Lab 4: Consistent hashing

Consistent Hashing

1. Áp dụng Consistent hashing vào bài lab

- Trong bài lab 4, em đã ứng dụng Consistent hashing vào hệ thống Key-Value store đã thực hiện ở các bài lab trước.
- Cấu trúc của bài lab:
    - **Server/Node**: bao gồm file server_main.go chứa logic của các RPC.
    - **Load Balancer**: đảm nhận nhiệm vụ lắng nghe request của **Client** → thực hiện **Consistent Hashing** → điều hướng request của **Client** tới đúng **Server/Node** tương ứng.
    - Client: Gửi request đến LoadBalancer.
- Mã nguồn **Load Balancer:**
    - **consistenthash.go**: Chứa một số hàm hỗ trợ **consistent hashing** như khởi tạo hash ring, kiểm tra hash ring rỗng, tìm ra server tương ứng cho key mới, thêm một server key mới vào hash ring
    - **loadbalancer.go** (port: 9000) : Thực hiện **consistent hashing** khi client gửi request đến về điều hướng request tới server thích hợp. Đồng thời thực hiện đăng kí server mới vào hash ring (mỗi server khi được bật lên sẽ tự động gửi request RegisterServer tới port 9000 để đăng kí vào hash ring) và loại bỏ server khỏi hash ring (để test chức năng thuận tiện, em đã cho client được phép gửi 1 request yêu cầu bỏ đi một server node khỏi hash ring trực tiếp tới **Load Balancer**)
- Mã nguồn Client**:**
    - **client_main.go**: có 3 hàm chủ yếu, test RPC Set bằng cách gửi SetRequest 10 lần với tham số ngẫu nhiên randomID (nếu true thì các Key sẽ được tạo ngẫu nhiên, nếu false thì sẽ được tạo tăng dần từ 1), test RPC Get bằng

cách gửi GetRequest và test RPC RemoveServer bằng cách gửi RPC RemoveServer cùng với địa chỉ của Server muốn xóa.

- Mã nguồn Server:
    - server_main.go: chứa logic của các RPC như đã định nghĩa từ các lab trước (Get, Set, GetAll, Delete, GetInfo). Khi server mới được khởi tạo, server_main sẽ gửi Request RegisterServer cùng địa chỉ của mình tới port 9000 có LoadBalancer và sẽ được đăng kí vào Hash ring.

2. Demo các test case:

Test case thêm một Node khi chưa khởi tạo hệ thống:

- Khởi chạy LoadBalancer:

```
PS D:\WorkSpace\Master\Master-DistributedSystem\Lab4\LoadBalancer> go
2025/03/03 19:31:30 LoadBalancer listening on port 9000...
```

- Khởi chạy một số server trên các port: VD: 1000, 2000, 3000

```
PS D:\WorkSpace\Master\Master-DistributedSystem\Lab4\Server> go run se
2025/03/03 19:32:44 Server started on port 1000 with database: server_1000
2025/03/03 19:32:45 Server registered with LoadBalancer: Added server: loc
```

```
PS D:\WorkSpace\Master\Master-DistributedSystem\Lab4\Server> go run se
2025/03/03 19:34:14 Server started on port 2000 with database: server_200
2025/03/03 19:34:15 Server registered with LoadBalancer: Added server: loc
```

```
PS D:\WorkSpace\Master\Master-DistributedSystem\Lab4\Server> go run se
2025/03/03 19:34:30 Server started on port 3000 with database: server_300
2025/03/03 19:34:31 Server registered with LoadBalancer: Added server: loc
```

```
PS D:\WorkSpace\Master\Master-DistributedSystem\Lab4\LoadBalancer> go
2025/03/03 19:31:30 LoadBalancer listening on port 9000...
2025/03/03 19:32:45 NewConsistentHash server registered: localhost:1000
2025/03/03 19:32:45 Current servers in LoadBalancer:
2025/03/03 19:32:45    - localhost:1000
2025/03/03 19:32:45 Rebalancing data for new server: localhost:1000
2025/03/03 19:32:45 Not enough servers for rebalancing
2025/03/03 19:32:45 --------------------------------
2025/03/03 19:34:15 NewConsistentHash server registered: localhost:2000
2025/03/03 19:34:15 Current servers in LoadBalancer:
2025/03/03 19:34:15    - localhost:2000
2025/03/03 19:34:15    - localhost:1000
2025/03/03 19:34:15 Rebalancing data for new server: localhost:2000
2025/03/03 19:34:15 Data will be moved from next server: localhost:1000
2025/03/03 19:34:15 --------------------------------
2025/03/03 19:34:31 NewConsistentHash server registered: localhost:3000
2025/03/03 19:34:31 Current servers in LoadBalancer:
2025/03/03 19:34:31    - localhost:1000
2025/03/03 19:34:31    - localhost:2000
2025/03/03 19:34:31    - localhost:3000
2025/03/03 19:34:31 Rebalancing data for new server: localhost:3000
2025/03/03 19:34:31 Data will be moved from next server: localhost:1000
2025/03/03 19:34:31 --------------------------------
```

Test case thêm Key-Value:

- Bên phía Client, mở client_main.go và chạy test case SetMultipleData(true) để set data ngẫu nhiên

```
func main() {
    // Kết nối với LoadBalancer
    lbClient, err := NewLoadBalancerClient("localhost:9000")
    if err != nil {
        log.Fatalf("Error connecting to LoadBalancer: %v", err)
```

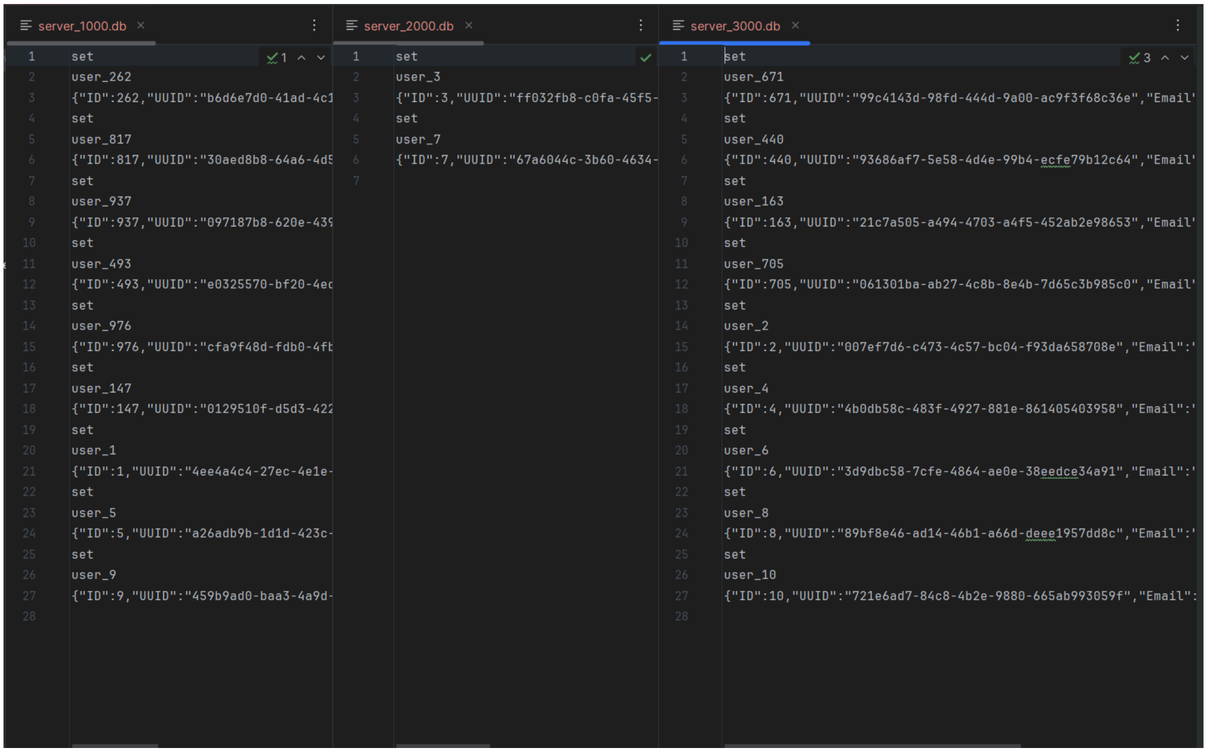
```
	}
	defer lbClient.client.Close()

	// Uncomment to set 10 new data entries
	lbClient.SetMultipleData(false)
	lbClient.SetMultipleData(true)

	// Uncomment to get 10 data entries
	//lbClient.GetMultipleData()

	// Uncomment to request remove server
	//serverToRemoveID := "localhost:2"
	//lbClient.RemoveServer(serverToRemoveID)
}
```

```
2025/03/03 19:36:51 LoadBalancer received Set request for key: 262, bucket
2025/03/03 19:36:51 user_262 will be moved/stayed at localhost:1000
2025/03/03 19:36:51 LoadBalancer selected server localhost:1000 for key 26
2025/03/03 19:36:51 LoadBalancer received response from server localhost:
2025/03/03 19:36:52 LoadBalancer received Set request for key: 671, bucket
2025/03/03 19:36:52 user_671 will be moved/stayed at localhost:3000
2025/03/03 19:36:52 LoadBalancer selected server localhost:3000 for key 6
2025/03/03 19:36:52 LoadBalancer received response from server localhost
2025/03/03 19:36:52 LoadBalancer received Set request for key: 817, bucket
2025/03/03 19:36:52 user_817 will be moved/stayed at localhost:1000
2025/03/03 19:36:52 LoadBalancer selected server localhost:1000 for key 81
2025/03/03 19:36:52 LoadBalancer received response from server localhost
2025/03/03 19:36:53 LoadBalancer received Set request for key: 440, bucke
2025/03/03 19:36:53 user_440 will be moved/stayed at localhost:3000
2025/03/03 19:36:53 LoadBalancer selected server localhost:3000 for key 4
2025/03/03 19:36:53 LoadBalancer received response from server localhost
2025/03/03 19:36:53 LoadBalancer received Set request for key: 937, bucket
2025/03/03 19:36:53 user_937 will be moved/stayed at localhost:1000
2025/03/03 19:36:53 LoadBalancer selected server localhost:1000 for key 93
2025/03/03 19:36:53 LoadBalancer received response from server localhost
```

```
2025/03/03 19:36:54 LoadBalancer received Set request for key: 163, bucket
2025/03/03 19:36:54 user_163 will be moved/stayed at localhost:3000
2025/03/03 19:36:54 LoadBalancer selected server localhost:3000 for key 16
2025/03/03 19:36:54 LoadBalancer received response from server localhost
2025/03/03 19:36:54 LoadBalancer received Set request for key: 493, bucke
2025/03/03 19:36:54 user_493 will be moved/stayed at localhost:1000
2025/03/03 19:36:54 LoadBalancer selected server localhost:1000 for key 49
2025/03/03 19:36:54 LoadBalancer received response from server localhost
2025/03/03 19:36:55 LoadBalancer received Set request for key: 976, bucke
2025/03/03 19:36:55 user_976 will be moved/stayed at localhost:1000
2025/03/03 19:36:55 LoadBalancer selected server localhost:1000 for key 97
2025/03/03 19:36:55 LoadBalancer received response from server localhost
2025/03/03 19:36:55 LoadBalancer received Set request for key: 705, bucke
2025/03/03 19:36:55 user_705 will be moved/stayed at localhost:3000
2025/03/03 19:36:55 LoadBalancer selected server localhost:3000 for key 70
2025/03/03 19:36:55 LoadBalancer received response from server localhost
2025/03/03 19:36:56 LoadBalancer received Set request for key: 147, bucket
2025/03/03 19:36:56 user_147 will be moved/stayed at localhost:1000
2025/03/03 19:36:56 LoadBalancer selected server localhost:1000 for key 14
2025/03/03 19:36:56 LoadBalancer received response from server localhost
2025/03/03 19:37:24 LoadBalancer received Set request for key: 1, bucket: u
2025/03/03 19:37:24 user_1 will be moved/stayed at localhost:1000
2025/03/03 19:37:24 LoadBalancer selected server localhost:1000 for key 1
2025/03/03 19:37:24 LoadBalancer received response from server localhost:
2025/03/03 19:37:24 LoadBalancer received Set request for key: 2, bucket: u
2025/03/03 19:37:24 user_2 will be moved/stayed at localhost:3000
2025/03/03 19:37:24 LoadBalancer selected server localhost:3000 for key 2
2025/03/03 19:37:24 LoadBalancer received response from server localhost:
2025/03/03 19:37:24 LoadBalancer received Set request for key: 3, bucket: u
2025/03/03 19:37:24 user_3 will be moved/stayed at localhost:2000
2025/03/03 19:37:24 LoadBalancer selected server localhost:2000 for key 3
2025/03/03 19:37:24 LoadBalancer received response from server localhost:
2025/03/03 19:37:25 LoadBalancer received Set request for key: 4, bucket: u
2025/03/03 19:37:25 user_4 will be moved/stayed at localhost:3000
2025/03/03 19:37:25 LoadBalancer selected server localhost:3000 for key 4
2025/03/03 19:37:25 LoadBalancer received response from server localhost:
```

```
2025/03/03 19:37:25 LoadBalancer received Set request for key: 5, bucket: u
2025/03/03 19:37:25 user_5 will be moved/stayed at localhost:1000
2025/03/03 19:37:25 LoadBalancer selected server localhost:1000 for key 5
2025/03/03 19:37:25 LoadBalancer received response from server localhost:
2025/03/03 19:37:25 LoadBalancer received Set request for key: 6, bucket: u
2025/03/03 19:37:25 user_6 will be moved/stayed at localhost:3000
2025/03/03 19:37:25 LoadBalancer selected server localhost:3000 for key 6
2025/03/03 19:37:25 LoadBalancer received response from server localhost:
2025/03/03 19:37:26 LoadBalancer received Set request for key: 7, bucket: u
2025/03/03 19:37:26 user_7 will be moved/stayed at localhost:2000
2025/03/03 19:37:26 LoadBalancer selected server localhost:2000 for key 7
2025/03/03 19:37:26 LoadBalancer received response from server localhost:
2025/03/03 19:37:26 LoadBalancer received Set request for key: 8, bucket: u
2025/03/03 19:37:26 user_8 will be moved/stayed at localhost:3000
2025/03/03 19:37:26 LoadBalancer selected server localhost:3000 for key 8
2025/03/03 19:37:26 LoadBalancer received response from server localhost:
2025/03/03 19:37:27 LoadBalancer received Set request for key: 9, bucket: u
2025/03/03 19:37:27 user_9 will be moved/stayed at localhost:1000
2025/03/03 19:37:27 LoadBalancer selected server localhost:1000 for key 9
2025/03/03 19:37:27 LoadBalancer received response from server localhost:
2025/03/03 19:37:27 LoadBalancer received Set request for key: 10, bucket:
2025/03/03 19:37:27 user_10 will be moved/stayed at localhost:3000
2025/03/03 19:37:27 LoadBalancer selected server localhost:3000 for key 10
2025/03/03 19:37:27 LoadBalancer received response from server localhost:
```

Database:



server_1000.db

```
set
user_262
{"ID":262,"UUID":"b6d6e7d0-41ad-4c1
set
user_817
{"ID":817,"UUID":"30aed8b8-64a6-4d5
set
user_937
{"ID":937,"UUID":"097187b8-620e-439
set
user_493
{"ID":493,"UUID":"e0325570-bf20-4ec
set
user_976
{"ID":976,"UUID":"cfa9f48d-fdb0-4fb
set
user_147
{"ID":147,"UUID":"0129510f-d5d3-422
set
user_1
{"ID":1,"UUID":"4ee4a4c4-27ec-4e1e-
set
user_5
{"ID":5,"UUID":"a26adb9b-1d1d-423c-
set
user_9
{"ID":9,"UUID":"459b9ad0-baa3-4a9d-
```

server_2000.db

```
set
user_3
{"ID":3,"UUID":"ff032fb8-c0fa-45f5-
set
user_7
{"ID":7,"UUID":"67a6044c-3b60-4634-
```

server_3000.db

```
set
user_671
{"ID":671,"UUID":"99c4143d-98fd-444d-9a00-ac9f3f68c36e","Email'
set
user_440
{"ID":440,"UUID":"93686af7-5e58-4d4e-99b4-ecfe79b12c64","Email'
set
user_163
{"ID":163,"UUID":"21c7a505-a494-4703-a4f5-452ab2e98653","Email'
set
user_705
{"ID":705,"UUID":"061301ba-ab27-4c8b-8e4b-7d65c3b985c0","Email'
set
user_2
{"ID":2,"UUID":"007ef7d6-c473-4c57-bc04-f93da658708e","Email":'
set
user_4
{"ID":4,"UUID":"4b0db58c-483f-4927-881e-861405403958","Email":'
set
user_6
{"ID":6,"UUID":"3d9dbc58-7cfe-4864-ae0e-38eedce34a91","Email":'
set
user_8
{"ID":8,"UUID":"89bf8e46-ad14-46b1-a66d-deee1957dd8c","Email":'
set
user_10
{"ID":10,"UUID":"721e6ad7-84c8-4b2e-9880-665ab993059f","Email":
```

Test case lấy dữ liệu từ Key:

- Bên phía Client, mở client_main.go và chạy test case GetMultipleData(true) để get data có key từ 1 tới 10:

```
func main() {
    // Kết nối với LoadBalancer
    lbClient, err := NewLoadBalancerClient("localhost:9000")
    if err != nil {
        log.Fatalf("Error connecting to LoadBalancer: %v", err)
    }
    defer lbClient.client.Close()

    // Uncomment to set 10 new data entries
    //lbClient.SetMultipleData(false)
    //lbClient.SetMultipleData(true)

    // Uncomment to get 10 data entries
    lbClient.GetMultipleData()

    // Uncomment to request remove server
    //serverToRemoveID := "localhost:2"
    //lbClient.RemoveServer(serverToRemoveID)
}
```

Log Client:

```
2025/03/03 19:40:47 Client sending Get request - Bucket: user, Key: 1
2025/03/03 19:40:47 Client received response for Key 1: {"ID":1,"UUID":"4ee
2025/03/03 19:40:48 Client sending Get request - Bucket: user, Key: 2
2025/03/03 19:40:48 Client received response for Key 2: {"ID":2,"UUID":"00
2025/03/03 19:40:48 Client sending Get request - Bucket: user, Key: 3
2025/03/03 19:40:48 Client received response for Key 3: {"ID":3,"UUID":"ff0
2025/03/03 19:40:49 Client sending Get request - Bucket: user, Key: 4
2025/03/03 19:40:49 Client received response for Key 4: {"ID":4,"UUID":"4b
2025/03/03 19:40:49 Client sending Get request - Bucket: user, Key: 5
2025/03/03 19:40:49 Client received response for Key 5: {"ID":5,"UUID":"a2
2025/03/03 19:40:50 Client sending Get request - Bucket: user, Key: 6
2025/03/03 19:40:50 Client received response for Key 6: {"ID":6,"UUID":"3d
2025/03/03 19:40:50 Client sending Get request - Bucket: user, Key: 7
2025/03/03 19:40:50 Client received response for Key 7: {"ID":7,"UUID":"67a
2025/03/03 19:40:51 Client sending Get request - Bucket: user, Key: 8
2025/03/03 19:40:51 Client received response for Key 8: {"ID":8,"UUID":"89b
2025/03/03 19:40:51 Client sending Get request - Bucket: user, Key: 9
2025/03/03 19:40:51 Client received response for Key 9: {"ID":9,"UUID":"45
2025/03/03 19:40:52 Client sending Get request - Bucket: user, Key: 10
2025/03/03 19:40:52 Client received response for Key 10: {"ID":10,"UUID":"7
```

Log LoadBalancer:

```
2025/03/03 19:40:47 LoadBalancer received Get request for key: 1, bucket: u
2025/03/03 19:40:47 user_1 will be moved/stayed at localhost:1000
2025/03/03 19:40:47 LoadBalancer selected server localhost:1000 for key 1
2025/03/03 19:40:47 LoadBalancer received response from server localhost
2025/03/03 19:40:48 LoadBalancer received Get request for key: 2, bucket: u
2025/03/03 19:40:48 user_2 will be moved/stayed at localhost:3000
2025/03/03 19:40:48 LoadBalancer selected server localhost:3000 for key 2
2025/03/03 19:40:48 LoadBalancer received response from server localhost
2025/03/03 19:40:48 LoadBalancer received Get request for key: 3, bucket: u
2025/03/03 19:40:48 user_3 will be moved/stayed at localhost:2000
2025/03/03 19:40:48 LoadBalancer selected server localhost:2000 for key 3
2025/03/03 19:40:48 LoadBalancer received response from server localhost
2025/03/03 19:40:49 LoadBalancer received Get request for key: 4, bucket: u
2025/03/03 19:40:49 user_4 will be moved/stayed at localhost:3000
2025/03/03 19:40:49 LoadBalancer selected server localhost:3000 for key 4
2025/03/03 19:40:49 LoadBalancer received response from server localhost
2025/03/03 19:40:49 LoadBalancer received Get request for key: 5, bucket: u
2025/03/03 19:40:49 user_5 will be moved/stayed at localhost:1000
2025/03/03 19:40:49 LoadBalancer selected server localhost:1000 for key 5
2025/03/03 19:40:49 LoadBalancer received response from server localhost
2025/03/03 19:40:50 LoadBalancer received Get request for key: 6, bucket: u
2025/03/03 19:40:50 user_6 will be moved/stayed at localhost:3000
2025/03/03 19:40:50 LoadBalancer selected server localhost:3000 for key 6
2025/03/03 19:40:50 LoadBalancer received response from server localhost
2025/03/03 19:40:50 LoadBalancer received Get request for key: 7, bucket: u
2025/03/03 19:40:50 user_7 will be moved/stayed at localhost:2000
2025/03/03 19:40:50 LoadBalancer selected server localhost:2000 for key 7
2025/03/03 19:40:50 LoadBalancer received response from server localhost
2025/03/03 19:40:51 LoadBalancer received Get request for key: 8, bucket: u
2025/03/03 19:40:51 user_8 will be moved/stayed at localhost:3000
2025/03/03 19:40:51 LoadBalancer selected server localhost:3000 for key 8
2025/03/03 19:40:51 LoadBalancer received response from server localhost:
2025/03/03 19:40:51 LoadBalancer received Get request for key: 9, bucket: u
2025/03/03 19:40:51 user_9 will be moved/stayed at localhost:1000
2025/03/03 19:40:51 LoadBalancer selected server localhost:1000 for key 9
```

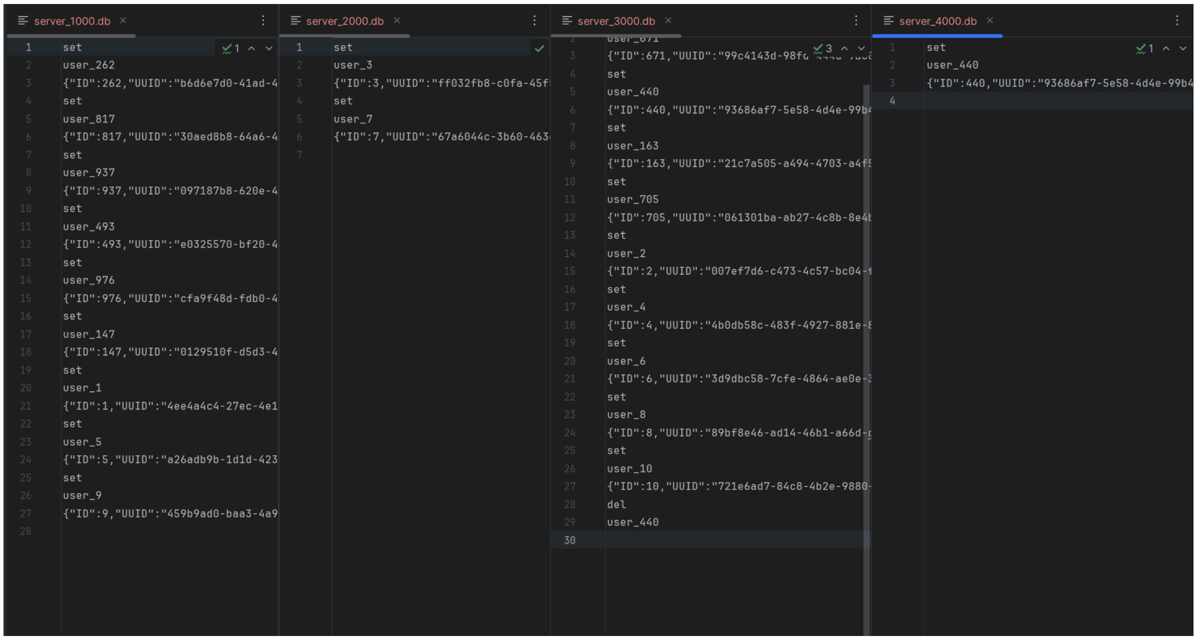
```
2025/03/03 19:40:51 LoadBalancer received response from server localhost:
2025/03/03 19:40:52 LoadBalancer received Get request for key: 10, bucket:
2025/03/03 19:40:52 user_10 will be moved/stayed at localhost:3000
2025/03/03 19:40:52 LoadBalancer selected server localhost:3000 for key 10
2025/03/03 19:40:52 LoadBalancer received response from server localhost
```

⇒ Consistent hashing đã điều hướng request đúng

Test case thêm một Node khi hệ thống đã chạy từ trước:

- Khởi tạo thêm server ở port 4000:

```
PS D:\WorkSpace\Master\Master-DistributedSystem\Lab4\Server> go run se
2025/03/03 19:43:57 Server started on port 4000 with database: server_400
2025/03/03 19:43:58 Server received Set request - Bucket: user, Key: 440
2025/03/03 19:43:58 Server successfully stored data - Key: 440
2025/03/03 19:43:58 Server registered with LoadBalancer: Added server: loc
```



server_1000.db

```
set
user_262
{"ID":262,"UUID":"b6d6e7d0-41ad-4
set
user_817
{"ID":817,"UUID":"30aed8b8-64a6-4
set
user_937
{"ID":937,"UUID":"097187b8-620e-4
set
user_493
{"ID":493,"UUID":"e0325570-bf20-4
set
user_976
{"ID":976,"UUID":"cfa9f48d-fdb0-4
set
user_147
{"ID":147,"UUID":"0129510f-d5d3-4
set
user_1
{"ID":1,"UUID":"4ee4a4c4-27ec-4e1
set
user_5
{"ID":5,"UUID":"a26adb9b-1d1d-423
set
user_9
{"ID":9,"UUID":"459b9ad0-baa3-4a9
```

server_2000.db

```
set
user_3
{"ID":3,"UUID":"ff032fb8-c0fa-45f
set
user_7
{"ID":7,"UUID":"67a6044c-3b60-463
```

server_3000.db

```
user_671
{"ID":671,"UUID":"99c4143d-98fd
set
user_440
{"ID":440,"UUID":"93686af7-5e58-4d4e-99b4
set
user_163
{"ID":163,"UUID":"21c7a505-a494-4703-a4f5
set
user_705
{"ID":705,"UUID":"061301ba-ab27-4c8b-8e4b
set
user_2
{"ID":2,"UUID":"007ef7d6-c473-4c57-bc04-
set
user_4
{"ID":4,"UUID":"4b0db58c-483f-4927-881e-
set
user_6
{"ID":6,"UUID":"3d9dbc58-7cfe-4864-ae0e-
set
user_8
{"ID":8,"UUID":"89bf8e46-ad14-46b1-a66d-
set
user_10
{"ID":10,"UUID":"721e6ad7-84c8-4b2e-9880-
del
user_440
```

server_4000.db

```
set
user_440
{"ID":440,"UUID":"93686af7-5e58-4d4e-99b4
```

⇒ Dữ liệu được migrate tới server node mới.

Test case xóa một Node khi hệ thống đang chạy:

- Bên phía Client, mở client_main.go và chạy test case RemoveServer(serverAddress) với address là địa chỉ của node muốn xóa

```
func main() {
    // Kết nối với LoadBalancer
    lbClient, err := NewLoadBalancerClient("localhost:9000")
    if err != nil {
        log.Fatalf("Error connecting to LoadBalancer: %v", err)
    }
    defer lbClient.client.Close()

    // Uncomment to set 10 new data entries
    //lbClient.SetMultipleData(false)
    //lbClient.SetMultipleData(true)

    // Uncomment to get 10 data entries
    //lbClient.GetMultipleData()

    // Uncomment to request remove server
    serverToRemoveID := "localhost:3000"
    lbClient.RemoveServer(serverToRemoveID)
}
```

Log client:

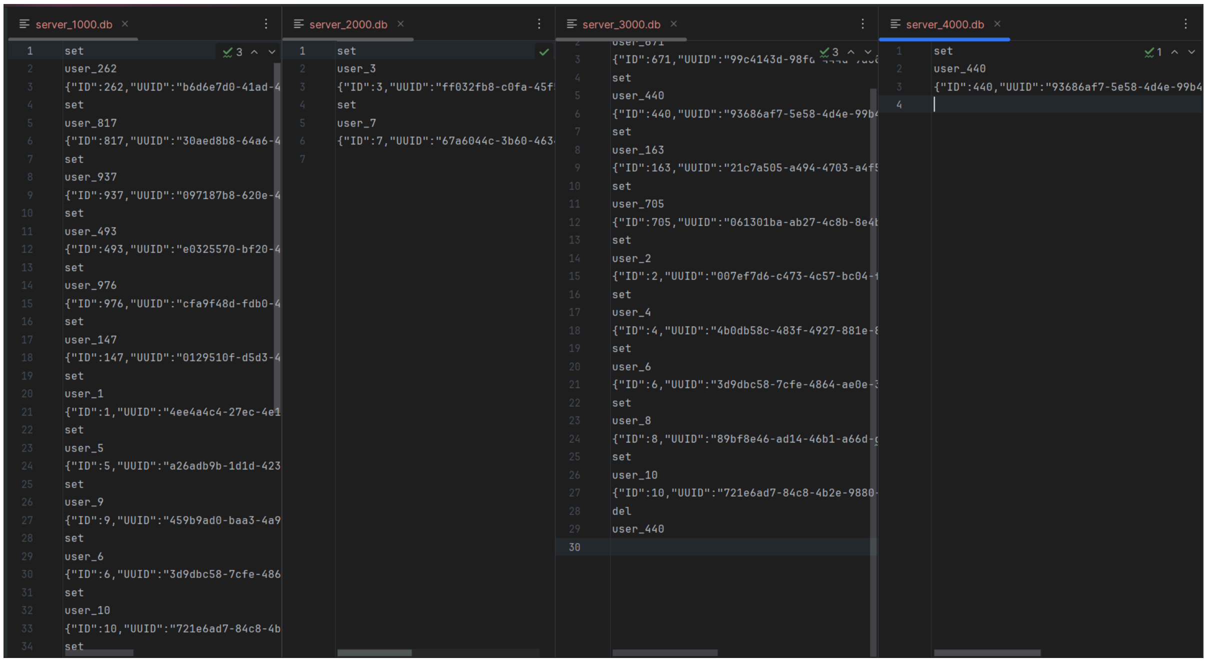
```
PS D:\WorkSpace\Master\Master-DistributedSystem\Lab4\Client> go run clien
2025/03/03 19:49:03 Client sending RemoveServer request - ServerID: localh
2025/03/03 19:49:03 Client received response: Success = true
```

Log loadbalancer:

```
2025/03/03 19:49:03 Rebalancing data after removal of server localhost:300(
2025/03/03 19:49:03 user_6 will be moved/stayed at localhost:1000
```

```
2025/03/03 19:49:03 Migrating key 6 to new server localhost:1000
2025/03/03 19:49:03 Successfully migrated key 6 to server localhost:1000
2025/03/03 19:49:03 user_10 will be moved/stayed at localhost:1000
2025/03/03 19:49:03 Migrating key 10 to new server localhost:1000
2025/03/03 19:49:03 Successfully migrated key 10 to server localhost:1000
2025/03/03 19:49:03 user_671 will be moved/stayed at localhost:1000
2025/03/03 19:49:03 Migrating key 671 to new server localhost:1000
2025/03/03 19:49:03 Successfully migrated key 671 to server localhost:1000
2025/03/03 19:49:03 user_163 will be moved/stayed at localhost:1000
2025/03/03 19:49:03 Migrating key 163 to new server localhost:1000
2025/03/03 19:49:03 Successfully migrated key 163 to server localhost:1000
2025/03/03 19:49:03 user_2 will be moved/stayed at localhost:1000
2025/03/03 19:49:03 Migrating key 2 to new server localhost:1000
2025/03/03 19:49:03 Successfully migrated key 2 to server localhost:1000
2025/03/03 19:49:03 user_8 will be moved/stayed at localhost:1000
2025/03/03 19:49:03 Migrating key 8 to new server localhost:1000
2025/03/03 19:49:03 Successfully migrated key 8 to server localhost:1000
2025/03/03 19:49:03 user_705 will be moved/stayed at localhost:1000
2025/03/03 19:49:03 Migrating key 705 to new server localhost:1000
2025/03/03 19:49:03 Successfully migrated key 705 to server localhost:1000
2025/03/03 19:49:03 user_4 will be moved/stayed at localhost:1000
2025/03/03 19:49:03 Migrating key 4 to new server localhost:1000
2025/03/03 19:49:03 Successfully migrated key 4 to server localhost:1000
2025/03/03 19:49:03 Removed server: localhost:3000
```

Database sau khi remove node ở port 3000:



```
set
user_262
{"ID":262,"UUID":"b6d6e7d0-41ad-4
set
user_817
{"ID":817,"UUID":"30aed8b8-64a6-4
set
user_937
{"ID":937,"UUID":"097187b8-620e-4
set
user_493
{"ID":493,"UUID":"e0325570-bf20-4
set
user_976
{"ID":976,"UUID":"cfa9f48d-fdb0-4
set
user_147
{"ID":147,"UUID":"0129510f-d5d3-4
set
user_1
{"ID":1,"UUID":"4ee4a4c4-27ec-4e1
set
user_5
{"ID":5,"UUID":"a26adb9b-1d1d-423
set
user_9
{"ID":9,"UUID":"459b9ad0-baa3-4a9
set
user_6
{"ID":6,"UUID":"3d9dbc58-7cfe-486
set
user_10
{"ID":10,"UUID":"721e6ad7-84c8-4b
set
```

```
set
user_3
{"ID":3,"UUID":"ff032fb8-c0fa-45f
set
user_7
{"ID":7,"UUID":"67a6044c-3b60-463
```

```
user_671
{"ID":671,"UUID":"99c4143d-98fc
set
user_440
{"ID":440,"UUID":"93686af7-5e58-4d4e-99b4
set
user_163
{"ID":163,"UUID":"21c7a505-a494-4703-a4f5
set
user_705
{"ID":705,"UUID":"061301ba-ab27-4c8b-8e4b
set
user_2
{"ID":2,"UUID":"007ef7d6-c473-4c57-bc04-
set
user_4
{"ID":4,"UUID":"4b0db58c-483f-4927-881e-
set
user_6
{"ID":6,"UUID":"3d9dbc58-7cfe-4864-ae0e-
set
user_8
{"ID":8,"UUID":"89bf8e46-ad14-46b1-a66d-
set
user_10
{"ID":10,"UUID":"721e6ad7-84c8-4b2e-9880-
del
user_440
```

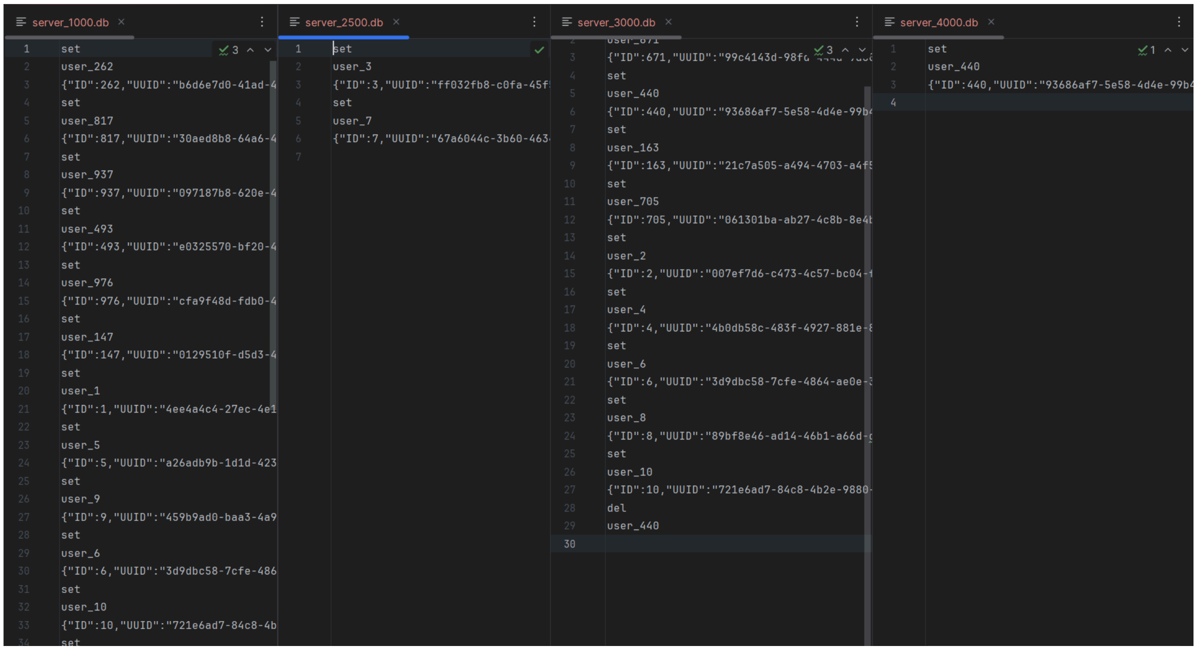
```
set
user_440
{"ID":440,"UUID":"93686af7-5e58-4d4e-99b4
```

⇒ Dữ liệu ở node tại port 3000 đã được migrate đi

Test case thêm một Node sau khi xóa một Node:

- Khởi tạo thêm một server node tại port 2500:

```
PS D:\WorkSpace\Master\Master-DistributedSystem\Lab4\Server> go run se
2025/03/03 19:51:47 Server started on port 2500 with database: server_250
2025/03/03 19:51:48 Server received Set request - Bucket: user, Key: 3
2025/03/03 19:51:48 Server successfully stored data - Key: 3
2025/03/03 19:51:48 Server received Set request - Bucket: user, Key: 7
2025/03/03 19:51:48 Server successfully stored data - Key: 7
2025/03/03 19:51:48 Server registered with LoadBalancer: Added server: loc
```



```
set
user_262
{"ID":262,"UUID":"b6d6e7d0-41ad-4
set
user_817
{"ID":817,"UUID":"30aed8b8-64a6-4
set
user_937
{"ID":937,"UUID":"097187b8-620e-4
set
user_493
{"ID":493,"UUID":"e0325570-bf20-4
set
user_976
{"ID":976,"UUID":"cfa9f48d-fdb0-4
set
user_147
{"ID":147,"UUID":"0129510f-d5d3-4
set
user_1
{"ID":1,"UUID":"4ee4a4c4-27ec-4e1
set
user_5
{"ID":5,"UUID":"a26adb9b-1d1d-423
set
user_9
{"ID":9,"UUID":"459b9ad0-baa3-4a9
set
user_6
{"ID":6,"UUID":"3d9dbc58-7cfe-486
set
user_10
{"ID":10,"UUID":"721e6ad7-84c8-4b
set
```

```
set
user_3
{"ID":3,"UUID":"ff032fb8-c0fa-45f
set
user_7
{"ID":7,"UUID":"67a6044c-3b60-463
```

```
user_671
{"ID":671,"UUID":"99c4143d-98fa
set
user_440
{"ID":440,"UUID":"93686af7-5e58-4d4e-99b
set
user_163
{"ID":163,"UUID":"21c7a505-a494-4703-a4f
set
user_705
{"ID":705,"UUID":"061301ba-ab27-4c8b-8e4
set
user_2
{"ID":2,"UUID":"007ef7d6-c473-4c57-bc04-
set
user_4
{"ID":4,"UUID":"4b0db58c-483f-4927-881e-
set
user_6
{"ID":6,"UUID":"3d9dbc58-7cfe-4864-ae0e-
set
user_8
{"ID":8,"UUID":"89bf8e46-ad14-46b1-a66d-
set
user_10
{"ID":10,"UUID":"721e6ad7-84c8-4b2e-9880-
del
user_440
```

```
set
user_440
{"ID":440,"UUID":"93686af7-5e58-4d4e-99b
```

Log loadbalancer:

```
2025/03/03 19:51:48 NewConsistentHash server registered: localhost:2500
2025/03/03 19:51:48 Current servers in LoadBalancer:
2025/03/03 19:51:48    - localhost:1000
2025/03/03 19:51:48    - localhost:2000
2025/03/03 19:51:48    - localhost:2500
2025/03/03 19:51:48    - localhost:4000
2025/03/03 19:51:48 Rebalancing data for new server: localhost:2500
2025/03/03 19:51:48 Data will be moved from next server: localhost:2000
2025/03/03 19:51:48 user_3 will be moved/stayed at localhost:2500
2025/03/03 19:51:48 Migrating key 3 to new server localhost:2500
2025/03/03 19:51:48 Successfully migrated key 3 to server localhost:2500
2025/03/03 19:51:48 Deleting key 3 from old server localhost:2000
2025/03/03 19:51:48 Successfully deleted key 3 from old server localhost:20
2025/03/03 19:51:48 user_7 will be moved/stayed at localhost:2500
2025/03/03 19:51:48 Migrating key 7 to new server localhost:2500
2025/03/03 19:51:48 Successfully migrated key 7 to server localhost:2500
2025/03/03 19:51:48 Deleting key 7 from old server localhost:2000
2025/03/03 19:51:48 Successfully deleted key 7 from old server localhost:20
2025/03/03 19:51:48 --------------------------------
```

⇒ Data cũng đã được migrate tới server node mới, và node 3000 đã remove khỏi danh sách