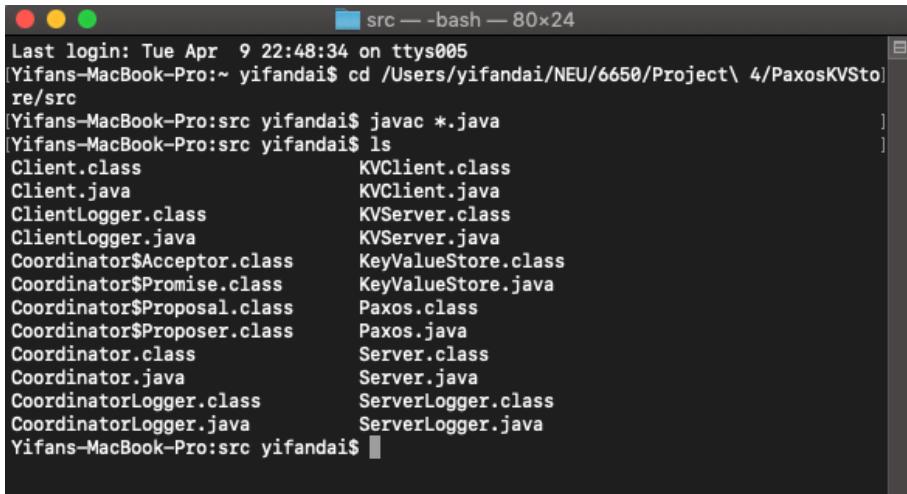

Paxos-Based, Multi-threaded, Replicated Key-Value Store using RPC

README

Build Code

Compile: *javac *.java*



```
src — bash — 80x24
Last login: Tue Apr  9 22:48:34 on ttys005
[Yifans-MacBook-Pro:~ yifandai$ cd /Users/yifandai/NEU/6650/Project\ 4/PaxosKVSto]re/src
[Yifans-MacBook-Pro:src yifandai$ javac *.java
[Yifans-MacBook-Pro:src yifandai$ ls
Client.class          KVClient.class
Client.java           KVClient.java
ClientLogger.class    KVServer.class
ClientLogger.java     KVServer.java
Coordinator$Acceptor.class KeyValueStore.class
Coordinator$Promise.class KeyValueStore.java
Coordinator$Proposal.class Paxos.class
Coordinator$Proposer.class Paxos.java
Coordinator.class      Server.class
Coordinator.java       Server.java
CoordinatorLogger.class ServerLogger.class
CoordinatorLogger.java ServerLogger.java
Yifans-MacBook-Pro:src yifandai$ ]
```

Run Server

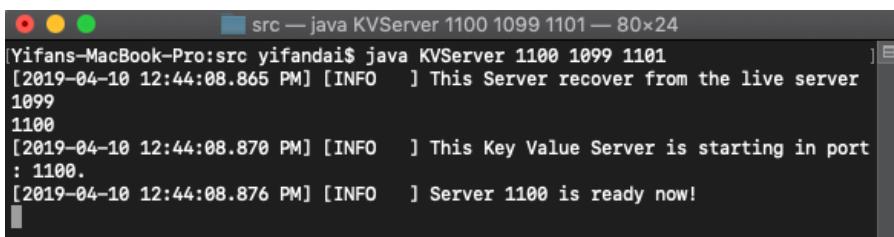
- 1) Run a server at the first time, you can simply run it by: *java KVServer <portNumber>*



```
src — java KVServer 1099 — 80x24
[Yifans-MacBook-Pro:src yifandai$ java KVServer 1099
1099
[2019-04-10 12:41:30.924 PM] [INFO  ] This Key Value Server is starting in port
: 1099.
[2019-04-10 12:41:30.954 PM] [INFO  ] Server 1099 is ready now!
] ]
```

- 2) If you want to run a server and recover it from the live server, you can run:

java KVServer <portNumber> <livePort1> <livePort2> ...



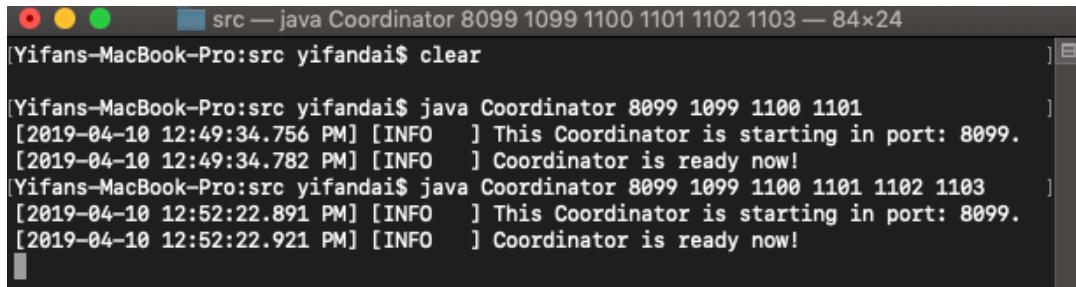
```
src — java KVServer 1100 1099 1101 — 80x24
[Yifans-MacBook-Pro:src yifandai$ java KVServer 1100 1099 1101
[2019-04-10 12:44:08.865 PM] [INFO  ] This Server recover from the live server
1099
1100
[2019-04-10 12:44:08.870 PM] [INFO  ] This Key Value Server is starting in port
: 1100.
[2019-04-10 12:44:08.876 PM] [INFO  ] Server 1100 is ready now!
] ]
```

The *portNumber* is the port number of current server, the *livePort1*, *livePort2* and etc is the port number of the live ports which are currently running.

The server will recover the data from *<livePort1>*, *<livePort2>* and etc. The recover logic is: **the server will first try to connect to the live server 1 and recover. If it recover successfully then it will complete the recovery, otherwise, it will try the live server 2 and etc until it is success.**

Run Coordinator

Run Coordinator by: *java Coordinator <portNumber> <serverPort1> ... <serverPort5>*

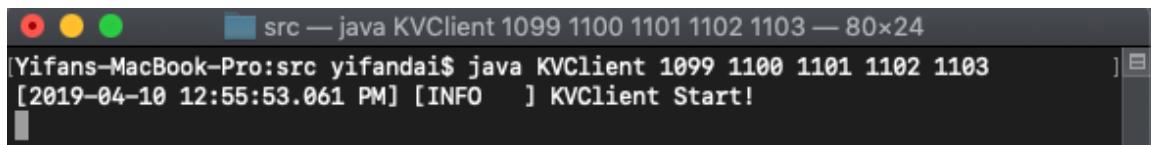


```
[Yifans-MacBook-Pro:src yifandai$ clear
[Yifans-MacBook-Pro:src yifandai$ java Coordinator 8099 1099 1100 1101 1102 1103 — 84x24
[2019-04-10 12:49:34.756 PM] [INFO    ] This Coordinator is starting in port: 8099.
[2019-04-10 12:49:34.782 PM] [INFO    ] Coordinator is ready now!
[Yifans-MacBook-Pro:src yifandai$ java Coordinator 8099 1099 1100 1101 1102 1103 — 84x24
[2019-04-10 12:52:22.891 PM] [INFO    ] This Coordinator is starting in port: 8099.
[2019-04-10 12:52:22.921 PM] [INFO    ] Coordinator is ready now!
```

The *serverPort1* to *serverPort5* are the port numbers of the live servers.

Run Client

Run Client by: *java Client <serverPort1> ... <serverPort5>*



```
[Yifans-MacBook-Pro:src yifandai$ java KVClient 1099 1100 1101 1102 1103 — 80x24
[2019-04-10 12:55:53.061 PM] [INFO    ] KVClient Start!
```

The *serverPort1* to *serverPort5* are the port numbers of the live servers.

Notice

1. If some servers are down, then the quorum is based on the number of live servers, not including the servers which are already down.
2. When starting a new server by running the *java KVServer <portNumber> <livePort1> <livePort2> ...* this current server will try to recover data from the live servers. If all the servers provided here are all down, then the current server will start with an empty KV.
3. The live servers are always consistent (the data in every live servers are always the same). The client could send request and receive correct response if there is at least one live server. If there is no live server currently, then the client will retry until a live server is available and send request to the live server.

How to make the servers randomly fail

There is a *Coordinator.java* file in the source code directory.

As the screenshot showed below, we can change the float which is underlined by the red line. This float represent the failure probability (the probability to reject the update) when clients send request to the servers. Please feel free to change the float value when testing.

```
208     public static class Acceptor implements Serializable {
209
210         // last vote result
211         public Proposal last = new Proposal();
212         public String name;
213
214         public Acceptor(String name) { this.name = name; }
215
216         public Promise onPrepare(Proposal proposal) {
217             // We suppose that the failure probability is 10%
218             if (Math.random() < 0.1) {
219                 printInfo(subject: "Server " + name, operation: "PREPARE", result: "NO RESPONSE");
220                 return null;
221             }
222             if (proposal == null)
223                 throw new IllegalArgumentException("null proposal");
224             if (proposal.getVoteNumber() > last.getVoteNumber()) {
225                 Promise response = new Promise(ack: true, last);
226                 last = proposal;
227                 printInfo(subject: "Server " + name, operation: "PREPARE", result: "OK");
228                 return response;
229             } else {
230                 printInfo(subject: "Server " + name, operation: "PREPARE", result: "REJECTED");
231                 return new Promise(ack: false, proposal: null);
232             }
233         }
234
235         public boolean onAccept(Proposal proposal) {
236             // We suppose that the failure probability is 10%
237             if (Math.random() < 0.1) {
238                 printInfo(subject: "Server " + name, operation: "ACCEPT", result: "NO RESPONSE");
239                 return false;
240             }
241             printInfo(subject: "Server " + name, operation: "ACCEPT", result: "OK");
242             return last.equals(proposal);
243         }
244     }
245 }
```

How to make the servers down

We could simulate that by simply shut down the server (ctrl + c or close the terminal).

Code Test Example

We could start 5 servers, 1 coordinator and 2 clients for testing first (I use the screenshot on my Mac as the example):

The screenshot shows five terminal windows for servers and one for the Coordinator, each displaying log output. The servers are labeled Server 1099, Server 1100, Server 1101, Server 1102, and Server 1103. The Coordinator window is labeled "Coordinator". The Client windows are labeled Client 1 and Client 2. Each window shows the Java application starting up and reporting that it is ready.

```
Yifans-MacBook-Pro:src yifandai$ java KVServer 1099 — 84x20
1099
[2019-04-10 1:48:24.418 PM] [INFO ] This Key Value Server is starting in port: 1099.
[2019-04-10 1:48:24.445 PM] [INFO ] Server 1099 is ready now!
Yifans-MacBook-Pro:src yifandai$ java KVServer 1099
1099
[2019-04-10 1:48:24.418 PM] [INFO ] This Key Value Server is starting in port: 1099.
[2019-04-10 1:48:24.445 PM] [INFO ] Server 1099 is ready now!
Yifans-MacBook-Pro:src yifandai$ java KVServer 1100 — 84x20
1100
[2019-04-10 1:48:31.579 PM] [INFO ] This Key Value Server is starting in port: 1100.
[2019-04-10 1:48:31.607 PM] [INFO ] Server 1100 is ready now!
Yifans-MacBook-Pro:src yifandai$ java KVServer 1101 — 84x20
1101
[2019-04-10 1:48:40.285 PM] [INFO ] This Key Value Server is starting in port: 1101.
[2019-04-10 1:48:40.312 PM] [INFO ] Server 1101 is ready now!
Yifans-MacBook-Pro:src yifandai$ java KVServer 1102 — 92x20
1102
[2019-04-10 1:48:44.598 PM] [INFO ] This Key Value Server is starting in port: 1102.
[2019-04-10 1:48:44.618 PM] [INFO ] Server 1102 is ready now!
Yifans-MacBook-Pro:src yifandai$ java KVServer 1103 — 84x20
1103
[2019-04-10 1:48:48.871 PM] [INFO ] This Key Value Server is starting in port: 1103.
[2019-04-10 1:48:48.901 PM] [INFO ] Server 1103 is ready now!
Yifans-MacBook-Pro:src yifandai$ java Coordinator 8099 1099 1100 1101 1102 1103 — 92x42
8099 1099 1100 1101 1102 1103
[2019-04-10 1:48:55.984 PM] [INFO ] This Coordinator is starting in port: 8099.
[2019-04-10 1:48:55.933 PM] [INFO ] Coordinator is ready now!
Yifans-MacBook-Pro:src yifandai$ java KVClient 1099 1100 1101 1102 1103 — 84x20
1099 1100 1101 1102 1103
[2019-04-10 1:41:13.086 PM] [INFO ] KVClient Start!
Yifans-MacBook-Pro:src yifandai$ java KVClient 1099 1100 1101 1102 1103 — 84x20
1099 1100 1101 1102 1103
[2019-04-10 1:41:19.725 PM] [INFO ] KVClient Start!
```

The client 1 send requests PUT:

The screenshot shows six terminal windows for servers and one for the Coordinator, illustrating the PUT request process. The servers are labeled Server 1099, Server 1100, Server 1101, Server 1102, and Server 1103. The Coordinator window is labeled "Coordinator". The Client window is labeled "Client 1". Arrows point from the Coordinator logs to the "Prepare" and "Accept" stages of the request. The Client 1 window shows the command being sent.

```
Yifans-MacBook-Pro:src yifandai$ java KVServer 1099 — 84x20
1099
[2019-04-10 2:30:16.593 PM] [INFO ] This Key Value Server is starting in port: 1099.
[2019-04-10 2:30:16.711 PM] [INFO ] Server 1099 is ready now!
[2019-04-10 2:31:02.292 PM] [INFO ] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.293 PM] [INFO ] Successful request PUT with updating an key-value pair.
Yifans-MacBook-Pro:src yifandai$ java KVServer 1100 — 84x20
1100
[2019-04-10 2:30:16.593 PM] [INFO ] This Key Value Server is starting in port: 1100.
[2019-04-10 2:30:16.621 PM] [INFO ] Server 1100 is ready now!
[2019-04-10 2:31:02.295 PM] [INFO ] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.295 PM] [INFO ] Successful request PUT with updating an key-value pair.
Yifans-MacBook-Pro:src yifandai$ java KVServer 1101 — 84x20
1101
[2019-04-10 2:30:18.874 PM] [INFO ] This Key Value Server is starting in port: 1101.
[2019-04-10 2:30:18.819 PM] [INFO ] Server 1101 is ready now!
[2019-04-10 2:31:02.298 PM] [INFO ] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.298 PM] [INFO ] Successful request PUT with updating an key-value pair.
Yifans-MacBook-Pro:src yifandai$ java KVServer 1102 — 92x20
1102
[2019-04-10 2:30:26.027 PM] [INFO ] This Key Value Server is starting in port: 1102.
[2019-04-10 2:30:28.062 PM] [INFO ] Server 1102 is ready now!
[2019-04-10 2:31:02.381 PM] [INFO ] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.381 PM] [INFO ] Successful request PUT with updating an key-value pair.
Yifans-MacBook-Pro:src yifandai$ java KVServer 1103 — 84x20
1103
[2019-04-10 2:30:23.064 PM] [INFO ] This Key Value Server is starting in port: 1103.
[2019-04-10 2:30:23.090 PM] [INFO ] Server 1103 is ready now!
[2019-04-10 2:31:02.243 PM] [INFO ] Client with hash code: 112573441 is connected!
[2019-04-10 2:31:02.289 PM] [INFO ] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.289 PM] [INFO ] Successful request PUT with updating an key-value pair.
Yifans-MacBook-Pro:src yifandai$ java Coordinator 8099 1099 1100 1101 1102 1103 — 92x42
8099 1099 1100 1101 1102 1103
[2019-04-10 2:30:38.321 PM] [INFO ] This Coordinator is starting in port: 8099.
[2019-04-10 2:30:38.344 PM] [INFO ] Coordinator is ready now!
Server 1099 :PREPARE<OK>
Server 1100 :PREPARE<OK>
Server 1101 :PREPARE<OK>
Server 1102 :PREPARE<OK>
Server 1103 :PREPARE<OK>
Server 1099 :ACCEPT<NO RESPONSE>
Server 1100 :ACCEPT<NO RESPONSE>
Server 1101 :ACCEPT<NO RESPONSE>
Server 1102 :ACCEPT<NO RESPONSE>
Server 1103 :ACCEPT<NO RESPONSE>
PROPOSER[1: "put yifan 24"] :VOTE<SUCCESS>
Yifans-MacBook-Pro:src yifandai$ java KVClient 1099 1100 1101 1102 1103 — 84x20
1099 1100 1101 1102 1103
[2019-04-10 2:30:07.305 PM] [INFO ] KVClient Start!
```

We can see that for the requests PUT, all the servers update at the same time. It is also the same for the delete:

```

Yifans-MacBook-Pro:src yifanda$ java KVServer 1099
1099
[2019-04-10 2:38:13.711 PM] [INFO ] This Key Value Server is starting in port: 1099.
[2019-04-10 2:38:13.738 PM] [INFO ] Server 1099 is ready now!
[2019-04-10 2:31:02.292 PM] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.293 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-10 2:33:12.242 PM] Response: "The key: 24 is not exist!"
[2019-04-10 2:33:12.242 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-10 2:33:21.588 PM] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-10 2:33:21.588 PM] [INFO ] Successful request DELETE.

Yifans-MacBook-Pro:src yifanda$ java KVServer 1100
1100
[2019-04-10 2:38:16.593 PM] [INFO ] This Key Value Server is starting in port: 1100.
[2019-04-10 2:38:16.421 PM] [INFO ] Server 1100 is ready now!
[2019-04-10 2:31:02.295 PM] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.295 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-10 2:33:12.214 PM] [INFO ] Client with hash code: -769801141 is connected !
[2019-04-10 2:33:12.237 PM] Response: "The key: 24 is not exist!"
[2019-04-10 2:33:12.237 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-10 2:33:21.582 PM] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-10 2:33:21.582 PM] [INFO ] Successful request DELETE.

Yifans-MacBook-Pro:src yifanda$ java KVServer 1101
1101
[2019-04-10 2:38:18.794 PM] [INFO ] This Key Value Server is starting in port: 1101.
[2019-04-10 2:38:18.819 PM] [INFO ] Server 1101 is ready now!
[2019-04-10 2:31:02.298 PM] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.298 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-10 2:33:12.244 PM] Response: "The key: 24 is not exist!"
[2019-04-10 2:33:12.244 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-10 2:33:21.559 PM] [INFO ] Client with hash code: -769801141 is connected !
[2019-04-10 2:33:21.577 PM] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-10 2:33:21.577 PM] [INFO ] Successful request DELETE.

Yifans-MacBook-Pro:src yifanda$ java KVServer 1102
1102
[2019-04-10 2:38:20.927 PM] [INFO ] This Key Value Server is starting in port: 1102.
[2019-04-10 2:38:20.952 PM] [INFO ] Server 1102 is ready now!
[2019-04-10 2:31:02.381 PM] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.381 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-10 2:33:12.246 PM] Response: "The key: 24 is not exist!"
[2019-04-10 2:33:12.247 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-10 2:33:21.585 PM] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-10 2:33:21.585 PM] [INFO ] Successful request DELETE.

Yifans-MacBook-Pro:src yifanda$ java KVClient 1099 1100 1101 1102 1103
[2019-04-10 2:30:07.305 PM] [INFO ] KVClient Start!
put yifan 24
Set the key value pairs: yifan -> 24
[2019-04-10 2:30:07.305 PM] [INFO ] KVClient Start!
put yifan 10
Set the key value pairs: yifan -> 10
[2019-04-10 2:30:07.305 PM] [INFO ] KVClient Start!
get yifan
The value of the key: yifan is 10

```

You can see that the coordinator has some log for the result of the **Prepare** and **Accept** phase. It will show whether a server accept, reject or has no response to the proposal. Every proposal will have a proposal number and a string which is same as the request the client sent.

```

Yifans-MacBook-Pro:src yifanda$ java KVServer 1099
1099
[2019-04-10 2:38:13.711 PM] [INFO ] This Key Value Server is starting in port: 1099.
[2019-04-10 2:38:13.738 PM] [INFO ] Server 1099 is ready now!
[2019-04-10 2:31:02.292 PM] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.293 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-10 2:33:12.242 PM] Response: "The key: 24 is not exist!"
[2019-04-10 2:33:12.242 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-10 2:33:21.588 PM] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-10 2:33:21.588 PM] [INFO ] Successful request DELETE.

Yifans-MacBook-Pro:src yifanda$ java KVServer 1100
1100
[2019-04-10 2:38:16.593 PM] [INFO ] This Key Value Server is starting in port: 1100.
[2019-04-10 2:38:16.421 PM] [INFO ] Server 1100 is ready now!
[2019-04-10 2:31:02.295 PM] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.295 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-10 2:33:12.214 PM] [INFO ] Client with hash code: -769801141 is connected !
[2019-04-10 2:33:12.237 PM] Response: "The key: 24 is not exist!"
[2019-04-10 2:33:12.237 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-10 2:33:21.582 PM] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-10 2:33:21.582 PM] [INFO ] Successful request DELETE.

Yifans-MacBook-Pro:src yifanda$ java KVServer 1101
1101
[2019-04-10 2:38:18.794 PM] [INFO ] This Key Value Server is starting in port: 1101.
[2019-04-10 2:38:18.819 PM] [INFO ] Server 1101 is ready now!
[2019-04-10 2:31:02.298 PM] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.298 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-10 2:33:12.244 PM] Response: "The key: 24 is not exist!"
[2019-04-10 2:33:12.244 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-10 2:33:21.559 PM] [INFO ] Client with hash code: -769801141 is connected !
[2019-04-10 2:33:21.577 PM] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-10 2:33:21.577 PM] [INFO ] Successful request DELETE.

Yifans-MacBook-Pro:src yifanda$ java KVServer 1102
1102
[2019-04-10 2:38:20.927 PM] [INFO ] This Key Value Server is starting in port: 1102.
[2019-04-10 2:38:20.952 PM] [INFO ] Server 1102 is ready now!
[2019-04-10 2:31:02.381 PM] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.381 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-10 2:33:12.246 PM] Response: "The key: 24 is not exist!"
[2019-04-10 2:33:12.247 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-10 2:33:21.585 PM] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-10 2:33:21.585 PM] [INFO ] Successful request DELETE.

Yifans-MacBook-Pro:src yifanda$ java KVClient 1099 1100 1101 1102 1103
[2019-04-10 2:30:07.305 PM] [INFO ] KVClient Start!
put yifan 24
Set the key value pairs: yifan -> 24
[2019-04-10 2:30:07.305 PM] [INFO ] KVClient Start!
put yifan 10
Set the key value pairs: yifan -> 10
[2019-04-10 2:30:07.305 PM] [INFO ] KVClient Start!
get yifan
The value of the key: yifan is 10

```


I shut down the **server 1099** and there are only 4 running servers. And the Coordinator only collect 4 responses but not 5 responses. If some servers are down, then the quorum is based on the number of live servers, not including the servers which are already down.

Now, we can test whether the recovery works well by this:

We first recover the **server 1099** and then close all other 4 servers and check whether the **get kobe** request works (If it works, then the recover is success, because all other 4 servers are down and the **server 1099** is the only available one).

First start **server 1099** and then shut down all other 4 servers:

```

src --> java KVServer 1099 1100 1101 1102 1103 — 84x20
[2019-04-10 2:33:12.242 PM] Response: "The key: 24 is not exist!"
[2019-04-10 2:33:12.242 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-10 2:33:12.598 PM] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-10 2:33:21.588 PM] [INFO ] Successful request DELETE.
[2019-04-10 2:34:11.897 PM] Response: "Set the key value pairs: yifan -> 10"
[2019-04-10 2:34:11.897 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-10 2:34:13.635 PM] [INFO ] Client with hash code: 112573441 is connected!
[2019-04-10 2:34:13.652 PM] Response: "The value of the key: yifan is 10"
[2019-04-10 2:34:13.652 PM] [INFO ] Successful request GET.
[Yifans-MacBook-Pro:src yifandai$ java KVServer 1099 1100 1101 1102 1103 ] This Server recover From the live server 1109
[2019-04-10 2:37:05.299 PM] [INFO ] This Key Value Server is starting in port: 1099.
[2019-04-10 2:37:05.306 PM] [INFO ] Server 1099 is ready now!
[2019-04-10 2:37:05.306 PM] [INFO ] Server 1099 is ready now! Recover
src --> bash — 84x20

[2019-04-10 2:38:16.621 PM] [INFO ] Server 1100 is ready now!
[2019-04-10 2:38:16.621 PM] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:38:16.625 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-10 2:38:16.625 PM] [INFO ] Client with hash code: 769001141 is connected!
[2019-04-10 2:38:16.625 PM] Response: "The key: 24 is not exist!"
[2019-04-10 2:38:16.625 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-10 2:38:16.625 PM] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-10 2:38:21.582 PM] [INFO ] Successful request DELETE.
[2019-04-10 2:38:21.582 PM] Response: "Set the key value pairs: yifan -> 10"
[2019-04-10 2:38:21.582 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-10 2:38:40.518 PM] [INFO ] Client with hash code: 112573441 is connected!
[2019-04-10 2:38:40.523 PM] Response: "Set the key value pairs: kobe -> 99"
[2019-04-10 2:38:40.523 PM] [INFO ] Successful request PUT with updating an key-value pair.
[Yifans-MacBook-Pro:src yifandai$ ]

src --> bash — 92x20
[2019-04-10 2:33:12.244 PM] Response: "The key: 24 is not exist!"
[2019-04-10 2:33:12.244 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-10 2:33:21.559 PM] [INFO ] Client with hash code: 112573441 is connected!
[2019-04-10 2:33:21.577 PM] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-10 2:33:21.577 PM] [INFO ] Successful request DELETE.
[2019-04-10 2:34:11.888 PM] [INFO ] Client with hash code: 112573441 is connected!
[2019-04-10 2:34:11.895 PM] Response: "Set the key value pairs: yifan -> 10"
[2019-04-10 2:34:11.895 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-10 2:34:52.035 PM] Response: "There are only three operation accepted: 1. put 2. get 3. delete"
[2019-04-10 2:34:52.036 PM] [WARNING] Receive invalid request to key value store.
[2019-04-10 2:38:40.526 PM] Response: "Set the key value pairs: kobe -> 99"
[2019-04-10 2:38:40.526 PM] [INFO ] Successful request PUT with updating an key-value pair
*Yifans-MacBook-Pro:src yifandai$ ]
```

```

src --> java KVCoordinator 8099 1099 1100 1101 1102 1103 — 92x42
[2019-04-10 2:30:07.308 PM] [INFO ] KVCoordinator Start!
put yifan 24
Set the key value pairs: yifan -> 24
put yifan 10
Set the key value pairs: yifan -> 10
get yifan
The value of the key: yifan is 10
play music
There are only three operation accepted: 1. put 2. get 3. delete
put kobe 99
Set the key value pairs: kobe -> 99

src --> java KVClient 1099 1100 1101 1102 1103 — 84x20
[Yifans-MacBook-Pro:src yifandai$ java KVClient 1099 1100 1101 1102 1103 ] [2019-04-10 2:30:07.308 PM] [INFO ] KVClient Start!
put yifan
The key: 24 is not exist!
delete yifan
Successfully delete the key value pairs of the key: yifan
[2019-04-10 2:30:25.988 PM] [INFO ] KVClient Start!
delete yifan
The key: 24 is not exist!
delete yifan
Successfully delete the key value pairs of the key: yifan
[2019-04-10 2:31:02.243 PM] [INFO ] Client with hash code: 112573441 is connected!
[2019-04-10 2:31:02.289 PM] Response: "Set the key value pairs: yifan -> 24"
[2019-04-10 2:31:02.289 PM] [INFO ] Successful request PUT with updating an key-value pair
[2019-04-10 2:31:02.289 PM] Response: "The key: 24 is not exist!"
[2019-04-10 2:31:02.289 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-10 2:31:02.289 PM] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-10 2:33:12.246 PM] Response: "The key: 24 is not exist!"
[2019-04-10 2:33:12.246 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-10 2:33:21.585 PM] Response: "Set the key value pairs: yifan -> 10"
[2019-04-10 2:33:21.585 PM] [INFO ] Successful request DELETE.
[2019-04-10 2:34:11.981 PM] Response: "Set the key value pairs: yifan -> 10"
[2019-04-10 2:34:11.981 PM] [INFO ] Successful request PUT with updating an key-value pair
[2019-04-10 2:35:40.528 PM] Response: "Set the key value pairs: kobe -> 99"
[2019-04-10 2:35:40.528 PM] [INFO ] Successful request PUT with updating an key-value pair
[2019-04-10 2:35:40.536 PM] Response: "Set the key value pairs: kobe -> 99"
[2019-04-10 2:35:40.536 PM] [INFO ] Successful request PUT with updating an key-value pair
*Yifans-MacBook-Pro:src yifandai$ ]
```

Then we test whether the **get kobe** request works:

```

src -- java KVServer 1099 1100 1101 1102 1103 — 84x20
[2019-04-18 2:34:26.588 PM] [INFO ] Successful request DELETE.
[2019-04-18 2:34:11.897 PM] [INFO ] Response: "Set the key value pairs: yifan -> 10"
[2019-04-18 2:34:11.897 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-18 2:34:13.635 PM] [INFO ] Client with hash code: 112573441 is connected!
[2019-04-18 2:34:13.652 PM] [INFO ] Response: "The value of the key: yifan is 10"
[2019-04-18 2:34:13.652 PM] [INFO ] Successful request GET.
*CYifans-MacBook-Pro:src:yifandais$ java KVServer 1099 1100 1101 1102 1103
[2019-04-18 2:37:05.294 PM] [INFO ] This Server recover from the live server 1100
[2019-04-18 2:37:06.299 PM] [INFO ] This Key Value Server is starting in port: 1099.
[2019-04-18 2:37:06.306 PM] [INFO ] Server 1099 is ready now!
[2019-04-18 2:38:41.929 PM] [INFO ] Client with hash code: 112573441 is connected!
[2019-04-18 2:38:41.949 PM] [INFO ] Response: "The value of the key: kobe is 99"
[2019-04-18 2:38:41.949 PM] [INFO ] Successful request GET.

src -- bash — 84x20
[2019-04-18 2:30:15.421 PM] [INFO ] Server 1099 is ready now!
[2019-04-18 2:31:02.295 PM] [INFO ] Response: "Set the key value pairs: yifan -> 24"
[2019-04-18 2:31:02.295 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-18 2:33:12.214 PM] [INFO ] Client with hash code: 769801141 is connected!
[2019-04-18 2:33:12.237 PM] [INFO ] Response: "The key: 24 is not exist!"
[2019-04-18 2:33:12.237 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-18 2:33:21.582 PM] [INFO ] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-18 2:33:21.582 PM] [INFO ] Successful request DELETE.
[2019-04-18 2:34:11.899 PM] [INFO ] Response: "Set the key value pairs: yifan -> 10"
[2019-04-18 2:34:11.899 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-18 2:35:40.518 PM] [INFO ] Client with hash code: 112573441 is connected!
[2019-04-18 2:35:40.523 PM] [INFO ] Response: "Set the key value pairs: kobe -> 99"
[2019-04-18 2:35:40.523 PM] [INFO ] Successful request PUT with updating an key-value pair.
*CYifans-MacBook-Pro:src:yifandais$ 

src -- bash — 84x20
[2019-04-18 2:33:12.244 PM] [INFO ] Response: "The key: 24 is not exist!"
[2019-04-18 2:33:12.244 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-18 2:33:21.589 PM] [INFO ] Client with hash code: 769801141 is connected!
[2019-04-18 2:33:21.577 PM] [INFO ] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-18 2:33:21.577 PM] [INFO ] Successful request DELETE.
[2019-04-18 2:34:11.888 PM] [INFO ] Client with hash code: 112573441 is connected!
[2019-04-18 2:34:11.895 PM] [INFO ] Response: "Set the key value pairs: yifan -> 10"
[2019-04-18 2:34:11.895 PM] [INFO ] Successful request PUT with updating an key-value pair.
[2019-04-18 2:34:52.835 PM] [INFO ] Response: "There are only three operation accepted: 1. put 2. get 3. delete"
[2019-04-18 2:35:40.526 PM] [WARNING] Receive invalid request to key value store.
[2019-04-18 2:35:40.526 PM] [INFO ] Response: "Set the key value pairs: kobe -> 99"
[2019-04-18 2:35:40.526 PM] [INFO ] Successful request PUT with updating an key-value pair.
*CYifans-MacBook-Pro:src:yifandais$ 

src -- bash — 92x20
[2019-04-18 2:30:15.421 PM] [INFO ] This Key Value Server is starting in port: 1100.
[2019-04-18 2:30:20.227 PM] [INFO ] This Key Value Server is starting in port: 1102.
[2019-04-18 2:30:20.952 PM] [INFO ] Server 1100 is ready now!
[2019-04-18 2:31:02.381 PM] [INFO ] Response: "Set the key value pairs: yifan -> 24"
[2019-04-18 2:31:02.381 PM] [INFO ] Successful request PUT with updating an key-value pair
[2019-04-18 2:33:12.246 PM] [INFO ] Response: "The key: 24 is not exist!"
[2019-04-18 2:33:12.247 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-18 2:33:21.585 PM] [INFO ] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-18 2:33:21.585 PM] [INFO ] Successful request DELETE.
[2019-04-18 2:34:11.981 PM] [INFO ] Response: "Set the key value pairs: yifan -> 10"
[2019-04-18 2:34:11.981 PM] [INFO ] Successful request PUT with updating an key-value pair
[2019-04-18 2:35:40.528 PM] [INFO ] Response: "Set the key value pairs: kobe -> 99"
[2019-04-18 2:35:40.528 PM] [INFO ] Successful request PUT with updating an key-value pair.
*CYifans-MacBook-Pro:src:yifandais$ 

src -- bash — 84x20
[2019-04-18 2:30:23.064 PM] [INFO ] This Key Value Server is starting in port: 1103.
[2019-04-18 2:30:23.098 PM] [INFO ] Server 1103 is ready now!
[2019-04-18 2:31:02.243 PM] [INFO ] Client with hash code: 112573441 is connected!
[2019-04-18 2:31:02.289 PM] [INFO ] Response: "Set the key value pairs: yifan -> 24"
[2019-04-18 2:31:02.289 PM] [INFO ] Successful request PUT with updating an key-value pair
[2019-04-18 2:33:12.249 PM] [INFO ] Response: "The key: 24 is not exist!"
[2019-04-18 2:33:12.249 PM] [WARNING] The key for request DELETE is non-existed
[2019-04-18 2:33:21.587 PM] [INFO ] Response: "Successfully delete the key value pairs of the key: yifan"
[2019-04-18 2:33:21.587 PM] [INFO ] Successful request DELETE.
[2019-04-18 2:34:11.981 PM] [INFO ] Response: "Set the key value pairs: yifan -> 10"
[2019-04-18 2:34:11.981 PM] [INFO ] Successful request PUT with updating an key-value pair
[2019-04-18 2:35:40.536 PM] [INFO ] Response: "Set the key value pairs: kobe -> 99"
[2019-04-18 2:35:40.536 PM] [INFO ] Successful request PUT with updating an key-value pair.
*CYifans-MacBook-Pro:src:yifandais$ 

```

The `get kobe` can get the correct value. It means that the recovery works well!

At last, I will show how the requests are rejected. We can see the `Coordinator.java` file. Increase the failure probability to 50% (To increase the probability to fail).

```

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}

public static class Acceptor implements Serializable {
    // last vote result
    public Proposal last = new Proposal();
    public String name;

    public Acceptor(String name) { this.name = name; }

    public Promise onPrepare(Proposal proposal) {
        // We suppose that the failure probability is 10%
        if (Math.random() < 0.5) {
            printInfo(subject: "Server " + name, operation: "PREPARE", result: "NO RESPONSE");
            return null;
        }
        if (proposal == null)
            throw new IllegalArgumentException("null proposal");
        if (proposal.getVoteNumber() > last.getVoteNumber()) {
            Promise response = new Promise(ack: true, last);
            last = proposal;
            printInfo(subject: "Server " + name, operation: "PREPARE", result: "OK");
            return response;
        } else {
            printInfo(subject: "Server " + name, operation: "PREPARE", result: "REJECTED");
            return new Promise(ack: false, proposal: null);
        }
    }

    public boolean onAccept(Proposal proposal) {
        // We suppose that the failure probability is 10%
        if (Math.random() < 0.5)
            printInfo(subject: "Server " + name, operation: "ACCEPT", result: "NO RESPONSE");
        return false;
    }
    printInfo(subject: "Server " + name, operation: "ACCEPT", result: "OK");

    return last.equals(proposal);
}

```

Then we could run the codes again to see what will happen when fails.

Below is an example of failing at the prepare phase (3 no response when prepare).

The screenshot displays five terminal windows arranged in a grid. The top row contains three windows: KVServer 1099, Coordinator 8099, and KVClient 1099. The bottom row contains two windows: KVServer 1100 and KVServer 1101. A red arrow points from the Coordinator window to the KVClient window, indicating a connection between them. The Coordinator window shows a log entry: "PROPOSER1: [put 1 2] :VOTE-NOT PREPARED". The KVClient window shows a log entry: "This request is rejected!".

```
Yifans-MacBook-Pro:src yifanda$ java KVServer 1099 — 84x20
1099
[2019-04-10 2:48:52.761 PM] [INFO ] This Key Value Server is starting in port: 1099.
3.
[2019-04-10 2:48:52.798 PM] [INFO ] Server 1099 is ready now!
!src — java KVServer 1100 — 84x20
Yifans-MacBook-Pro:src yifanda$ java KVServer 1100
1100
[2019-04-10 2:48:54.910 PM] [INFO ] This Key Value Server is starting in port: 1100.
0.
[2019-04-10 2:48:54.938 PM] [INFO ] Server 1100 is ready now!
[2019-04-10 2:47:02.146 PM] [INFO ] Client with hash code: 1479790794 is connected
!src — java KVServer 1101 — 84x20
Yifans-MacBook-Pro:src yifanda$ java KVServer 1101
1101
[2019-04-10 2:48:57.024 PM] [INFO ] This Key Value Server is starting in port: 1101.
1.
[2019-04-10 2:48:57.061 PM] [INFO ] Server 1101 is ready now!
!src — java Coordinator 8099 1099 1100 1101 1102 1103 — 92x42
Yifans-MacBook-Pro:src yifanda$ java *.java
Yifans-MacBook-Pro:src yifanda$ java Coordinator 8099 1099 1100 1101 1102 1103
[2019-04-10 2:45:57.096 PM] [INFO ] This Coordinator is starting in port: 8099.
3.
[2019-04-10 2:45:57.123 PM] [INFO ] Coordinator is ready now!
Server 1099 :PREPARE-NOPREPONSE>
Server 1100 :PREPARE-NOPREPONSE>
Server 1101 :PREPARE-NOPREPONSE>
Server 1102 :PREPARE-NOPREPONSE>
Server 1103 :PREPARE-NOPREPONSE>
PROPOSER1: [put 1 2] :VOTE-NOT PREPARED>
!src — java KVClient 1099 1100 1101 1102 1103 — 84x20
Yifans-MacBook-Pro:src yifanda$ java KVClient 1099 1100 1101 1102 1103
[2019-04-10 2:41:26.011 PM] [INFO ] KVClient Start!
put 1 2
This request is rejected!
```

Below is an example of failing at the accept phase (3 no response when accept).

The screenshot displays five terminal windows arranged in a grid. The top row contains three windows: KVServer 1099, Coordinator 8099, and KVClient 1099. The bottom row contains two windows: KVServer 1100 and KVServer 1101. A red arrow points from the Coordinator window to the KVClient window, indicating a connection between them. The Coordinator window shows a log entry: "PROPOSER1(2): [put 1 2] :VOTE-NOT ACCEPTED". The KVClient window shows a log entry: "This request is rejected!".

```
Yifans-MacBook-Pro:src yifanda$ java KVServer 1099 — 84x20
1099
[2019-04-10 2:48:52.761 PM] [INFO ] This Key Value Server is starting in port: 1099.
3.
[2019-04-10 2:48:52.798 PM] [INFO ] Server 1099 is ready now!
[2019-04-10 2:47:02.146 PM] [INFO ] Client with hash code: 1479790794 is connected
!src — java KVServer 1100 — 84x20
Yifans-MacBook-Pro:src yifanda$ java KVServer 1100
1100
[2019-04-10 2:48:54.910 PM] [INFO ] This Key Value Server is starting in port: 1100.
0.
[2019-04-10 2:48:54.938 PM] [INFO ] Server 1100 is ready now!
[2019-04-10 2:47:02.146 PM] [INFO ] Client with hash code: 1479790794 is connected
!src — java KVServer 1101 — 84x20
Yifans-MacBook-Pro:src yifanda$ java KVServer 1101
1101
[2019-04-10 2:48:57.024 PM] [INFO ] This Key Value Server is starting in port: 1101.
1.
[2019-04-10 2:48:57.061 PM] [INFO ] Server 1101 is ready now!
!src — java Coordinator 8099 1099 1100 1101 1102 1103 — 92x42
Yifans-MacBook-Pro:src yifanda$ java *.java
Yifans-MacBook-Pro:src yifanda$ java Coordinator 8099 1099 1100 1101 1102 1103
[2019-04-10 2:45:57.096 PM] [INFO ] This Coordinator is starting in port: 8099.
3.
[2019-04-10 2:45:57.123 PM] [INFO ] Coordinator is ready now!
Server 1099 :PREPARE-NOPREPONSE>
Server 1100 :PREPARE-NOPREPONSE>
Server 1101 :PREPARE-NOPREPONSE>
Server 1102 :PREPARE-NOPREPONSE>
Server 1103 :PREPARE-NOPREPONSE>
PROPOSER1: [put 1 2] :VOTE-NOT ACCEPTED>
Server 1099 :PREPARE-NOPREPONSE>
Server 1100 :PREPARE-NOPREPONSE>
Server 1101 :PREPARE-NOPREPONSE>
Server 1102 :PREPARE-NOPREPONSE>
Server 1103 :PREPARE-NOPREPONSE>
PROPOSER1(2): [put 1 2] :VOTE-NOT ACCEPTED>
!src — java KVClient 1099 1100 1101 1102 1103 — 84x20
Yifans-MacBook-Pro:src yifanda$ java KVClient 1099 1100 1101 1102 1103
[2019-04-10 2:41:23.895 PM] [INFO ] KVClient Start!
put 1 2
This request is rejected!
```

Last, we can see a successful request:

```
Yifans-MacBook-Pro:src yifanda$ java KVServer 1099
1099
[2019-04-10 2:52:28.119 PM] [INFO ] This Key Value Server is starting in port: 1099
9.
[2019-04-10 2:52:28.144 PM] [INFO ] Server 1099 is ready now!
[2019-04-10 2:53:07.533 PM] [INFO ] Client with hash code: -2061075322 is connecte
d!
[2019-04-10 2:53:16.308 PM] Response: "Set the key value pairs: 1 -> 2"
[2019-04-10 2:53:16.309 PM] [INFO ] Successful request PUT with updating an key-va
lue pair.

Yifans-MacBook-Pro:src yifanda$ java KVServer 1100
1100
[2019-04-10 2:52:34.698 PM] [INFO ] This Key Value Server is starting in port: 110
0.
[2019-04-10 2:52:34.725 PM] [INFO ] Server 1100 is ready now!
[2019-04-10 2:53:16.311 PM] Response: "Set the key value pairs: 1 -> 2"
[2019-04-10 2:53:16.311 PM] [INFO ] Successful request PUT with updating an key-va
lue pair.

Yifans-MacBook-Pro:src yifanda$ java KVServer 1101
1101
[2019-04-10 2:52:43.412 PM] [INFO ] This Key Value Server is starting in port: 110
1.
[2019-04-10 2:52:43.438 PM] [INFO ] Server 1101 is ready now!
[2019-04-10 2:53:16.453 PM] [INFO ] Client with hash code: -2061075322 is connecte
d!
[2019-04-10 2:53:16.308 PM] Response: "Set the key value pairs: 1 -> 2"
[2019-04-10 2:53:16.309 PM] [INFO ] Successful request PUT with updating an key-va
lue pair.

Yifans-MacBook-Pro:src yifanda$ java Coordinator 8099 1099 1100 1101 1102 1103
Server 1103 :PREPARE<NO RESPONSE>
PROPOSER[4: "put 1 2"] :VOTE<NOT PREPARED>
Server 1099 :PREPARE<NO RESPONSE>
Server 1100 :PREPARE<NO RESPONSE>
Server 1101 :PREPARE<NO RESPONSE>
Server 1102 :PREPARE<NO RESPONSE>
Server 1103 :PREPARE<OK>
Server 1099 :ACCEPT<OK>
Server 1100 :ACCEPT<OK>
Server 1101 :ACCEPT<OK>
Server 1102 :ACCEPT<OK>
Server 1103 :ACCEPT<OK>
PROPOSER[6: "put 1 2"] :VOTE<NOT ACCEPTED>
Server 1100 :PREPARE<NO RESPONSE>
Server 1101 :PREPARE<OK>
Server 1102 :PREPARE<OK>
Server 1103 :PREPARE<OK>
Server 1099 :ACCEPT<OK>
Server 1100 :ACCEPT<OK>
Server 1101 :ACCEPT<OK>
Server 1102 :ACCEPT<OK>
Server 1103 :ACCEPT<OK>
PROPOSER[8: "put 1 2"] :VOTE<NOT ACCEPTED>
Server 1100 :PREPARE<OK>
Server 1101 :PREPARE<OK>
Server 1102 :PREPARE<OK>
Server 1103 :PREPARE<OK>
Server 1099 :ACCEPT<OK>
Server 1100 :ACCEPT<OK>
Server 1101 :ACCEPT<OK>
Server 1102 :ACCEPT<OK>
Server 1103 :ACCEPT<OK>
PROPOSER[6: "put 1 2"] :VOTE<NOT ACCEPTED>
Server 1100 :PREPARE<OK>
Server 1101 :PREPARE<OK>
Server 1102 :PREPARE<OK>
Server 1103 :PREPARE<OK>
Server 1099 :ACCEPT<OK>
Server 1100 :ACCEPT<OK>
Server 1101 :ACCEPT<OK>
Server 1102 :ACCEPT<OK>
Server 1103 :ACCEPT<OK>
PROPOSER[8: "put 1 2"] :VOTE<NOT ACCEPTED>
Server 1100 :PREPARE<OK>
Server 1101 :PREPARE<OK>
Server 1102 :PREPARE<OK>
Server 1103 :PREPARE<OK>
Server 1099 :ACCEPT<OK>
Server 1100 :ACCEPT<OK>
Server 1101 :ACCEPT<OK>
Server 1102 :ACCEPT<OK>
Server 1103 :ACCEPT<OK>
Set the key value pairs: 1 -> 2

Yifans-MacBook-Pro:src yifanda$ java KVClient 1099 1100 1101 1102 1103
[2019-04-10 2:52:11.939 PM] [INFO ] KVClient Start!
put 1 2
This request is rejected!
put 1 2
Set the key value pairs: 1 -> 2

Yifans-MacBook-Pro:src yifanda$ java KVClient 1099 1100 1101 1102 1103
[2019-04-10 2:52:09.697 PM] [INFO ] KVClient Start!
[2019-04-10 2:53:16.314 PM] Response: "Set the key value pairs: 1 -> 2"
[2019-04-10 2:53:16.314 PM] [INFO ] Successful request PUT with updating an key-va
lue pair.

Yifans-MacBook-Pro:src yifanda$ java KVServer 1102
1102
[2019-04-10 2:52:47.247 PM] [INFO ] This Key Value Server is starting in port: 1102.
[2019-04-10 2:52:47.272 PM] [INFO ] Server 1102 is ready now!
[2019-04-10 2:53:16.313 PM] Response: "Set the key value pairs: 1 -> 2"
[2019-04-10 2:53:16.314 PM] [INFO ] Successful request PUT with updating an key-va
lue pair.

Yifans-MacBook-Pro:src yifanda$ java KVServer 1103
1103
[2019-04-10 2:52:54.581 PM] [INFO ] This Key Value Server is starting in port: 1103.
[2019-04-10 2:52:54.582 PM] [INFO ] Server 1103 is ready now!
[2019-04-10 2:53:16.314 PM] Response: "Set the key value pairs: 1 -> 2"
[2019-04-10 2:53:16.314 PM] [INFO ] Successful request PUT with updating an key-va
lue pair.
```

Only when both the prepare phase and the accept phase reach the quorum, the proposal will be accepted and the requests will be executed by the server.

This is all the code instruction of the project 4.

Thank you!

Yifan Dai

On 04/10/2019