqueued or dequeued either (because even dequeuing jobs requires some free memory). This lead to the failure of many queue dependent jobs and a major setback to the production. Slack had to invest a lot of resources to overcome the problem and get the system up and running again.

The older architecture that slack used makes use of traditional messaging brokers.

Reasons to their failure -

1. It assumes that the consumption from the queue will always be very fast. But in certain cases, the enqueuing may get faster which makes the cache run out of memory, blocking even the dequeuing of jobs.

2. As the queue size increases, it gets harder to dequeue or empty the queue when required.

3. The jobs were highly dependent on the database (Redis in Slack's case), adding new jobs/Queues would exhaust the database even more.

OBJECTIVES

The developed aims to achieve the following objectives:

- Development of a messaging application which allows users to post fast, durable messages to other users and groups.

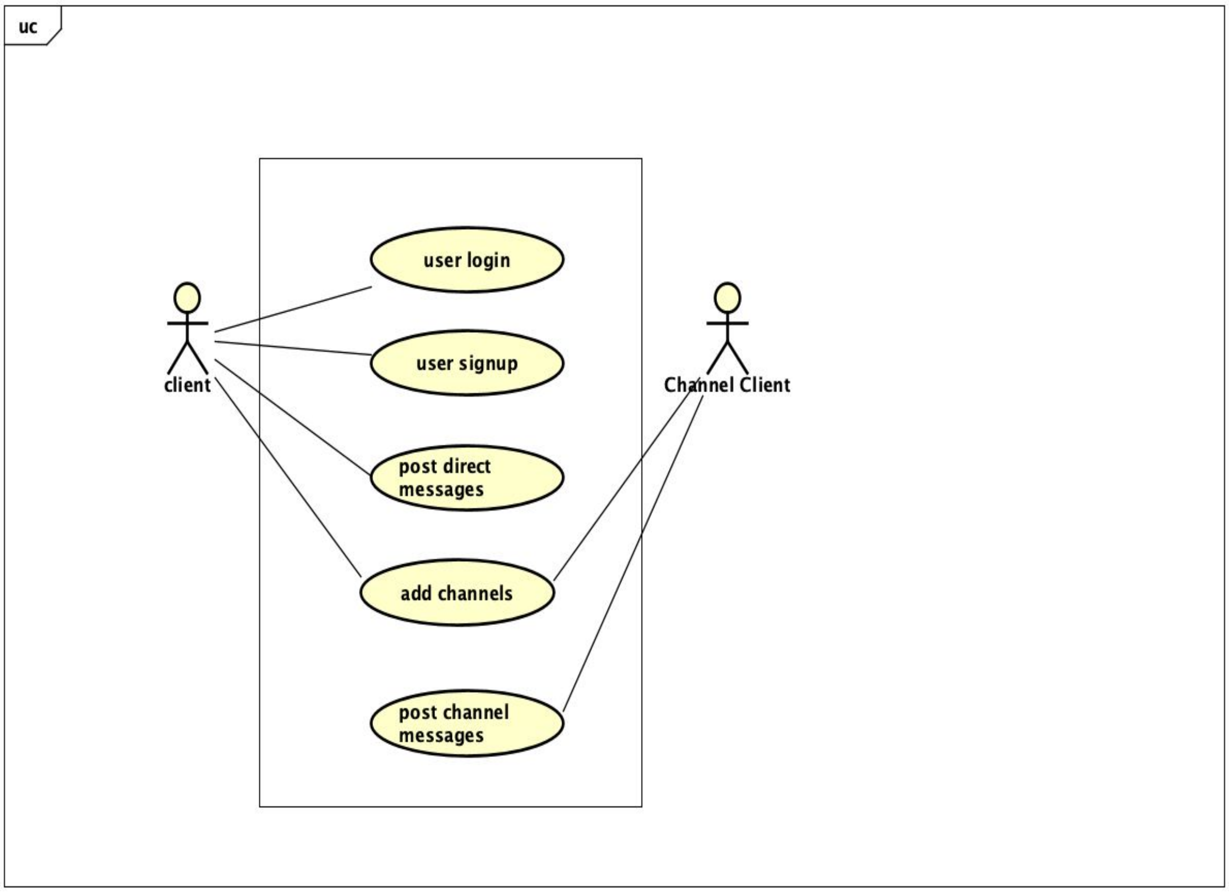
- Integration of the developed messaging application with a Buffer space (Kafka message Queue) that increases the durability of the stored messages in cases of complete memory consumption and network partition.

- Integrating a durable messaging system which allows the separation of concerns between scaling and database (Database independent message queueing).

- Kafka ensures message delivery at least once (Delivery guarantee). Message offsets that help consumers (The Backend Spring Boot Application here) track the point till which messages have been consumed from the Kafka queue.

- Deployment of the messaging application with the Kafka broker to the cloud (AWS) where replicated instances are maintained which are served with Elastic Load Balancers to forward requests fairly.

DESIGN

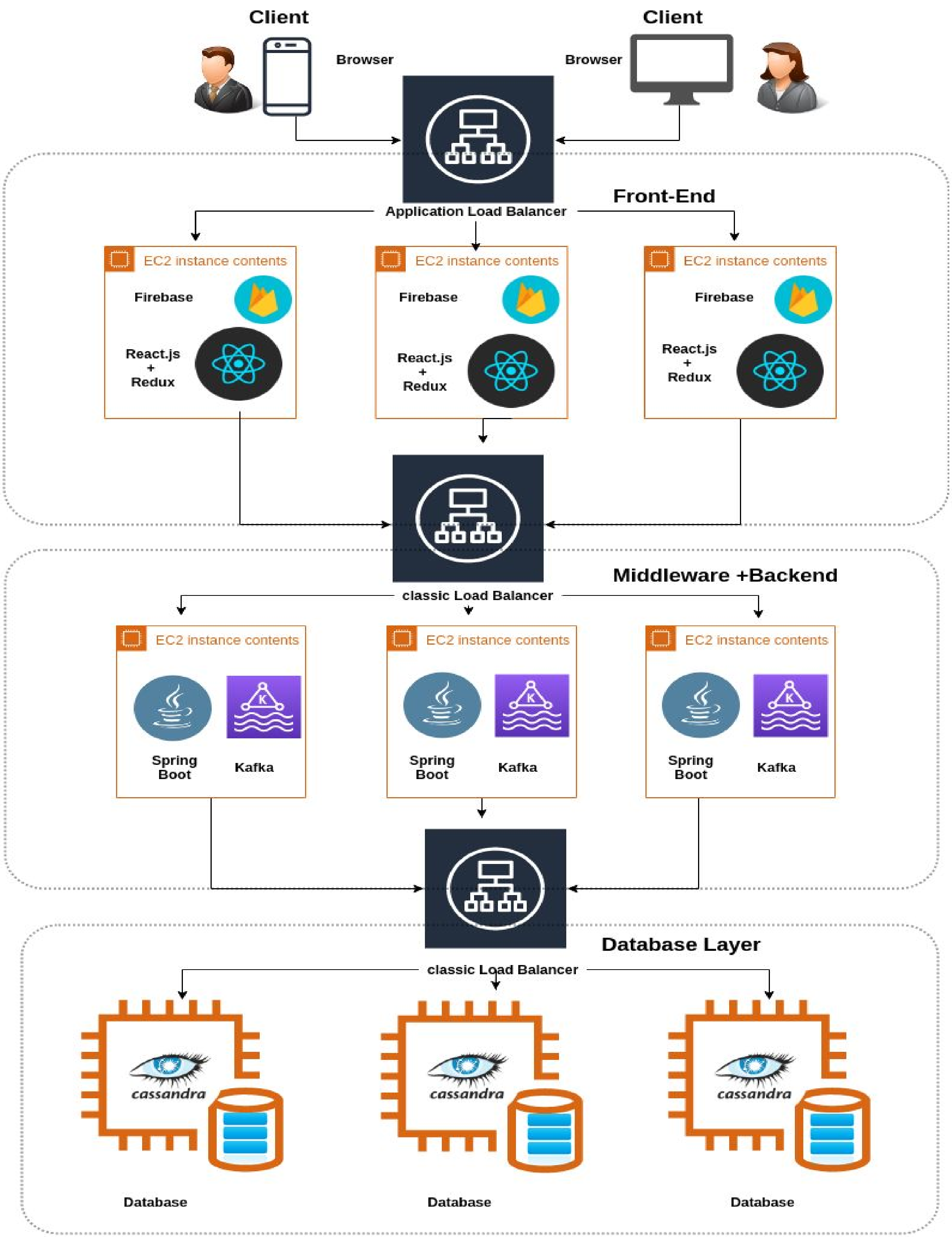


I. **Use Case Diagram**

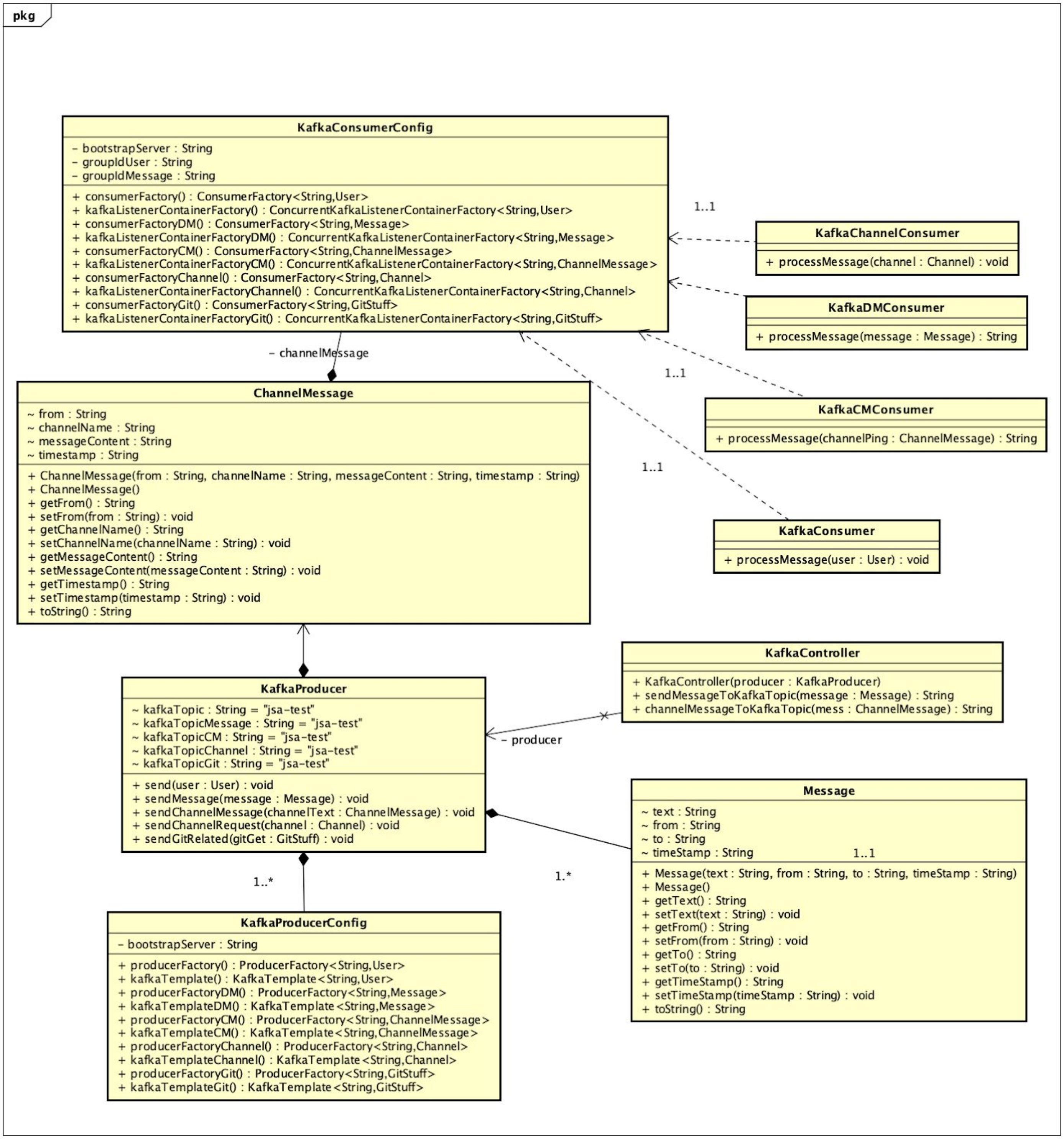
A user can perform the following functionalities -

1. Sign up to the messaging application
2. Sign in using their credentials
3. Post Direct Messages
4. Post channel Messages
5. Add new channels

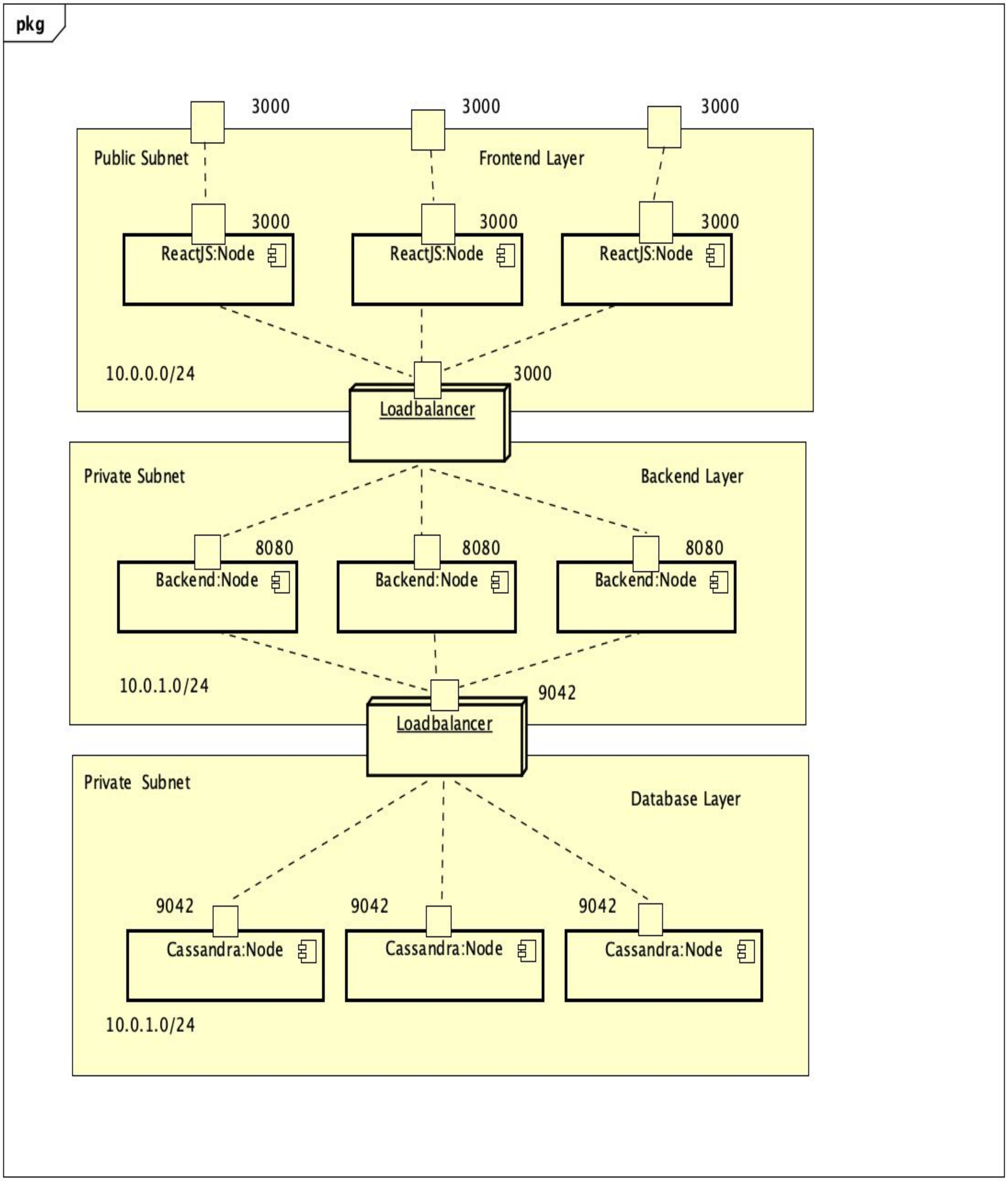
II. ARCHITECTURE



III. CLASS DIAGRAM



III. DEPLOYMENT DIAGRAM



IMPLEMENTATION

- **Technologies Used**
  Java, Spring Boot, Cassandra (Backend Database)
  Kafka (Middleware message Broker), React Redux (Frontend)
  Firebase (Caching) and Amazon Web Services (Cloud Deployment)

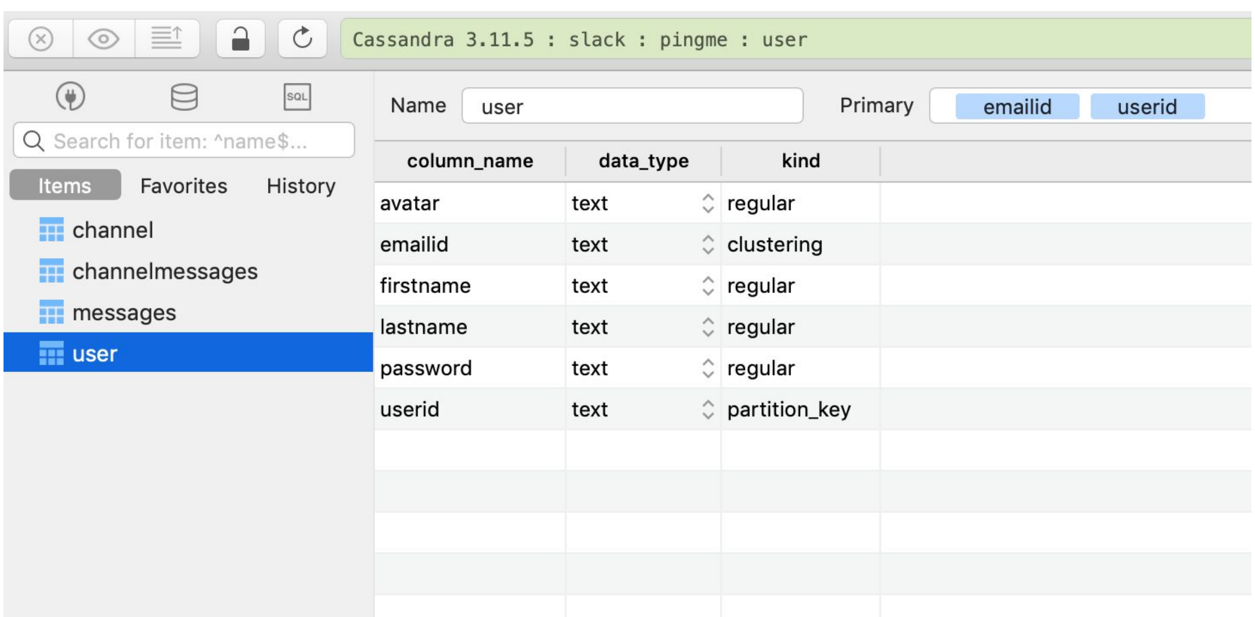
- **Cassandra KeySpace Creation :**

  CREATE KEYSPACE **pingme** WITH replication = {'class':'SimpleStrategy', 'replication_factor' : 3};

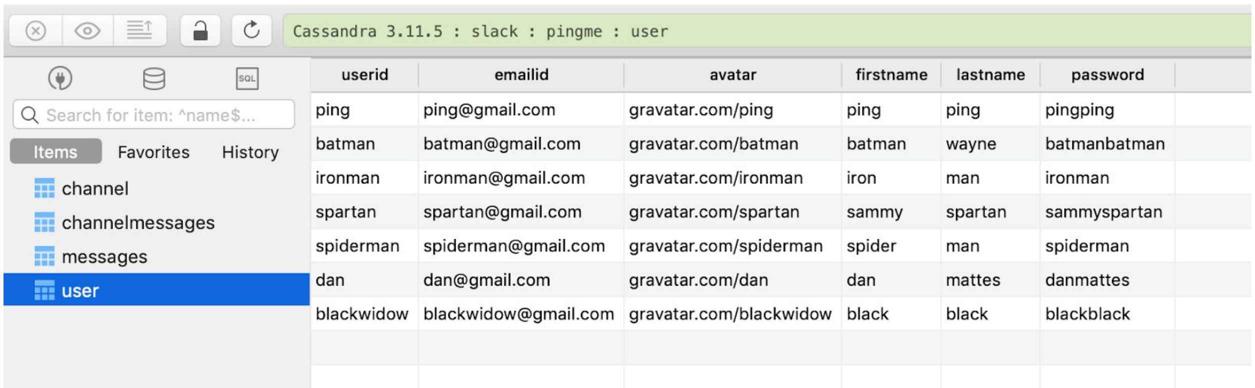
- **Cassandra Tables**

1. User

CREATE TABLE **user**(
avatar text,
emailid text,
userid text,
firstname text,
lastname text,
password text,
PRIMARY KEY(emailid, userid)
);



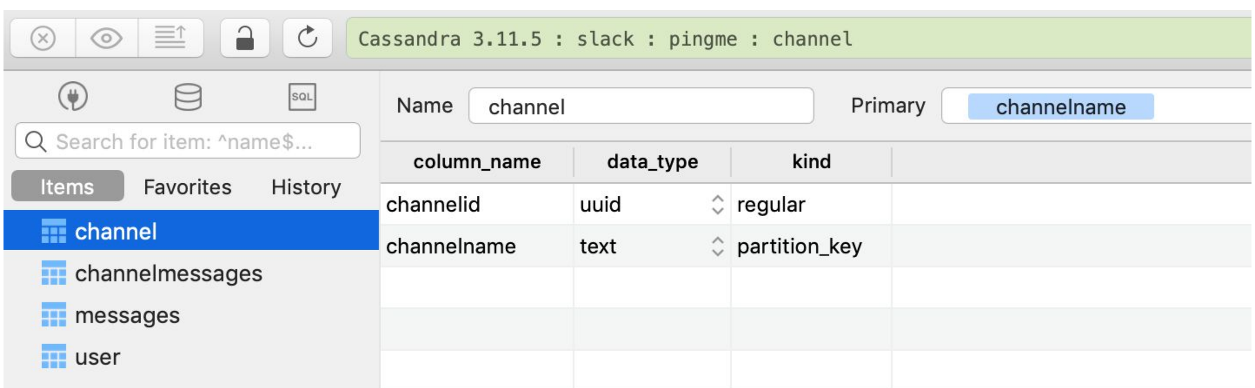
SELECT * from user;



userid	emailid	avatar	firstname	lastname	password
ping	ping@gmail.com	gravatar.com/ping	ping	ping	pingping
batman	batman@gmail.com	gravatar.com/batman	batman	wayne	batmanbatman
ironman	ironman@gmail.com	gravatar.com/ironman	iron	man	ironman
spartan	spartan@gmail.com	gravatar.com/spartan	sammy	spartan	sammyspartan
spiderman	spiderman@gmail.com	gravatar.com/spiderman	spider	man	spiderman
dan	dan@gmail.com	gravatar.com/dan	dan	mattes	danmattes
blackwidow	blackwidow@gmail.com	gravatar.com/blackwidow	black	black	blackblack

2. Channel

CREATE TABLE **channel**(
channelid uuid PRIMARY KEY,
channelname text,
);

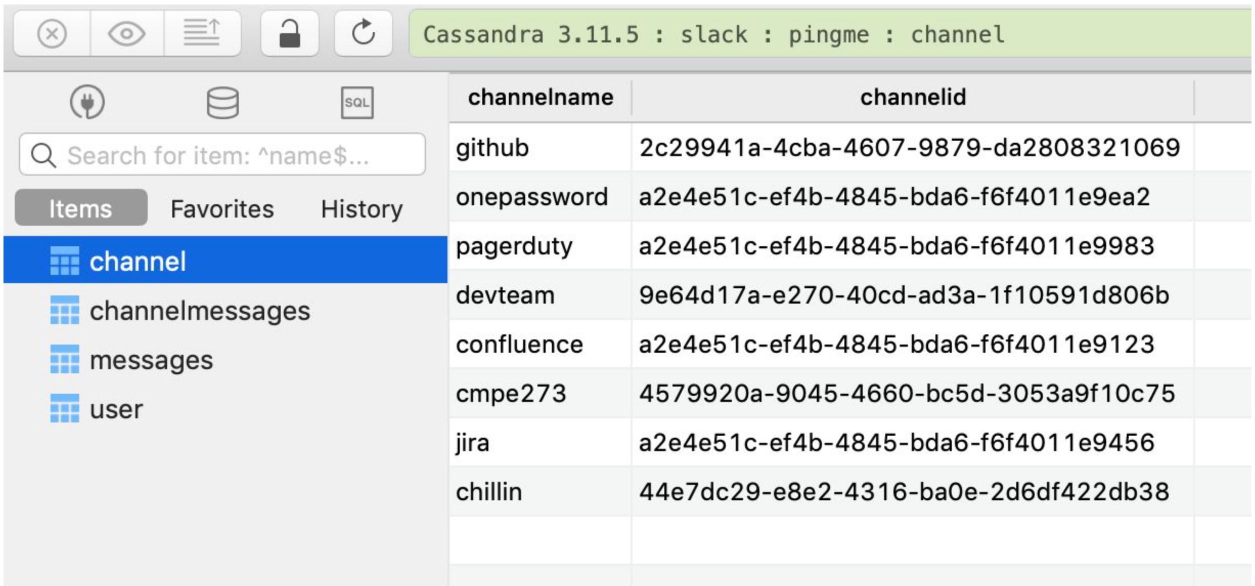


column_name	data_type	kind
channelid	uuid	regular
channelname	text	partition_key

Data Insertion Query

INSERT INTO channel (channelid, channelname)
VALUES("CMPE273");

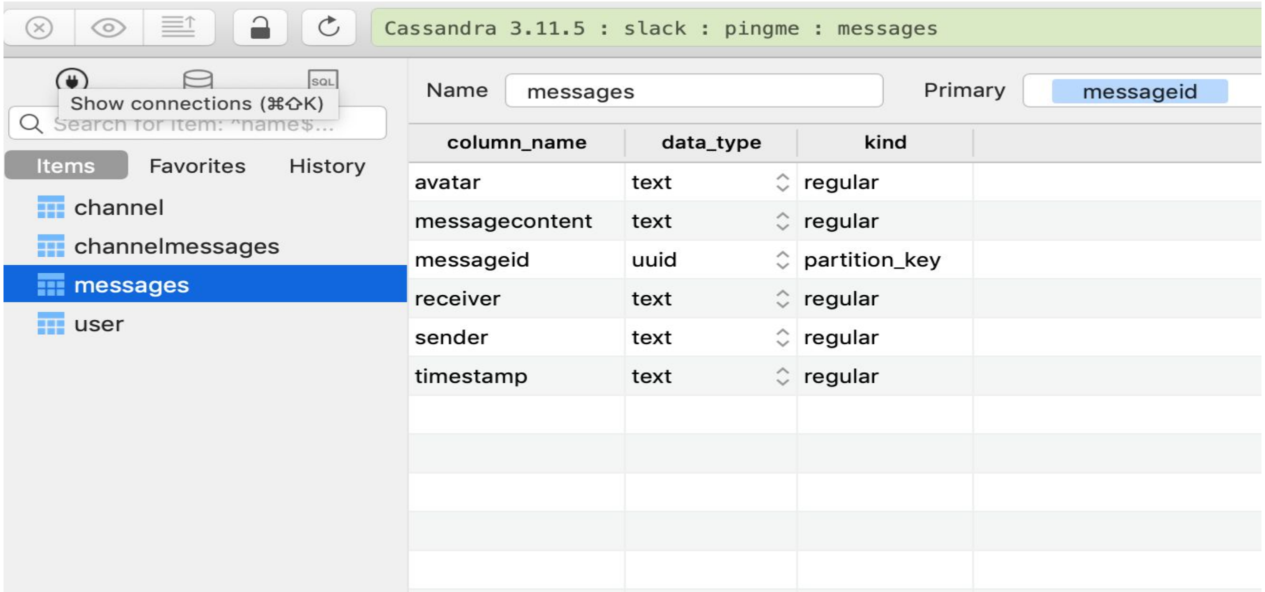
SELECT * FROM Channel;



channelname	channelid
github	2c29941a-4cba-4607-9879-da2808321069
onepassword	a2e4e51c-ef4b-4845-bda6-f6f4011e9ea2
pagerduty	a2e4e51c-ef4b-4845-bda6-f6f4011e9983
devteam	9e64d17a-e270-40cd-ad3a-1f10591d806b
confluence	a2e4e51c-ef4b-4845-bda6-f6f4011e9123
cmpe273	4579920a-9045-4660-bc5d-3053a9f10c75
jira	a2e4e51c-ef4b-4845-bda6-f6f4011e9456
chillin	44e7dc29-e8e2-4316-ba0e-2d6df422db38

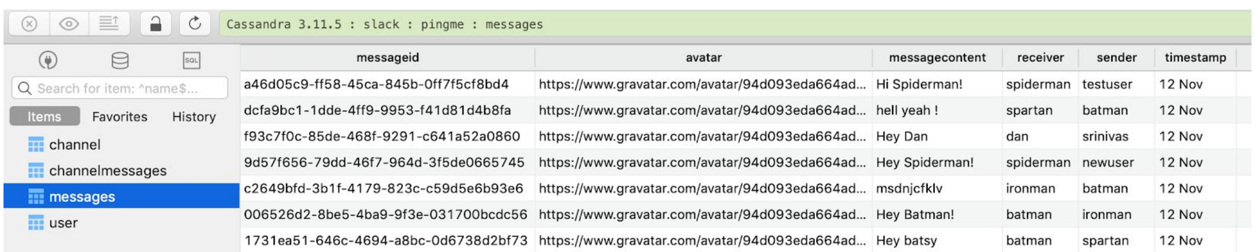
3. Messages

CREATE TABLE **messages**(
avatar text,
messageid uuid PRIMARY KEY,
sender text,
receiver text,
messagecontent text,
timestamp text,
);



column_name	data_type	kind
avatar	text	regular
messagecontent	text	regular
messageid	uuid	partition_key
receiver	text	regular
sender	text	regular
timestamp	text	regular

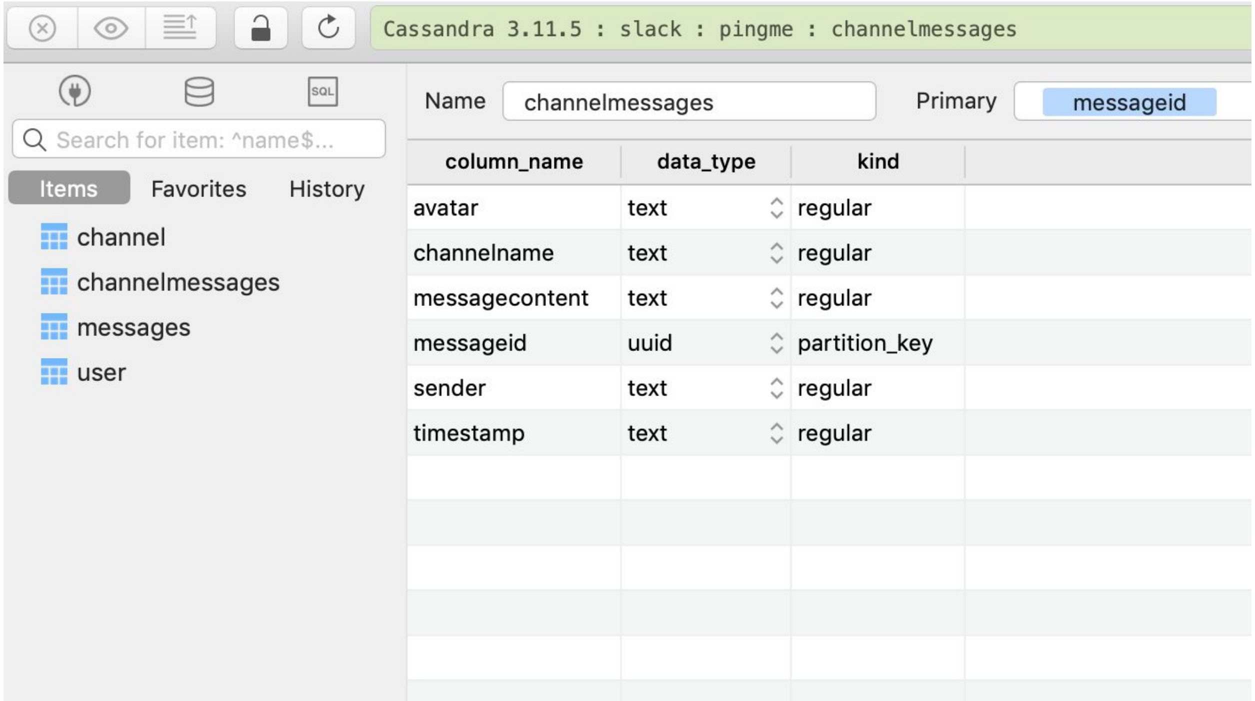
SELECT * FROM messages;



messageid	avatar	messagecontent	receiver	sender	timestamp
a46d05c9-ff58-45ca-845b-0ff7f5cf8bd4	https://www.gravatar.com/avatar/94d093eda664ad...	Hi Spiderman!	spiderman	testuser	12 Nov
dcfa9bc1-1dde-4ff9-9953-f41d81d4b8fa	https://www.gravatar.com/avatar/94d093eda664ad...	hell yeah !	spartan	batman	12 Nov
f93c7f0c-85de-468f-9291-c641a52a0860	https://www.gravatar.com/avatar/94d093eda664ad...	Hey Dan	dan	srinivas	12 Nov
9d57f656-79dd-46f7-964d-3f5de0665745	https://www.gravatar.com/avatar/94d093eda664ad...	Hey Spiderman!	spiderman	newuser	12 Nov
c2649bfd-3b1f-4179-823c-c59d5e6b93e6	https://www.gravatar.com/avatar/94d093eda664ad...	msdnjcfklv	ironman	batman	12 Nov
006526d2-8be5-4ba9-9f3e-031700bcdc56	https://www.gravatar.com/avatar/94d093eda664ad...	Hey Batman!	batman	ironman	12 Nov
1731ea51-646c-4694-a8bc-0d6738d2bf73	https://www.gravatar.com/avatar/94d093eda664ad...	Hey batsy	batman	spartan	12 Nov

4. Channelmessages

CREATE TABLE **channelmessages**(
messageid uuid PRIMARY KEY,
avatar text,
channelname text,
timestamp text,
sender text,
messagecontent text,
);



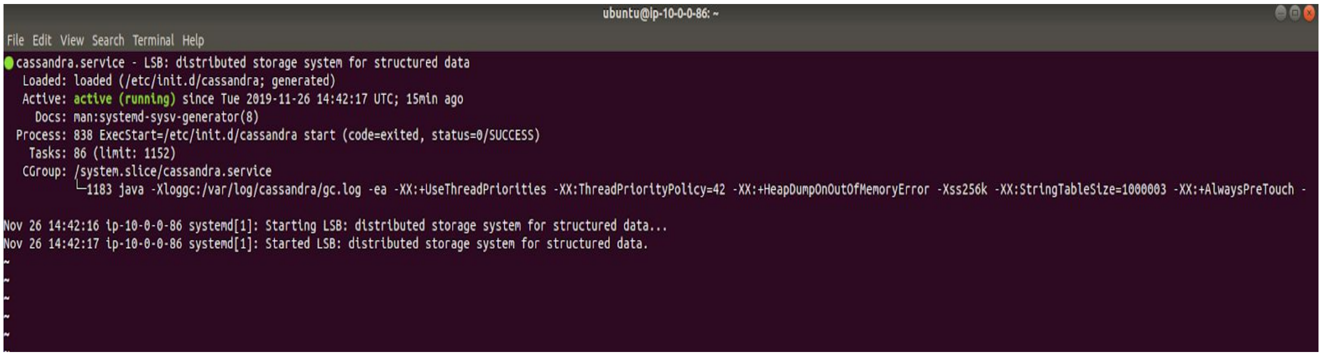
column_name	data_type	kind
avatar	text	regular
channelname	text	regular
messagecontent	text	regular
messageid	uuid	partition_key
sender	text	regular
timestamp	text	regular

SELECT * FROM channelmessages;

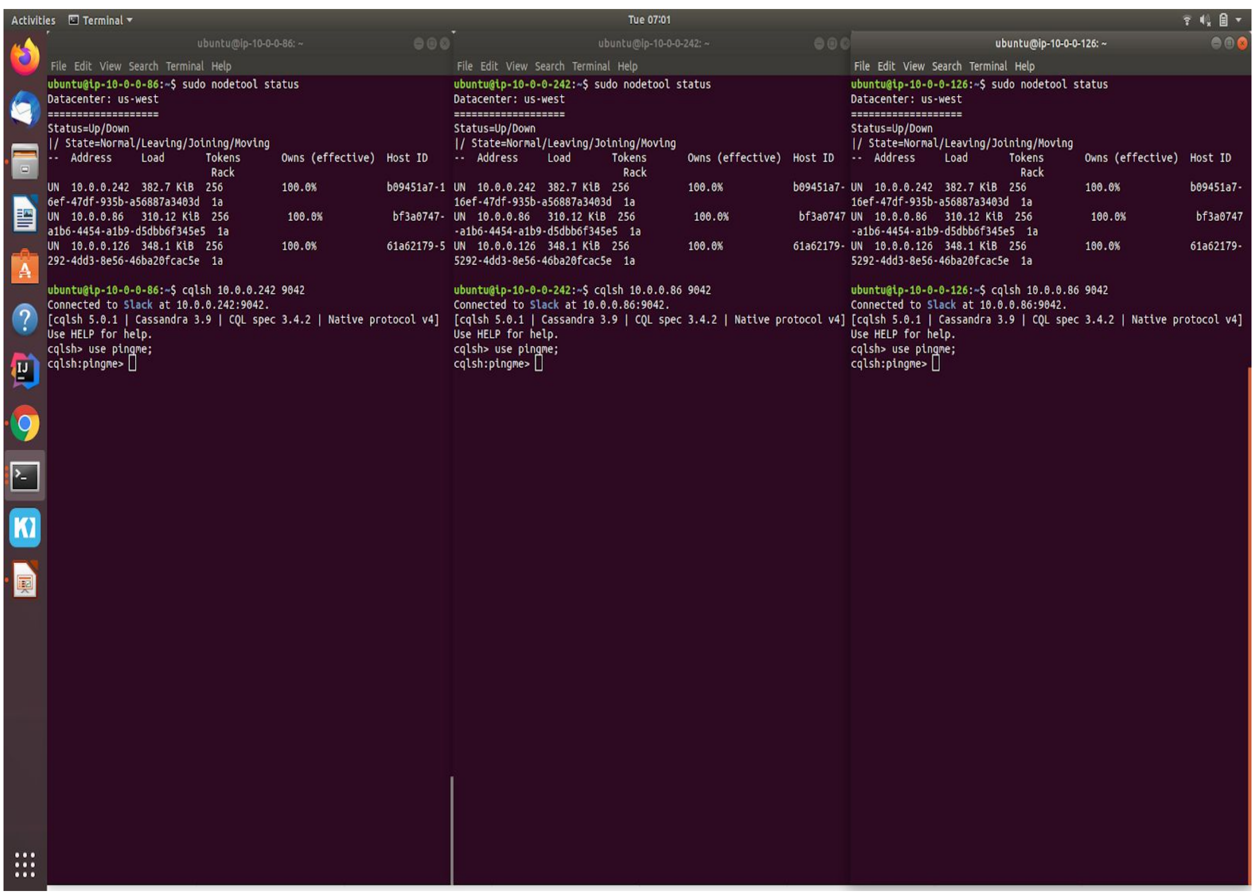
messageid	avatar	channelname	messagecontent	sender	timestamp
561b2292-492a-4295-aaa7-eac9b76d1f1f	https://www.gravatar.com/avatar/94d093eda664ad...	github	Hey this is sammy the spartan texting	spartan	12 Nov
fffeab68-092e-41ae-904c-284de169c056	https://www.gravatar.com/avatar/94d093eda664ad...	github	Hey!	batman	12 Nov
58416870-81b6-4ccd-b0eb-245344baa346	https://www.gravatar.com/avatar/94d093eda664ad...	jira	Hey!	batman	12 Nov
c11b3c8a-5953-44b4-9cca-020ebb2fb581	https://www.gravatar.com/avatar/94d093eda664ad...	github	This is Dan texting on github channel	dan	Nov 12
1bc4f116-a02f-45a4-b592-a942f1af079d	https://www.gravatar.com/avatar/94d093eda664ad...	chillin	Hey Spiderman!	spartan	12 Nov
c11b3c8a-5953-44b4-9cca-020ebb2fb585	https://www.gravatar.com/avatar/94d093eda664ad...	pagerduty	This is Spiderman!	spiderman	Nov 12

To check if the Cassandra Database is running

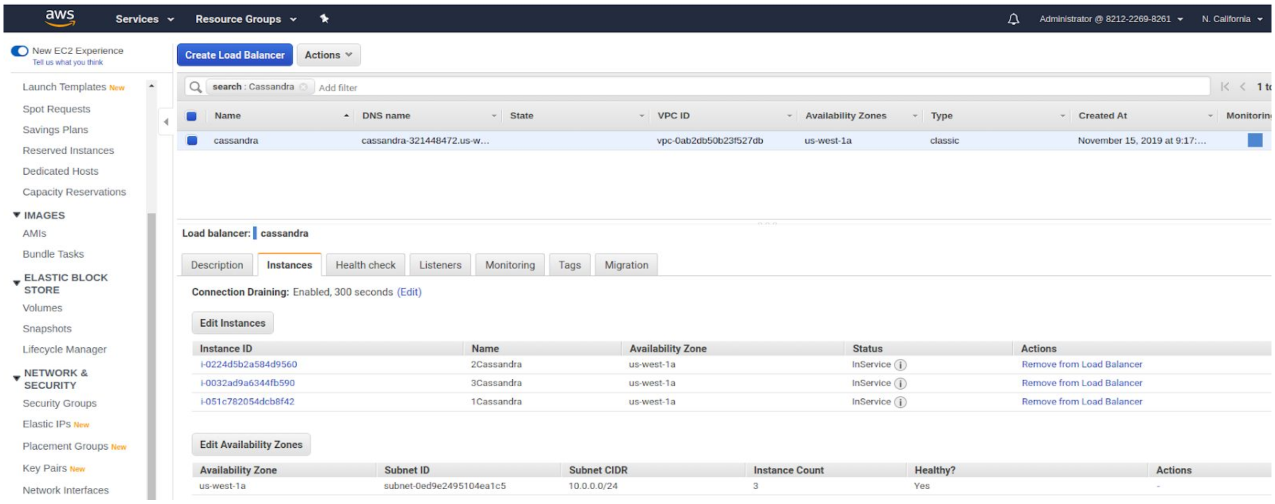
Command : sudo service cassandra status

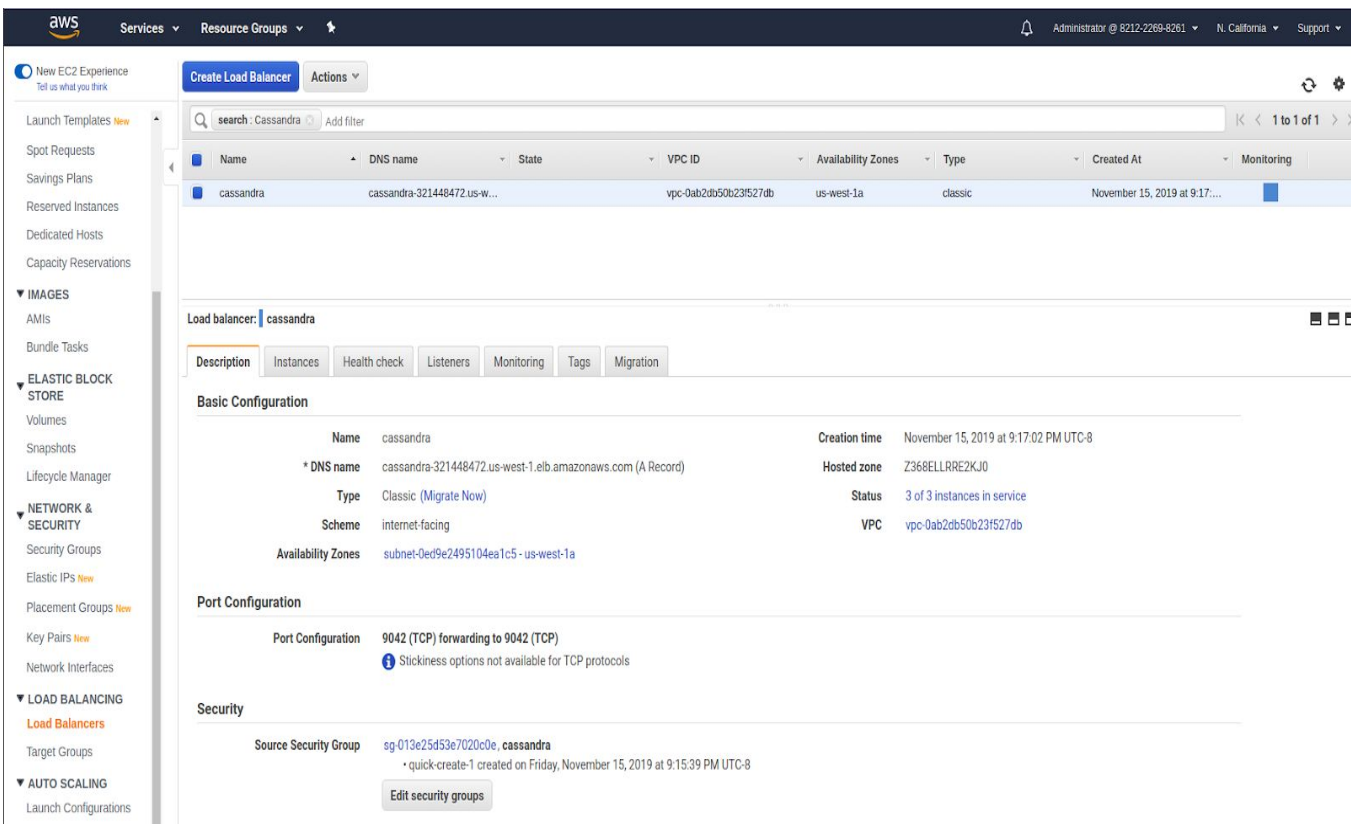


The three node cassandra cluster looks like this. Internal Ips as **10.0.0.86**, **10.0.0.242** and **10.0.0.126**



Cassandra Load Balancer





START THE KAFKA SERVERS

ZOOKEEPER

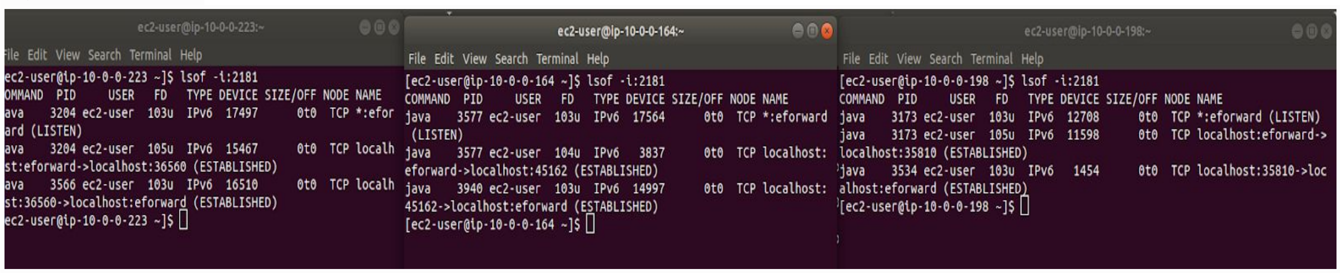
>$ nohup bin/zookeeper-server-start.sh config/zookeeper.properties > ~/zookeeper-logs &

KAFKA SERVER

>$ nohup bin/kafka-server-start.sh config/server.properties > ~/kafka-logs &

To check if Kafka servers are up and running :

>$ lsof -i:2181



START THE BACKEND SERVER

Build the Spring Kafka code, Since maven is being used -

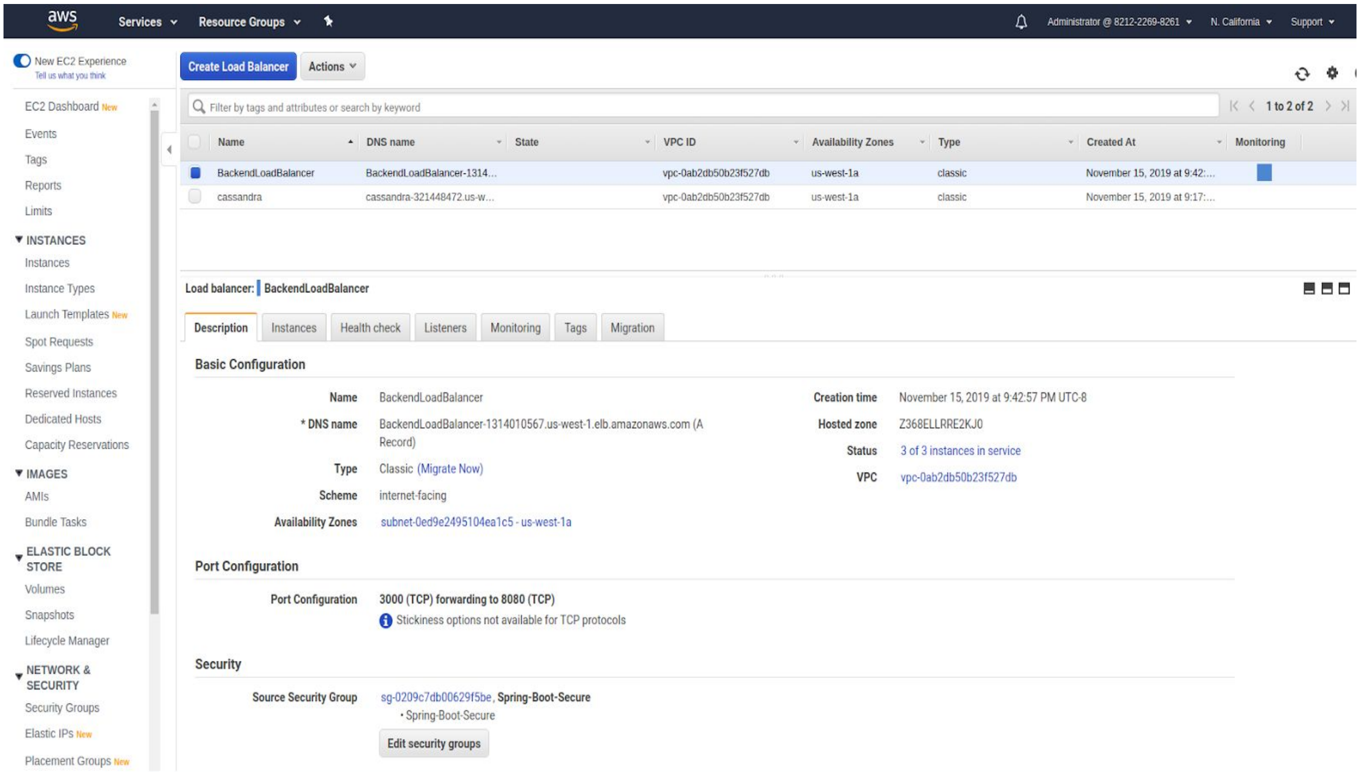
> $ mvn package

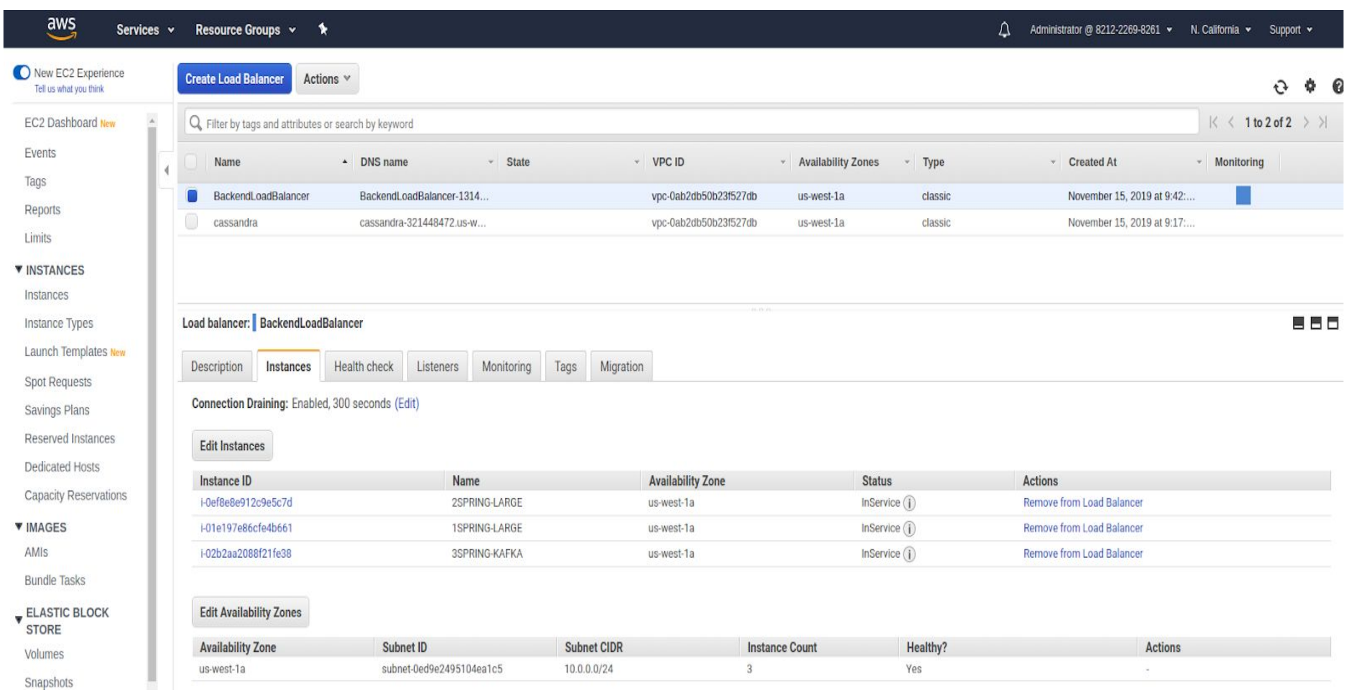
A java jar gets created in the target directory from the project folder.

> $ cd target
> $ java -jar SpringKafkaSendConsumeJavaObject-0.0.1.jar

The three instance terminals look something like this -

The Backend Load Balancer registers all the three Backend instances

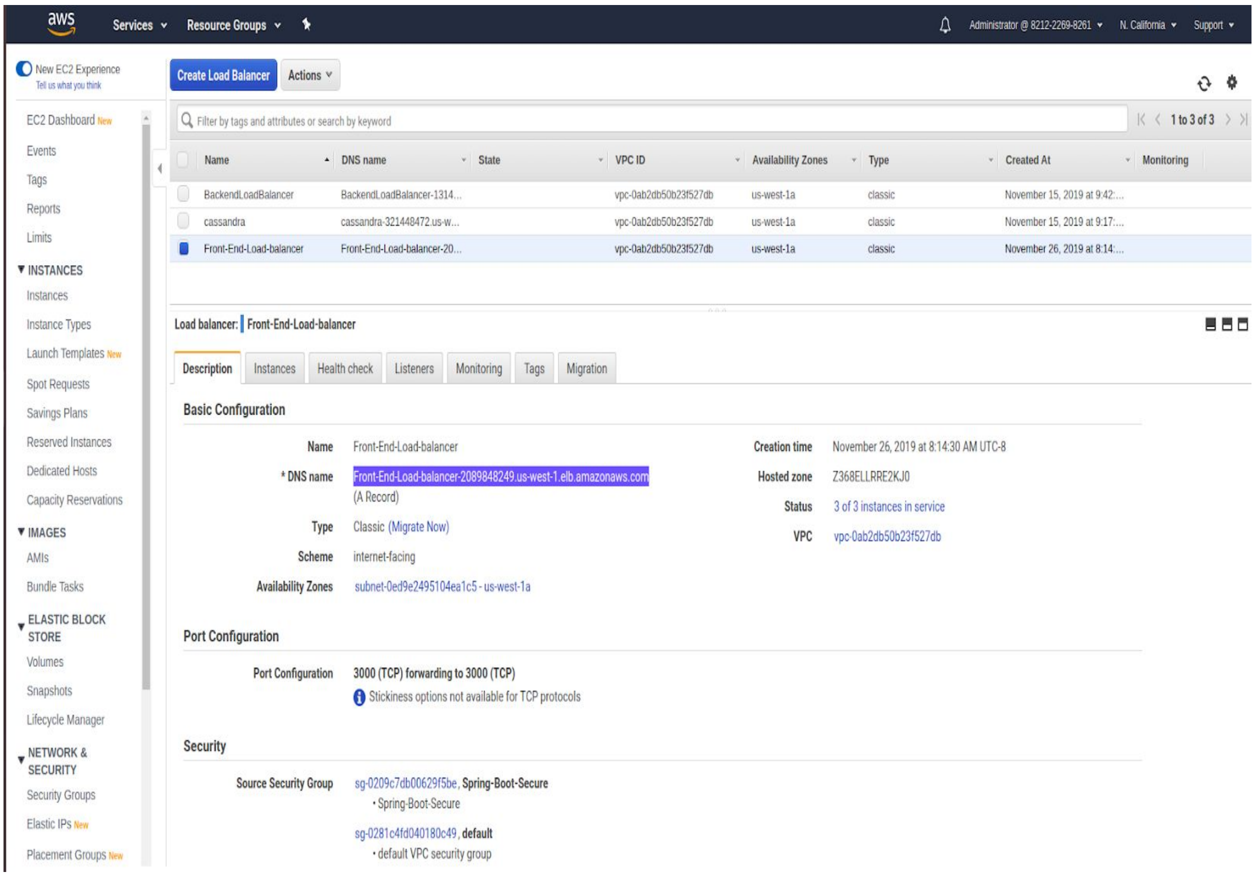

Services
Resource Groups
Administrator @ 8212-2269-8261
N. California
Support
New EC2 Experience
Tell us what you think
Create Load Balancer
Actions
EC2 Dashboard New
Events
Tags
Reports
Limits
INSTANCES
Instances
Instance Types
Launch Templates New
Spot Requests
Savings Plans
Reserved Instances
Dedicated Hosts
Capacity Reservations
IMAGES
AMIs
Bundle Tasks
ELASTIC BLOCK STORE
Volumes
Snapshots
Lifecycle Manager
NETWORK & SECURITY
Security Groups
Elastic IPs New
Placement Groups New
Filter by tags and attributes or search by keyword
1 to 2 of 2
Name
DNS name
State
VPC ID
Availability Zones
Type
Created At
Monitoring
BackendLoadBalancer
BackendLoadBalancer-1314...
vpc-0ab2db50b23f527db
us-west-1a
classic
November 15, 2019 at 9:42:...
cassandra
cassandra-321448472.us-w...
vpc-0ab2db50b23f527db
us-west-1a
classic
November 15, 2019 at 9:17:...
Load balancer: BackendLoadBalancer
Description
Instances
Health check
Listeners
Monitoring
Tags
Migration
Basic Configuration
Name
BackendLoadBalancer
* DNS name
BackendLoadBalancer-1314010567.us-west-1.elb.amazonaws.com (A Record)
Type
Classic (Migrate Now)
Scheme
internet-facing
Availability Zones
subnet-0ed9e2495104ea1c5 - us-west-1a
Creation time
November 15, 2019 at 9:42:57 PM UTC-8
Hosted zone
Z368ELLRRE2KJ0
Status
3 of 3 instances in service
VPC
vpc-0ab2db50b23f527db
Port Configuration
Port Configuration
3000 (TCP) forwarding to 8080 (TCP)
Stickiness options not available for TCP protocols
Security
Source Security Group
sg-0209c7db00629f5be, Spring-Boot-Secure
• Spring-Boot-Secure
Edit security groups

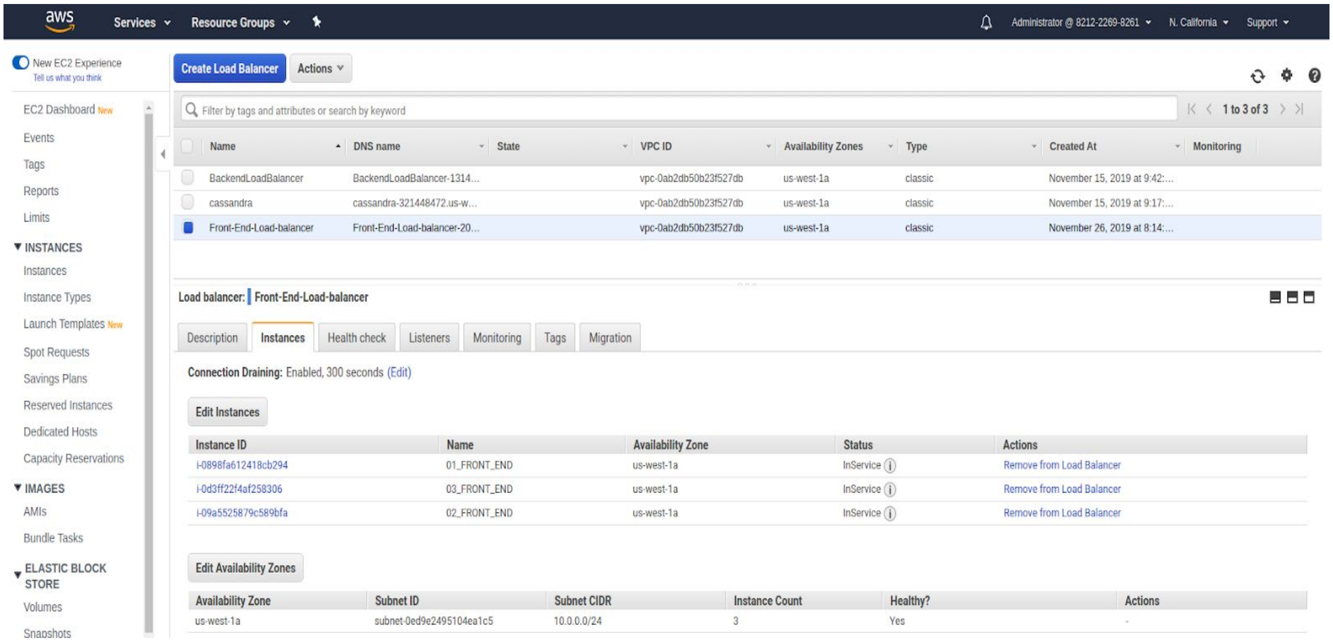

Services
Resource Groups
Administrator @ 8212-2269-8261
N. California
Support
New EC2 Experience
Tell us what you think
Create Load Balancer
Actions
EC2 Dashboard New
Events
Tags
Reports
Limits
INSTANCES
Instances
Instance Types
Launch Templates New
Spot Requests
Savings Plans
Reserved Instances
Dedicated Hosts
Capacity Reservations
IMAGES
AMIs
Bundle Tasks
ELASTIC BLOCK STORE
Volumes
Snapshots
Filter by tags and attributes or search by keyword
1 to 2 of 2
Name
DNS name
State
VPC ID
Availability Zones
Type
Created At
Monitoring
BackendLoadBalancer
BackendLoadBalancer-1314...
vpc-0ab2db50b23f527db
us-west-1a
classic
November 15, 2019 at 9:42:...
cassandra
cassandra-321448472.us-w...
vpc-0ab2db50b23f527db
us-west-1a
classic
November 15, 2019 at 9:17:...
Load balancer: BackendLoadBalancer
Description
Instances
Health check
Listeners
Monitoring
Tags
Migration
Connection Draining: Enabled, 300 seconds (Edit)
Edit Instances
Instance ID
Name
Availability Zone
Status
Actions
i-0ef8e8e912c9e5c7d
2SPRING-LARGE
us-west-1a
InService
Remove from Load Balancer
i-01e197e86cfe4b661
1SPRING-LARGE
us-west-1a
InService
Remove from Load Balancer
i-02b2aa2088f21fe38
3SPRING-KAFKA
us-west-1a
InService
Remove from Load Balancer
Edit Availability Zones
Availability Zone
Subnet ID
Subnet CIDR
Instance Count
Healthy?
Actions
us-west-1a
subnet-0ed9e2495104ea1c5
10.0.0.0/24
3
Yes

Start the Front-End Servers

```
cd /path/to/Front-end/Code
npm install
Npm start
```

Register the three Front-end servers with the Elastic Load Balancer



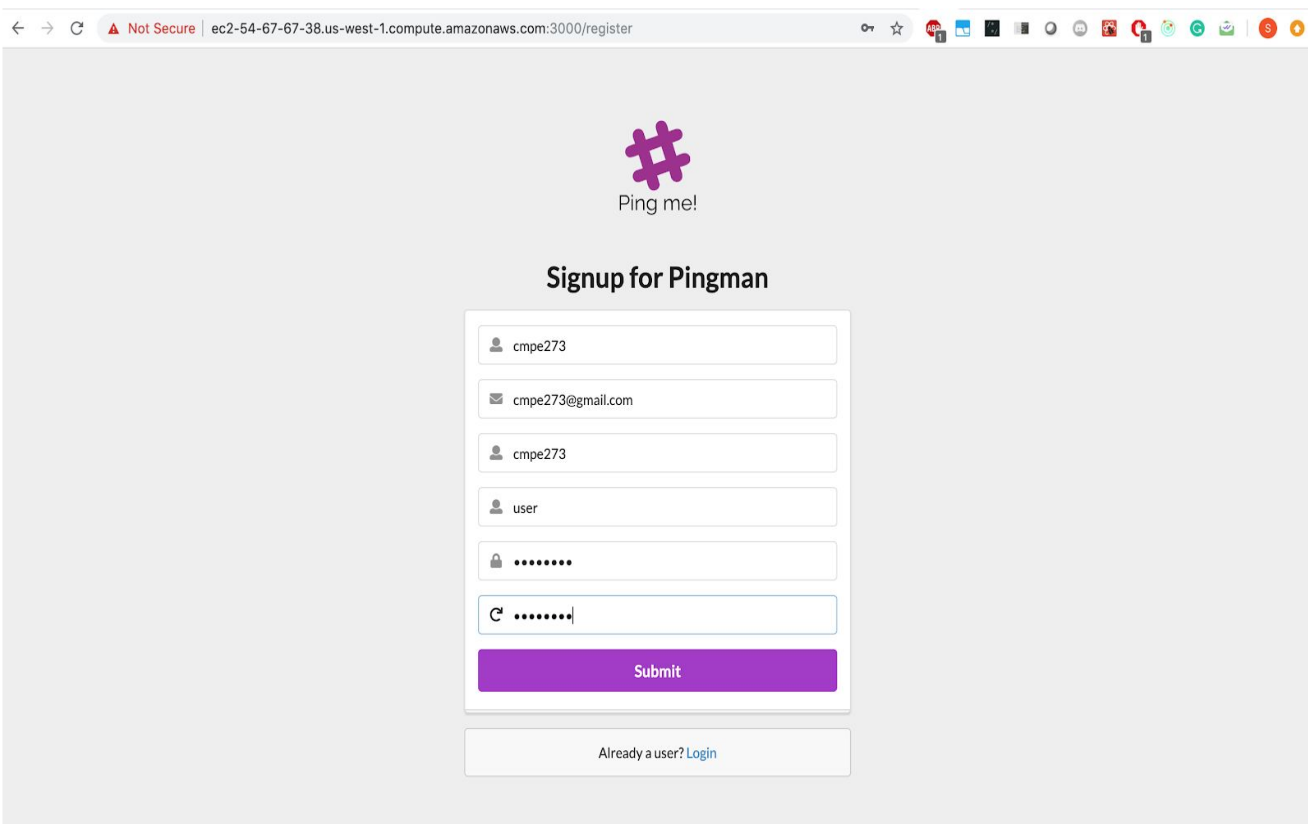


The Application starts running at port 3000 and the Elastic Load Balancer is listening on port 3000.
The Application can be accessed using the ELB's DNS Name followed by the port Number.

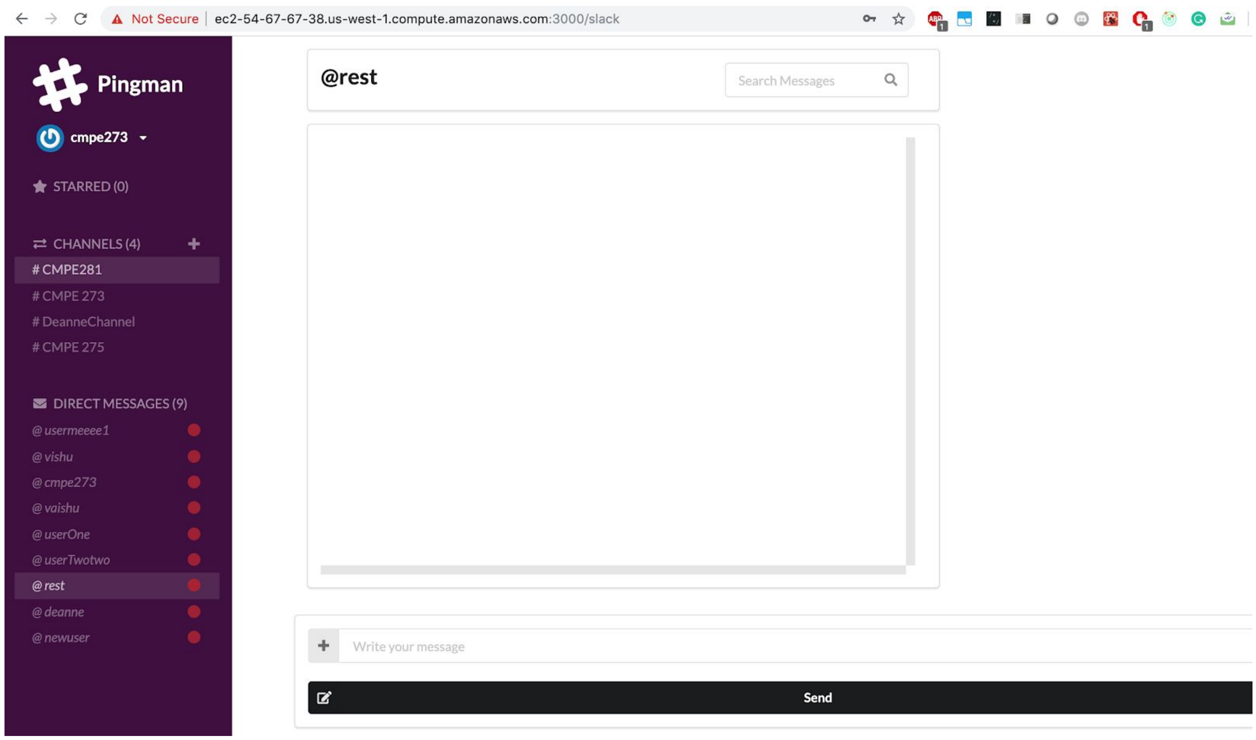
RESULTS

The Application can be accessed using the DNS Name of the Front-End Load Balancer followed by port 3000.
DNS_NAME:3000/login

The user needs to first register to access the Application. Say user cmpe273 tries to register



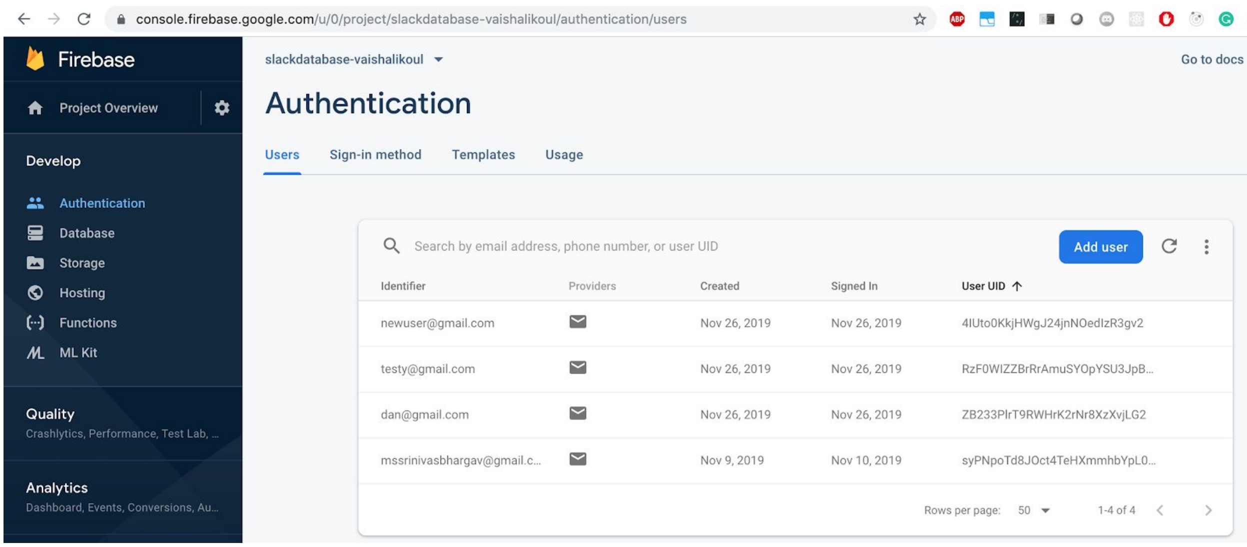
Once logged in, the application window looks like



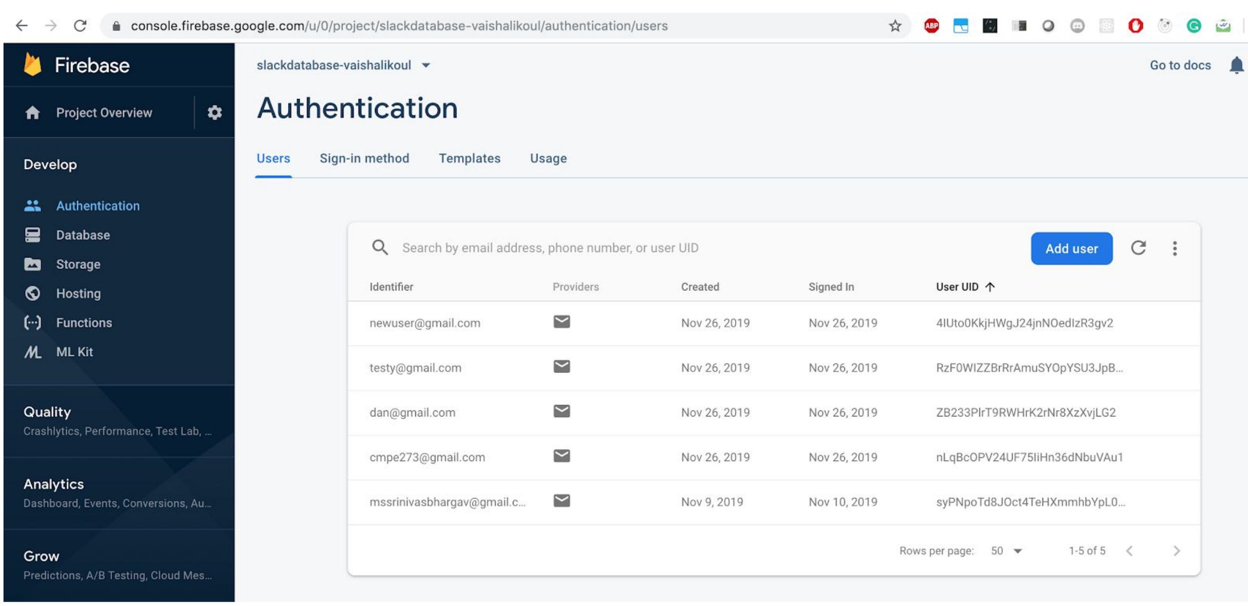
```
[ubuntu@ip-10-0-0-242:~$ cqlsh 10.0.0.242 9042
Connected to Slack at 10.0.0.242:9042.
[cqlsh 5.0.1 | Cassandra 3.9 | CQL spec 3.4.2 | Native protocol v4]
Use HELP for help.
[cqlsh> use pingme
[   ... ;
[cqlsh:pingme> select * from user;

 emailid            | userid      | avatar               | firstname | lastname | password
--------------------+-------------+----------------------+-----------+----------+---------------
     useme@gmail.com | usermeeee1 |             avataaqm |     useme | everyday | passsthewater
     vishu@gmail.com |      vishu |   gravatar.com/vishu |  vaishali |     kaul |      00120012
  vaishali@gmail.com |     vaishu |  gravatar.com/vaishu |  Vaishali |     Koul |      Vaishali
     user01.gmmi.com |    userOne |            avatarmy |  first101 |   last01 |      passs101
   user02.yahoo.com | userTwotwo |            avatarmy |  first102 |   last02 |      passs102
  restuser@gmail.com |       rest |    gravatar.com/rest |      rest |     user |      restuser
    deanne@gmail.com |     deanne |  gravatar.com/deanne |    deanne |   charan | deannecharan
   newuser@gmail.com |    newuser | gravatar.com/newuser |       new |     user |       newuser

(8 rows)
[cqlsh:pingme> select * from user;

 emailid            | userid      | avatar               | firstname | lastname | password
--------------------+-------------+----------------------+-----------+----------+---------------
     useme@gmail.com | usermeeee1 |             avataaqm |     useme | everyday | passsthewater
     vishu@gmail.com |      vishu |   gravatar.com/vishu |  vaishali |     kaul |      00120012
   cmpe273@gmail.com |    cmpe273 | gravatar.com/cmpe273 |   cmpe273 |     user |      cmpeuser
  vaishali@gmail.com |     vaishu |  gravatar.com/vaishu |  Vaishali |     Koul |      Vaishali
     user01.gmmi.com |    userOne |            avatarmy |  first101 |   last01 |      passs101
   user02.yahoo.com | userTwotwo |            avatarmy |  first102 |   last02 |      passs102
  restuser@gmail.com |       rest |    gravatar.com/rest |      rest |     user |      restuser
    deanne@gmail.com |     deanne |  gravatar.com/deanne |    deanne |   charan | deannecharan
   newuser@gmail.com |    newuser | gravatar.com/newuser |       new |     user |       newuser

(9 rows)
cqlsh:pingme>
```

After registration, the user details get stored in cassandra (Backend database). The Screenshot above shows the cassandra state before and after the user, cmpe273 registration.

As the front-end stores user credentials in Firebase Database, The Firebase Database maintains the state before and after registration as shown in the following Screenshots



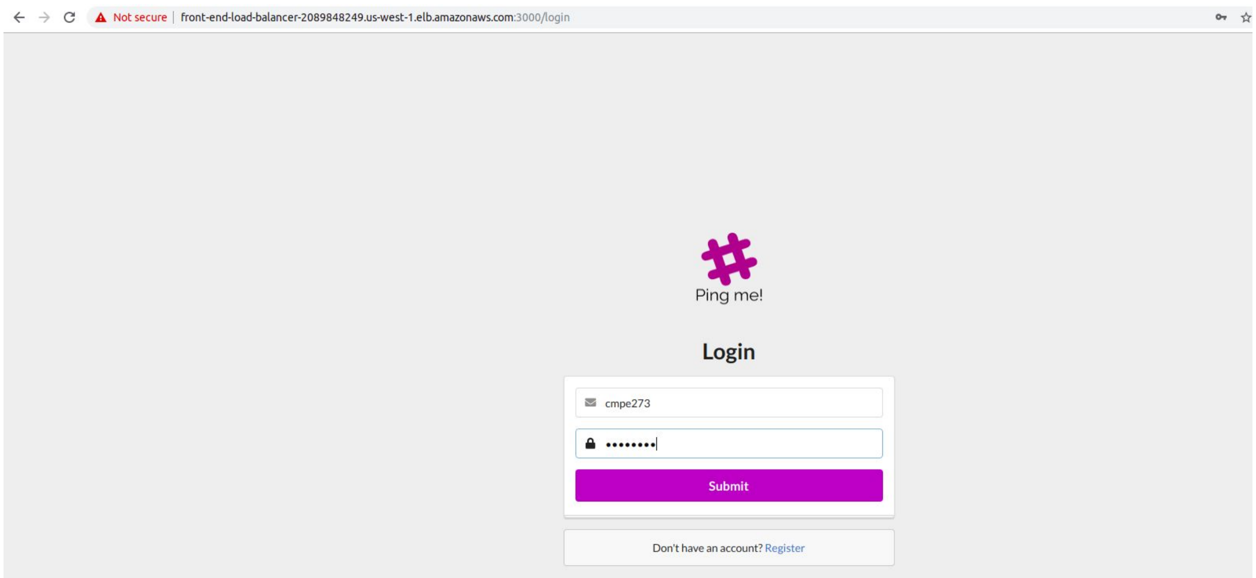
As it can be observed that the User Authentication credentials are stored by Firebase. CMPE273 user is not found until registered at a later stage.



User Login Module

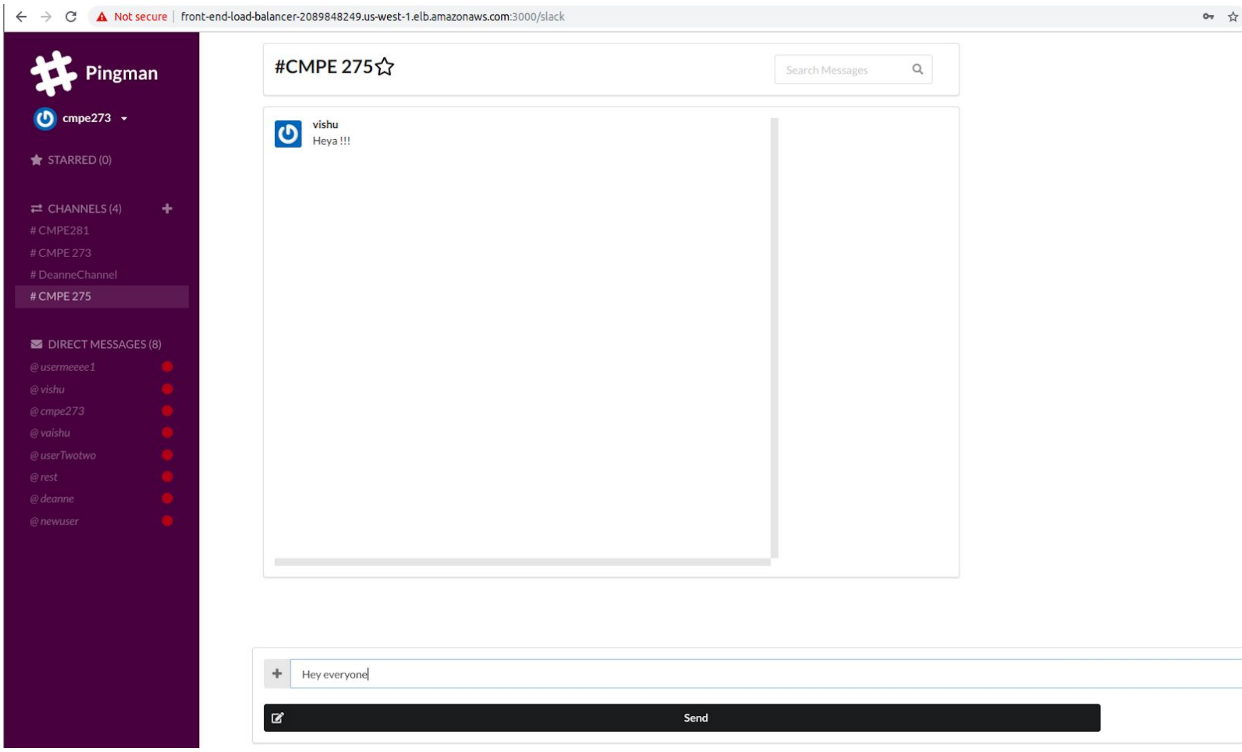
For the user to login, first the user credentials are checked in the firebase database and if not found there, the backend database cassandra is looked into and the user details are called from there. The user needs to enter login details to access the application and post messages.

User "cmpe273" trying to log in.

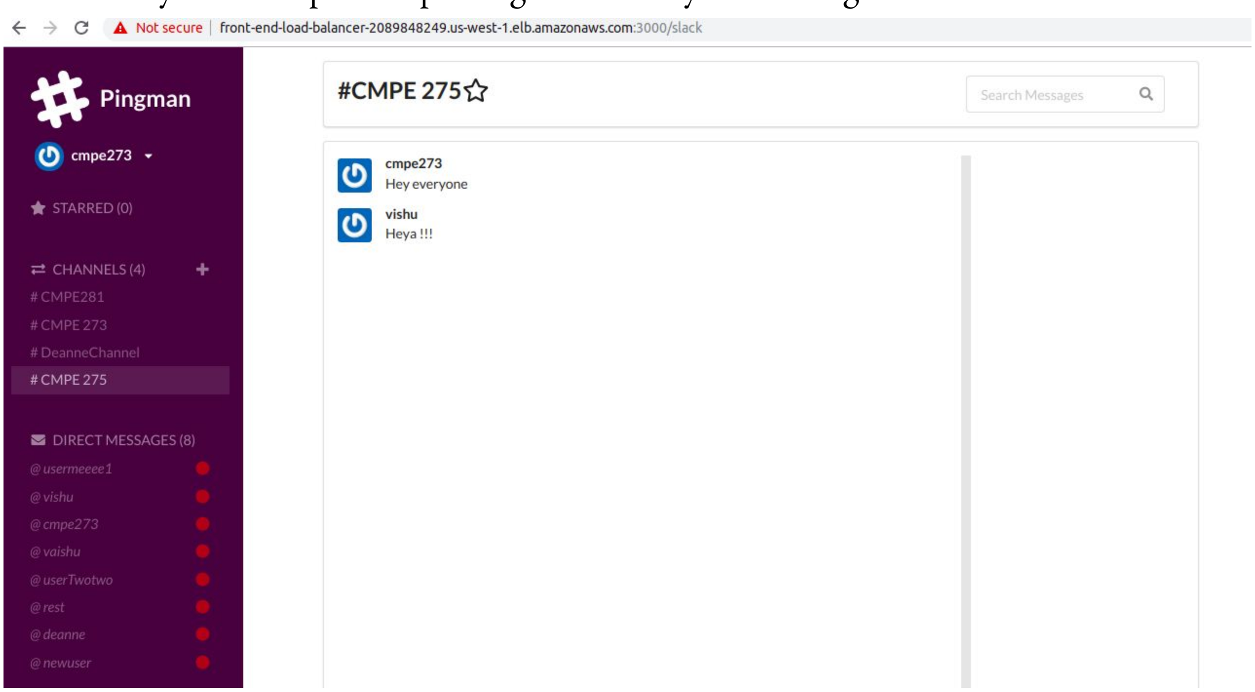


User "cmpe273" logged in

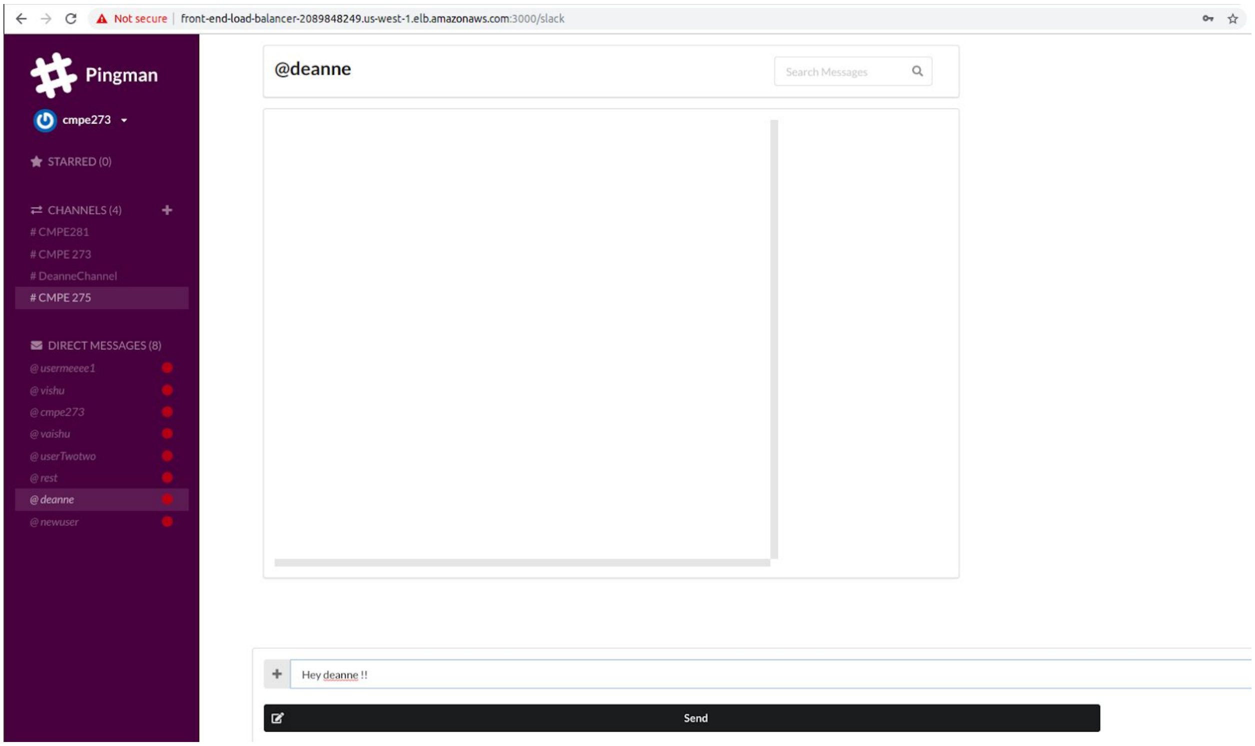
User “cmpe273” viewing channel “cmpe275” and about to send message “Hey everyone” there



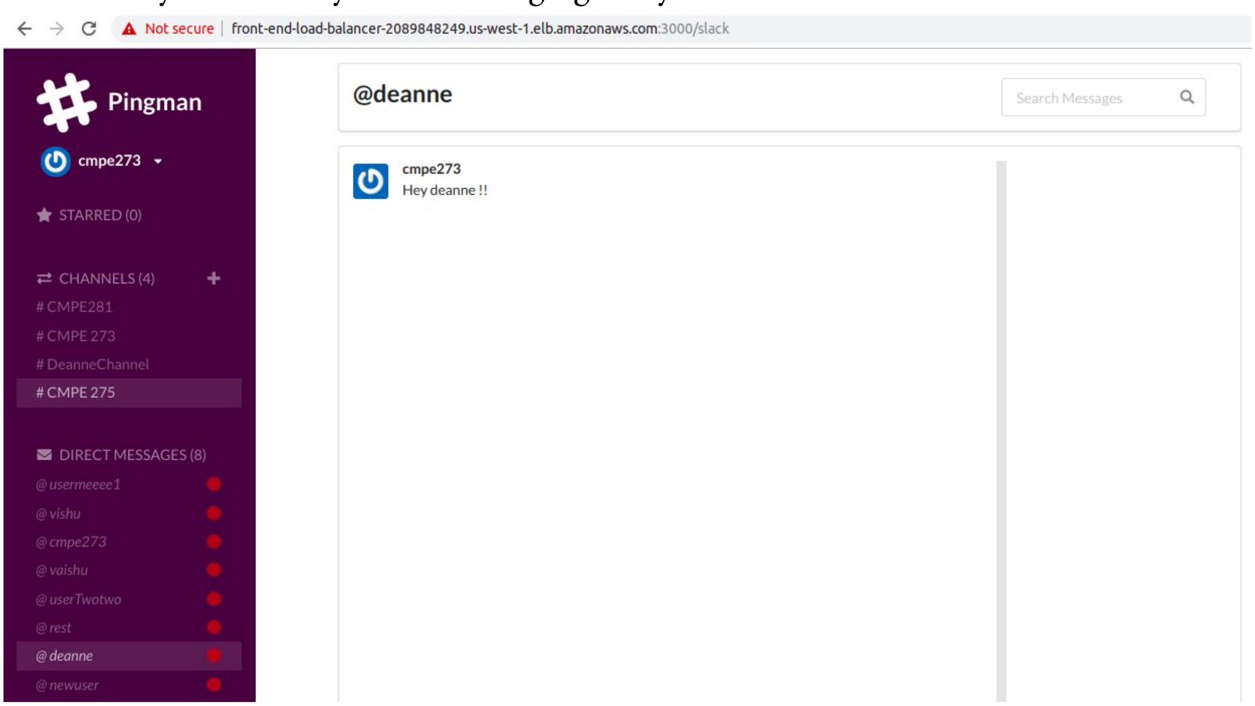
Followed by user “cmpe273” posting successfully the message



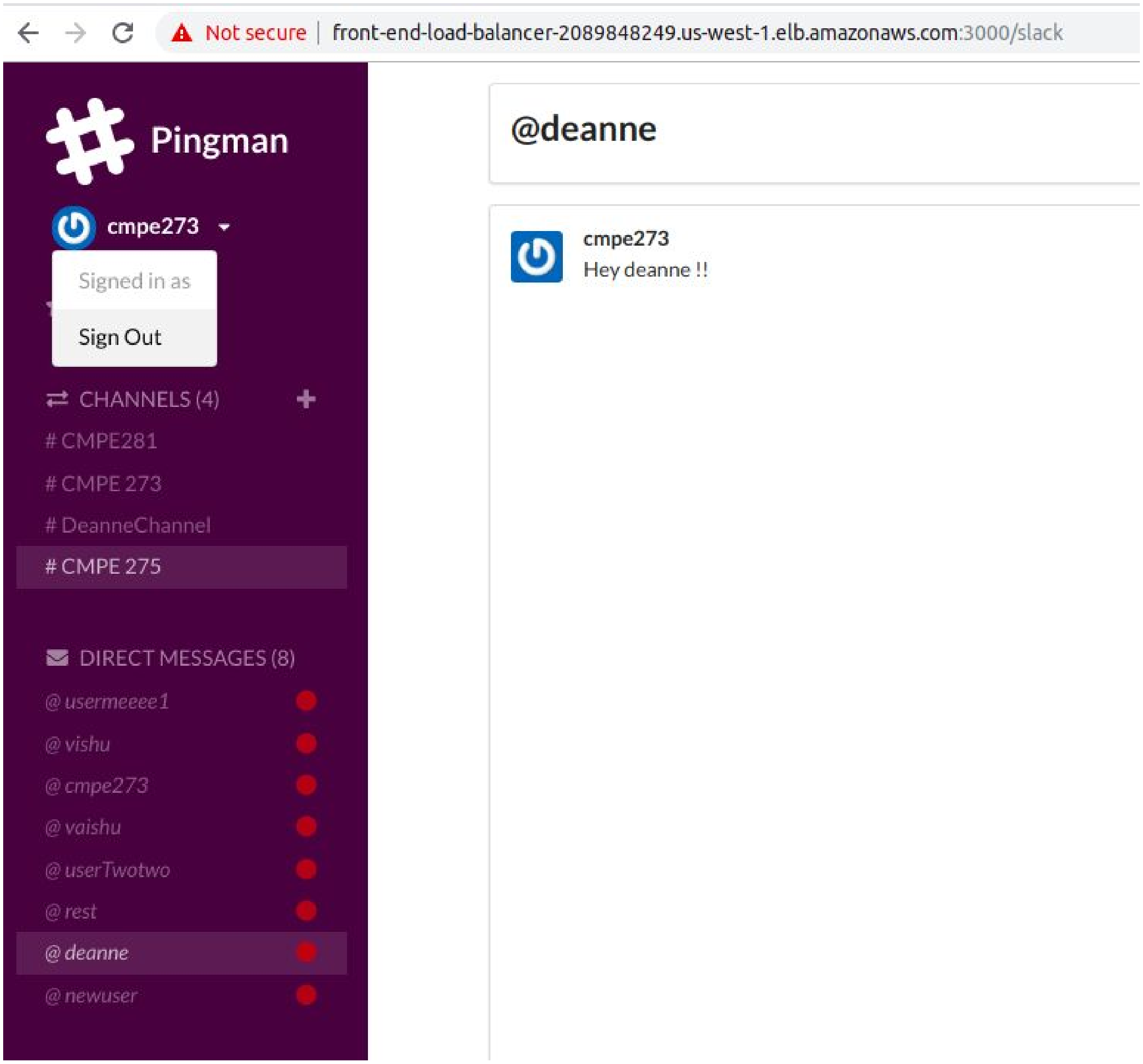
User “cmpe273” trying to post a “Hey deanne!!” message to another user “deanne”



Followed by successfully direct messaging “Hey deanne !!” to user “deanne”.



At the end , the user can sign out which will take the application to an initial login page for other users to access the application.



The steps explained previously give a walk through of the application. How the developed Application acts as a messaging system. Now the question arises, how does the application developed fulfil the idea for a fault-tolerant, durable messaging system.

1. At the Database Level -
   The Application uses a Cassandra cluster with sets of 3 cassandra databases which maintain replicas of the data being generated (the messages in this case). Also for larger, load intensive systems more cassandra servers can be added to the cluster set. Additionally, if even one cassandra server goes down, the others would still be up and store data durably. The cluster set is being served by a Load balancer which forwards the requests in a fair manner within all the database servers which makes the Application capable of handling high load.

2. At the Backend (Spring Boot Level)-
   The Backend servers are again a replica set of three with a load balancer at the end forwarding requests fairly. Even if one or two Backend servers go down, the system application will still be functioning.

3. At the Kafka (Middleware)
   Kafka has itself been developed to be fault tolerant. As long as the producer (the client side) is accepting requests, the Kafka message queue will still be storing messages durably in its topics and queuing them. When the consumer (Spring Boot) comes back up, the messages can be inserted to the database.

4. At the Front-End Level
   Generally distributed systems are all about taking care of the Backend, this messaging application makes sure that the front-end is fault tolerant too. The front end has been replicated in 3 servers to ensure availability during peak time.

5. The Load Balancers in the Deployment
   Each replicated servers part has been served with Load Balancers to ensure that the load gets distributed in a fair fashion and no server gets overburdened while others are free.

CONCLUSION

Kafka replacing the conventional messaging systems increases an application's performance during outages by making sure that the messages get delivered at least once.

It queues the messages until the Consumer is ready to consume the messages back again.

Additionally, contrary to traditional message systems, kafka has a retention period for messages and doesn't completely remove the message until the retention period is over.

Also, using a load balancer to ensure that requests get distributed fairly during sudden network traffic increase. This again ensures system performance and availability because rather than letting one server crash and die down during network spikes, it equally forwards the load. The biggest challenge for this project is the Spring kafka integration. Having the application hosted to cloud is a great idea in terms of allowing scalability and replicas in the Messaging application system. It queues the messages until the Consumer is ready to consume the messages back again.

RECOMMENDATION

The current Application has been developed and tested using data at a small scale but if released in production, this application may have to encounter huge traffic spike abruptly at times. Hence, it is necessary for it to be tested under such circumstances. Due to resource constraints and budget issues, Real Time testing with massive data was not possible but should be considered in future.
Many more functionalities can be added, like auto git commits, searching for users registered with the application using their user names and some security measures should be considered to make the application more secure.

REFERENCES

1. Overcoming Queue problems at Slack

2. Kafka: A distributed Messaging system for log processing

3. Integrating Apache Kafka with Spring

4. Confluent : An Intro of Kafka with Spring Boot

5. Creating a Spring Boot Apache Kafka Application

APPENDIX

1.Apache Kafka - A message streaming platform that helps in transmitting messages between systems and applications. It also helps create data pipelines for streaming.

2. Kafka Topic - An SQL Table like entity which is just a bunch of continuously being produced records. Used to store messages in Kafka.

3. Kafka Producer - Pushes messages to the kafka topics [The react front-end in this case].

4. Kafka Consumer - Pulls messages from the Kafka topic [The Backend Spring boot Application that inserts data into the databases].

5. Message offset - Kafka does not store messages with Ids. Instead, there are message offsets that Kafka Broker stores and the consumer is responsible for acknowledging offsets with the broker, hence keeps track of the amount of messages that have been consumed.

6. Elastic Load Balancer - Handles the incoming traffic and distributes the requests fairly among all the EC2 instances or servers that it is serving.

7. Cassandra - An AP Database that is used to store data and has capability of handling massive amounts of requests.