DESIGN SPECIFICATION

This project implements a simple book store through a client server model that is capable of handling a higher workload and uses REST API's to communicate between layers.

How it works

There are two tiers in the web-app: a front-end and a back-end.
The front end accepts incoming requests from clients and accordingly processes them, by forwarding the calls to relevant servers.The backend servers are replicated and the frontend server implements a load balancer to balance the load between the replicas of the respective backend servers.

The backend consists of two servers, each of which has two replicas:
1. Catalog server A and B: Each replica of the catalog server maintains a catalog (which currently consists of four books) and the relevant information corresponding to those books. Following is the schema for the catalog server.

```
{
        id: int (primary key),
        title: text
        cost: text
        count: text
        topic: text
}
```

2. Order Server A and B: Each replica of the order server maintains a list of all orders received for the books.
Following is the schema for order server:

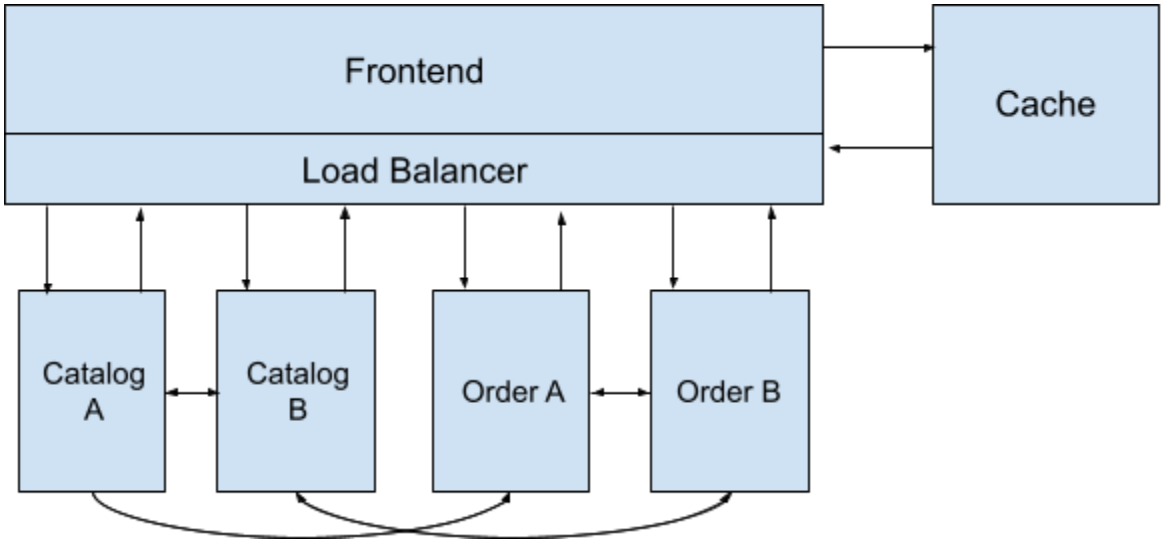
```
{
        id: int (primary key),
        item_id: int,
        Created: date
}
```

The front end server also implements a caching mechanism to cache the results of read requests, namely search and lookup, as it can be seen below.

The front end server supports three operations:

1. search(topic) - which allows the user to specify a topic and returns all entries belonging to that category (a title and an item number are displayed for each match).
2. lookup(item_number) - which allows an item number to be specified and returns details such as number of items in stock and cost
3. buy(item_number) - which specifies an item number for purchase.

The way the servers interact with each other is shown below:



IMPLEMENTATION

Catalog server

Each replica of the catalog server exposes a GET API ('item') which allows for books to be looked up from it's database, either by id, or by topic. The catalog server also exposes a PUT API on 'item' which allows for the altering the items database in the catalog server. For example, This can be used when a book is purchased or if the cost of a book needs to be updated. Each catalog server also has another PUT API that is called by other replicas of the catalog server for propagation of updates to the catalog database. This is how the catalog servers maintain consistency in the database. Whenever a copy of a catalog server makes an update to its own database, it also calls this PUT API on the other copies of the server to propagate this update. The catalog servers are designed so that they will resync their database in the event of a crash and recovery from this crash. If a replica of the catalog server, for example, recovers after a crash, it will read the database of the other, functional replica of the catalog server and accordingly update its own database to reflect the changes that took place while this replica was crashed. This ensures that even in the case of crash and failure, the replicas of the catalog server remain consistent.

Order Server

Each replica of the order server exposes a GET API('buy') method which looks for a book corresponding to a certain ID and then buys it from the catalog server. When a client invokes the buy function on the front end server to buy a book by an ID number, the frontend server calls the endpoint on the order server with this ID number to buy a book. The order server first queries the respective replica of the catalog server to ensure that the book to be bought is

available in stock, and then executes the buy operation and updates the database to reflect it. Each order server also has another PUT API that is called by other replicas of the order server for propagation of updates to the order database. This is how the order servers maintain consistency in the database. Whenever a copy of an order server makes an update to its own database, it also calls this PUT API on the other copies of the server to propagate this update.The order servers are designed so that they will resync their database in the event of a crash and recovery from this crash. If a replica of the order server, for example, recovers after a crash, it will read the database of the other, functional replica of the order server and accordingly update its own database to reflect the changes that took place while this replica was crashed. This ensures that even in the case of crash and failure, the replicas of the order server remain consistent.

Frontend Server
The front end server also allows the user to look for a book either by its ID or by its topic. The lookup function allows the user to look up the details of a particular book by it's ID. A query is made to the catalog server and specific details of the book corresponding to the ID is returned. Similarly, to search for all books belonging to a particular topic, the search function is implemented by the front end server which makes a call to the catalog server which returns a list of all the books belonging to that topic. The frontend server also allows the client to buy a specific item from the catalog via the GET API buy.

Load Balancing

Load balancing is implemented at the frontend server. We have used a simple round robin technique for load balancing. Since there are two copies each of order server and catalog server, this means that each request alternately goes to one of the two order/catalog servers.

Heartbeat Messages

Along with load balancing, the frontend server also implements a heartbeat mechanism to check if the backend servers are up. This is done so that if the frontend server detects that any replica of either the catalog, or the order server is down, it can forward the request to the other (functional) replica.

Caching

We have implemented caching so that lookup requests can be served more quickly. The frontend has three methods that a client can access, search, lookup and buy. For search and lookup a client gets returned either a list of books corresponding to the topic searched for, or return the details of the book corresponding to the id that is looked up. First, the frontend server will check it's own cache, and if the results of the query are present simply return that instead of

sending the request to the backend server. However, everytime the buy method is called, the entire cache is invalidated.

Replication

The frontend server has not been replicated.

For our project we have assumed there to be two replicas each of the order server and the catalog server. Each server is replicated along with its code and database files. When an update is made to the database on any server, it first updates the local copy of the database, and then propagates this update to all the replicated copies of the database by calling a method with PUT API on the other copies of the server. This is done to ensure that there is a consistency between the different copies of the database among the replicated backend servers.

Every copy of the order server, thus must have knowledge of the ports and IP addresses of the other copies of order servers so that it may propagate any update to its database to the other copies. It must also have knowledge of the corresponding catalog server that it must connect to. For the purpose of our project we have assumed that order A connects with catalog A and similarly order B connects with catalog B. Similarly, catalog server needs to have network information about its replicas as well.

Resync Mechanism

When a replica of the catalog server recovers from a crash, it calls a GET method of the functional replica of the catalog server which returns the most recent values corresponding to the different books. Accordingly, the replica that restarts from a crash updates these values in its own database to reflect these changes, thus maintaining consistency even in the case of a crash.

When a replica of the order server recovers a crash, it calls a GET method of the functional replica of the order server which returns the most recent list of transactions completed. Accordingly, the replica that restarts from a crash updates its database to reflect the transactions that were completed by the order server while this replica was crashed, thus maintaining consistency even in the case of a crash.

Dockerization

In the current implementation, each server will be deployed as a docker container which will be communicating with each other for serving the client request. Each folder in the *pygmy* repository contains a Dockerfile which is used to deploy the images containing source code and

required environment variables to the docker hub. Currently the docker images has been pushed to the public repository *himgupta1996/pygmy*.

1. **Frontend server docker image location with tag**: himgupta1996/pygmy:frontend
2. **Order server docker image location with tag**: himgupta1996/pygmy:order
3. **Catalog server docker image location with tag**: himgupta1996/pygmy:catalog

To pull the images from the repository and run the docker containers on the machines specified in the *env.cfg*, run the file "*runme.sh*" present in the main folder using the command: *. ./runme.sh*. This will deploy the docker server containers to respective machines and trigger the client.py to instantiate the traffic and test the servers. Logs of all the servers can be found in the directory logs/ inside the main folder *pygmy*. Client log can be found in the main folder itself.

How to Run and Test Pygmy

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1 PYGMY - The Retail Book Store 2.0

This repository contains implementation of the Lab 3 Project of COMPSCI 677 course at UMass Amherst.

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2 System requirement

Local VM (Linux), Local VM OS(ubuntu), Ec2 servers (Linux

3 Installing Required Packages

Installing Python and required dependencies: 1. sudo apt-get update

2. sudo apt-get install python
3. sudo apt-get install python-pip
4. Go to the main folder `pygmy` and run the command: pip install requirement.txt

Installing Docker

1. Follow the steps specified in the link: https://docs.docker.com/engine/installation/

4 Important Source File Descriptions

1. `catalog/catalog.py` implements the catalog server with the relevant GET and PUT methods.
2. `frontend/frontend.py` implements the front end server with the buy, search and lookup methods.
3. `order/order.py` implements the order server with the buy method.
4. `Docs` folder contains the design documentation and API documention.
5. `logs` folder contains all the logs of the servers after the execution of the script `runme.sh`. For eg. orderA.log, frontend.log etc. It will also contain the log file `heartbeat.log` which contains the heartbeats of different servers captured by frontend.

6. `requirements.txt` contains the python libraries required.
7. `env.cfg` contains the `PUBLIC_IP` and `PORT` of the machines where the catalog, order and frontend server has to be run. It also contains the reference to the `pem` file that is required to ssh, and scp to the remote machines. Modify the file according to your requirements.
8. `runme.sh` is a single script to automatically deploy catalog, order and frontend docker servers on specified machines in `env.cfg`, run the client.py and get the logs from all the servers.
9. `client.py` starts the traffic by sending multiple requests to frontend parrallely and sequentially. This script is called by `runme.sh` internally.
10. `simulate_fault_tolerance.sh` is a single script to check falut tolerance of the system. The script specifically brings down the catalogA and invokes the client.py to check if the system is working correctly even if one of the server is down. Then it brings the server up and calls the python file `test_server_recovery.py` to check if the system was able to recover from the crash.
11. `const.py` contains information about the books in the catalog server.
12. `Docs` contains the design documentation

Please find the instructions below for testing the implementation.

5 Instructions

5.0.1 To run the server locally

1. Define the ip and ports of order, catalog and front end server by editing the `env.cfg` file. For running locally make the IPs for the server as `http://<public_ip_of_local_vm>`.
2. Now, on your local machine, run the `runme.sh` file which deploy all the dockers and then trigger the client.py for starting the traffic. USAGE: `. ./runme.sh`.
3. You can observe the results of this run in different log files that should be accumulated under the folder `logs`. `client.log` in the main folder will contain the logs of `client.py` script.

5.0.2 To run servers remotely

1. Deploy an Ubuntu VM. We have used the AMI: `ami-013f17f36f8b1fefb` to deploy instances and test our code. You can use any other Ubuntu image as per your convenience. Make sure to install docker engine on the instances. You can follow the link: https://docs.docker.com/engine/installation/ for the same.
2. Get the private .pem file which will be used to coomunicate to the remote servers by the local machine.
3. Edit the security group to ensure that the ports required by the peers to communicate are open.
4. Set up password-less ssh from the local machine to the ec2 servers by running the following command from the local terminal: `ssh -i <pem_file_path> ubuntu@<ec2_public_ip>` with the private pem file and the public IP address of the EC2 instance that has been set up. (This will add the ec2 server to the known_host file so that you can ssh from the script without the need of a password). Please note that ubuntu is default username of an AWS Ubuntu VM. You can alter it according to your need.
5. Define the ip and ports of order, catalog and front end server by editing the `env.cfg` file. Change the port IDs of the servers as pleased. Also provide the path of the pem file. Instructions to change the file is specified in the same.

6. Now, on your local machine, run the `runme.sh` file which deploy all the dockers and then trigger the client.py for starting the traffic. USAGE: `. ./runme.sh`.
7. You can observe the results of this run in different log files that should be accumulated under the folder `logs`. `client.log` in the main folder will contain the logs of `client.py` script.

5.0.3 To simute and check fault tolerance of the system

1. Execute the shell script `simulate_fault_tolerance.sh` using the command `. ./simulate_fault_tolerance.sh`.
2. Check the the log file `test_server_recovery.log` to check if the system was able to recover from the crash of catalogA server.