

## Assignment 2 – Keyur Doshi – 10405923 – DHT Standalone Report

### Abstract:

Using Distributed hash table, a peer-peer structured network overlay, and communication between nodes using Representational State Transfer REST API.

### Approach:

Joining of three nodes together into a DHT network and run locally. Running these nodes on separate EC2 instances under control.

### Code

```
try{  
    //provides primary access to data of document  
    Document doc = getRequest(info.addr+UriApi.SUCC);  
    //return all elements in the document with given a tag name  
    NodeInfo succ= new  
    NodeInfo(Integer.parseInt(doc.getElementsByTagName("id").item(0).getTextContent()),  
    new URI(doc.getElementsByTagName("addr").item(0).getTextContent()));  
    return succ;  
}
```

**Now getting Successor and Predecessor, In DHT.java, performed a web service call to the node.**

```
/*  
* TODO: Do the Web service call  
*/  
try{  
    Document doc=getRequest(info.addr+UriApi.PRED);  
    if(doc.getElementsByTagName("id").getLength()>=1){  
        return new  
        NodeInfo(Integer.parseInt(doc.getElementsByTagName("id").item(0).getTextContent()),  
        new URI(doc.getElementsByTagName("addr").item(0).getTextContent()));  
    }  
}
```

**Now, to getfinger, setfinger and to get closest preceding finger for id.**

**The code is in state.java.**

```
public synchronized void setFinger(int i, NodeInfo info) {  
    /*  
    * TODO: Done. Set the ith finger.  
    */  
    finger[i] = info;  
}
```

```
public synchronized NodeInfo getFinger(int i) {  
    /*  
    * TODO: Done. Get the ith finger.  
    */  
    return finger[i];  
}
```

```
public synchronized NodeInfo closestPrecedingFinger(int id) {  
    /*  
    * TODO: Done. Get closest preceding finger for id, to continue search  
    at that  
    * node. Hint: See DHTBase.inInterval()  
    */  
    NodeInfo info = getNodeInfo();  
    for (int i = NFINGERS - 1; i >= 0; i--) {  
        if(DHTBase.inInterval(finger[i].id, info.id, id, false))
```

```
return finger[i];  
} return info;  
}
```

**Get, Put and delete methods to communicate between client and server and perform as a request parameter over HTTP protocol.**

@GET

```
@Path("find")  
@Produces("application/xml")  
public Response findSuccessor(@QueryParam("id") String index) {  
    int id = Integer.parseInt(index);  
    return new NodeService(headers, uriInfo).findSuccessor(id);  
}
```

@PUT

```
@Produces("application/xml")  
public Response setKeyValue(@QueryParam("key") String key, @QueryParam("val")  
String  
value) {  
    return new NodeService(headers, uriInfo).setKeyValue(key, value);  
}
```

@GET

```
@Produces("application/xml")  
public Response getKeyValue(@QueryParam("key") String key) {  
    return new NodeService(headers, uriInfo).getKeyValue(key);  
}
```

@DELETE

```
public void deleteKeyValue(@QueryParam("key") String key, @QueryParam("val")
String
value) {
new NodeService(headers, uriInfo).deleteKeyValue(key, value);
}
```

### Local Testing:

#### Local:

Initiating jersey and bound to 8082.

Connecting three ports in localhost.

```
keyur@ubuntu: ~/tmp/cs549/dht-test
[INFO] -----
keyur@ubuntu:~/cs549/Assignment2/dht-standalone$ cd /home/keyur/tmp/cs549/dht-test/
keyur@ubuntu:~/tmp/cs549/dht-test$ java -jar dht.jar --http 8080 --id 23 --host localhost
Oct 15, 2016 10:45:16 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting state server...
Oct 15, 2016 10:45:16 PM edu.stevens.cs549.dhts.main.Main info
INFO: State server bound.
Oct 15, 2016 10:45:17 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting HTTP server.
Oct 15, 2016 10:45:21 PM org.glassfish.grizzly.http.server.NetworkListener start
INFO: Started listener bound to [localhost:8080]
Oct 15, 2016 10:45:21 PM org.glassfish.grizzly.http.server.HttpServer start
INFO: [HttpServer] Started.
Oct 15, 2016 10:45:21 PM edu.stevens.cs549.dhts.main.Main info
INFO: DHT Web service started with WADL available at http://localhost:8080/applcation.wadl
Try out http://localhost:8080/dht
Entering command-line interface...
dht<23> bindings
No entries.
dht<23> join http://localhost:8082/dht
dht<23>

keyur@ubuntu:~/tmp/cs549/dht-test
keyur@ubuntu:~/tmp/cs549/dht-test$ cd /home/keyur/tmp/cs549/dht-test/
keyur@ubuntu:~/tmp/cs549/dht-test$ java -jar dht.jar --http 8081 --id 37 --host localhost
Oct 15, 2016 10:46:32 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting state server...
Oct 15, 2016 10:46:32 PM edu.stevens.cs549.dhts.main.Main info
INFO: State server bound.
Oct 15, 2016 10:46:32 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting HTTP server.
Oct 15, 2016 10:46:36 PM org.glassfish.grizzly.http.server.NetworkListener start
INFO: Started listener bound to [localhost:8081]
Oct 15, 2016 10:46:36 PM org.glassfish.grizzly.http.server.HttpServer start
INFO: [HttpServer] Started.
Oct 15, 2016 10:46:36 PM edu.stevens.cs549.dhts.main.Main info
INFO: DHT Web service started with WADL available at http://localhost:8081/applcation.wadl
Try out http://localhost:8081/dht
Entering command-line interface...
dht<37> bindings
No entries.
dht<37> join http://localhost:8082/dht
dht<37>

keyur@ubuntu:~/tmp/cs549/dht-test
keyur@ubuntu:~/tmp/cs549/dht-test$ cd /home/keyur/tmp/cs549/dht-test/
keyur@ubuntu:~/tmp/cs549/dht-test$ java -jar dht.jar --http 8082 --id 45 --host localhost
Oct 15, 2016 10:46:46 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting state server...
Oct 15, 2016 10:46:47 PM edu.stevens.cs549.dhts.main.Main info
INFO: State server bound.
Oct 15, 2016 10:46:47 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting HTTP server.
Oct 15, 2016 10:46:50 PM org.glassfish.grizzly.http.server.NetworkListener start
INFO: Started listener bound to [localhost:8082]
Oct 15, 2016 10:46:50 PM org.glassfish.grizzly.http.server.HttpServer start
INFO: [HttpServer] Started.
Oct 15, 2016 10:46:50 PM edu.stevens.cs549.dhts.main.Main info
INFO: DHT Web service started with WADL available at http://localhost:8082/applcation.wadl
Try out http://localhost:8082/dht
Entering command-line interface...
dht<45> bindings
No entries.
dht<45>
```

The image shows three terminal windows on a Linux system, demonstrating the setup and operation of a Distributed Hash Table (DHT) using the dht.jar application.

**Terminal 1 (Left):** Shows the initial state of node 23. It has no entries. A key 'baz2' with value '55' is added. The node then gets the value for 'foo1', which is '{first}'. It also shows the routes and predecessor/successor information for the node.

**Terminal 2 (Bottom Left):** Shows node 37 joining the DHT. It has no entries. A key 'baz' with value '27' is added. The node then gets the value for 'foo2', which is '{second}'. It also shows the routes and predecessor/successor information for the node.

**Terminal 3 (Right):** Shows node 45 joining the DHT. It has no entries. A key 'foo1' with value '43' is added. The node then gets the value for 'foo2', which is '{second}'. It also shows the routes and predecessor/successor information for the node.

Connect Three nodes and bind them in Distributed Hash Table.

```
java -jar dht.jar --http 8080 --id 23
```

```
java -jar dht.jar --http 8081 --id 37
```

```
java -jar dht.jar --http 8082 --id 45
```

Join two nodes to the node listens 8082 port.

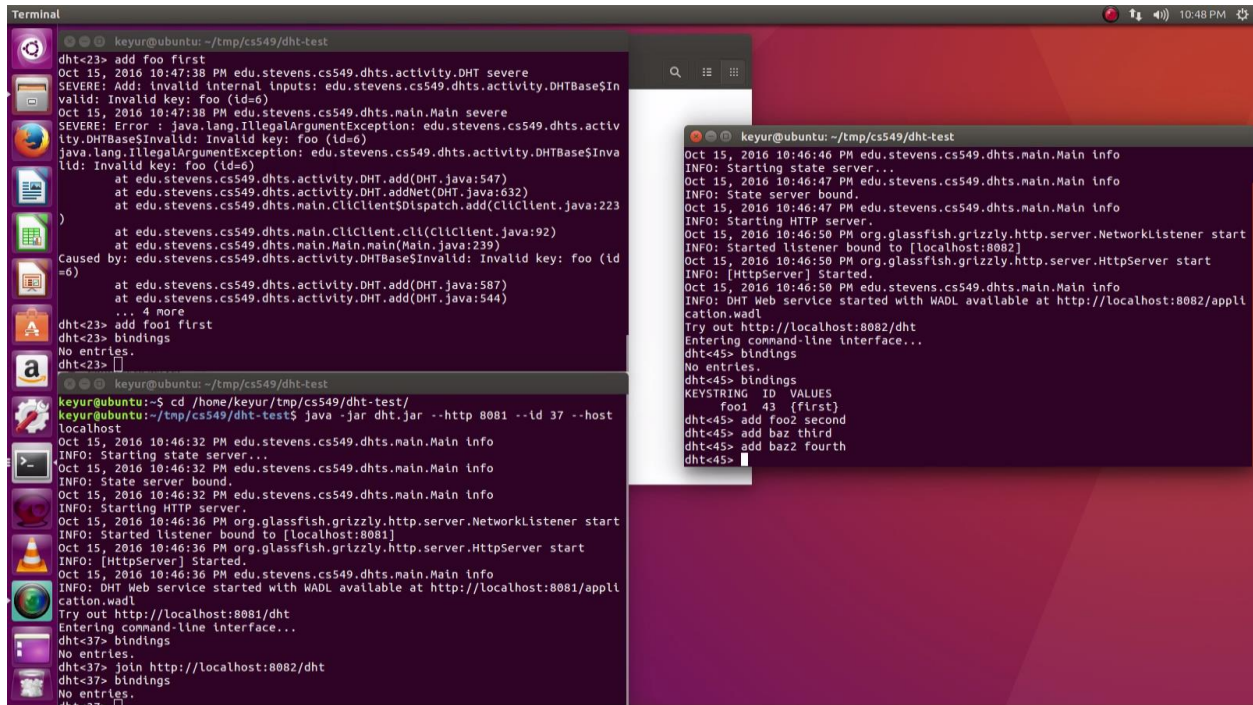
**Command:** join http://localhost:8082/dht

Routes to them with each other which tells you Successor and Predecessor.

Join to the first node by another two nodes and routes three points in DHT.

Add keys and values by **add [key] [values]** command and get keys by **get [key]** command  
delete keys by **del [key] [values]** command.

Adding key on three nodes and get from three different nodes using Distributed Hash Table.



```
Terminal
keyur@ubuntu: ~/tmp/cs549/dht-test
dht<23> add foo first
Oct 15, 2016 10:47:38 PM edu.stevens.cs549.dhts.activity.DHT severe
SEVERE: Add: Invalid internal inputs: edu.stevens.cs549.dhts.activity.DHTBaseInvalid: Invalid key: foo (id=6)
Oct 15, 2016 10:47:38 PM edu.stevens.cs549.dhts.main.Main severe
SEVERE: Error : java.lang.IllegalArgumentException: edu.stevens.cs549.dhts.activity.DHTBaseInvalid: Invalid key: foo (id=6)
java.lang.IllegalArgumentException: edu.stevens.cs549.dhts.activity.DHTBaseInvalid: Invalid key: foo (id=6)
    at edu.stevens.cs549.dhts.activity.DHT.add(DHT.java:547)
    at edu.stevens.cs549.dhts.activity.DHT.addNet(DHT.java:632)
    at edu.stevens.cs549.dhts.main.CliClientDispatch.add(CliClient.java:223)
    at edu.stevens.cs549.dhts.main.CliClient.cl(CliClient.java:92)
    at edu.stevens.cs549.dhts.main.Main.main(Main.java:239)
Caused by: edu.stevens.cs549.dhts.activity.DHTBaseInvalid: Invalid key: foo (id=6)
    at edu.stevens.cs549.dhts.activity.DHT.add(DHT.java:587)
    at edu.stevens.cs549.dhts.activity.DHT.add(DHT.java:544)
    ... 4 more
dht<23> add foo1 first
dht<23> bindings
No entries.
dht<23>

keyur@ubuntu: ~/tmp/cs549/dht-test
keyur@ubuntu:~$ cd /home/keyur/tmp/cs549/dht-test/
keyur@ubuntu:~/tmp/cs549/dht-test$ java -jar dht.jar --http 8081 --id 37 --host localhost
Oct 15, 2016 10:46:32 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting state server...
Oct 15, 2016 10:46:32 PM edu.stevens.cs549.dhts.main.Main info
INFO: State server bound.
Oct 15, 2016 10:46:32 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting HTTP server.
Oct 15, 2016 10:46:36 PM org.glassfish.grizzly.http.server.NetworkListener start
INFO: Started listener bound to [localhost:8081]
Oct 15, 2016 10:46:36 PM org.glassfish.grizzly.http.server.HttpServer start
INFO: [HttpServer] Started.
Oct 15, 2016 10:46:36 PM edu.stevens.cs549.dhts.main.Main info
INFO: DHT Web service started with WADL available at http://localhost:8081/application.wadl
Try out http://localhost:8081/dht
Entering command-line interface...
dht<37> bindings
No entries.
dht<37> join http://localhost:8082/dht
dht<37> bindings
No entries.
dht<37>

keyur@ubuntu: ~/tmp/cs549/dht-test
Oct 15, 2016 10:46:46 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting state server...
Oct 15, 2016 10:46:47 PM edu.stevens.cs549.dhts.main.Main info
INFO: State server bound.
Oct 15, 2016 10:46:47 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting HTTP server.
Oct 15, 2016 10:46:50 PM org.glassfish.grizzly.http.server.NetworkListener start
INFO: Started listener bound to [localhost:8082]
Oct 15, 2016 10:46:50 PM org.glassfish.grizzly.http.server.HttpServer start
INFO: [HttpServer] Started.
Oct 15, 2016 10:46:50 PM edu.stevens.cs549.dhts.main.Main info
INFO: DHT Web service started with WADL available at http://localhost:8082/application.wadl
Try out http://localhost:8082/dht
Entering command-line interface...
dht<45> bindings
No entries.
dht<45> bindings
KEYSTRING ID VALUES
foo1 43 {first}
dht<45> add foo2 second
dht<45> add baz third
dht<45> add baz2 fourth
dht<45>
```

Performed by Add, Delete, Bindings, Routes and Get operations In Distributed Hash Table with {key,Value} on three nodes.

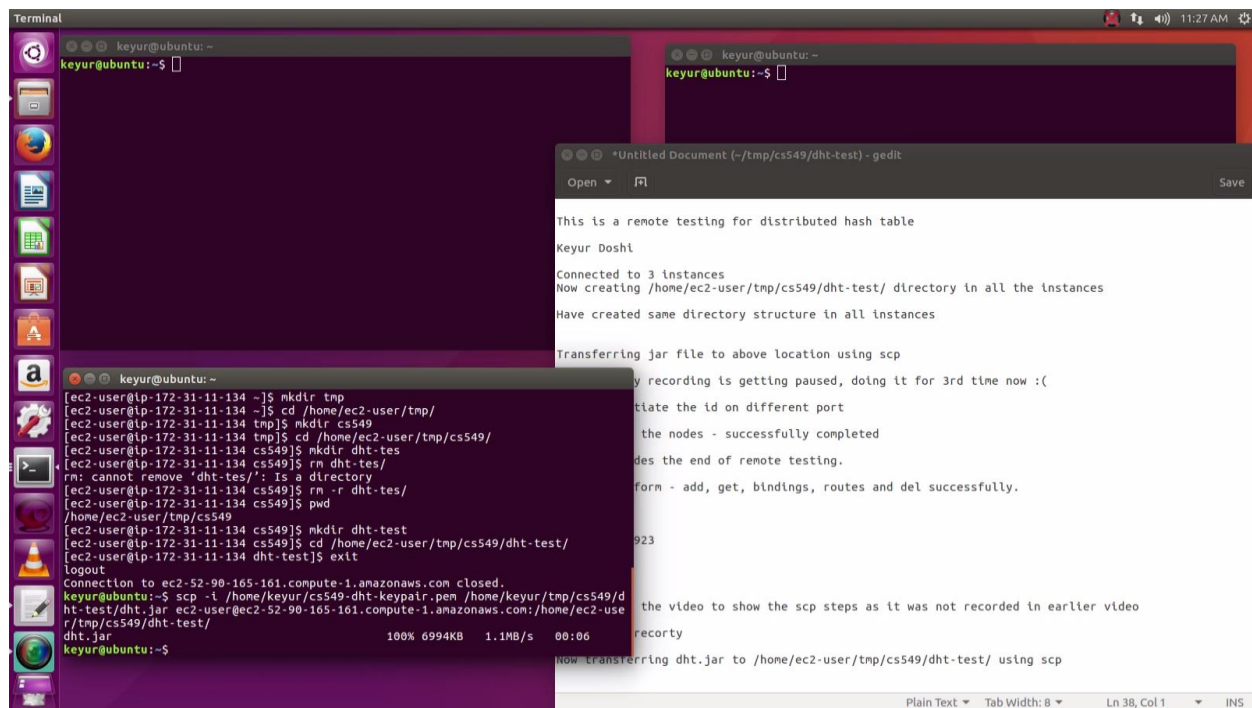
### Remote Testing:

Three ec2 instances created on Amazon web service and connect them through Secure Shell Script to communicate in DHT. Define security groups for instances.

```
ssh -i /home/keyur/cs549-dht-keypair.pem ec2-user@ec2-52-90-165-161.compute-1.amazonaws.com
```

Then Copy the dht.jar file using Secure copy command.

```
scp -i /home/keyur/cs549-dht-keypair.pem /home/keyur/tmp/cs549/dht-test/dht.jar ec2-user@ec2-52-90-165-161.compute-1.amazonaws.com: /home/ec2-user/tmp/cs549/dht-test/
```



Routes three nodes in DHT.

Add, Get, Delete keys and values using commands.



```
Terminal
ec2-user@ip-172-31-11-133:~/tmp/cs549/dht-test
Oct 16, 2016 3:09:40 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting state server...
Oct 16, 2016 3:09:40 PM edu.stevens.cs549.dhts.main.Main info
INFO: State server bound.
Oct 16, 2016 3:09:41 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting HTTP server.
Oct 16, 2016 3:09:43 PM org.glassfish.grizzly.http.server.NetworkListener start
INFO: Started listener bound to [172.31.11.133:8080]
Oct 16, 2016 3:09:43 PM org.glassfish.grizzly.http.server.HttpServer start
INFO: [HttpServer] Started.
Oct 16, 2016 3:09:43 PM edu.stevens.cs549.dhts.main.Main info
INFO: DHT Web service started with WADL available at http://172.31.11.133:8080/a
pplication.wadl
Try out http://172.31.11.133:8080/dht
Entering command-line interface...
dht<23> bindings
No entries.
dht<23> join http://172.31.11.135:8081/dht
dht<23> bindings
KEYSTRING ID VALUES
foo 6 {first}
dht<23>

ec2-user@ip-172-31-11-134:~/tmp/cs549/dht-test
INFO: State server bound.
Oct 16, 2016 3:11:05 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting HTTP server.
Oct 16, 2016 3:11:07 PM org.glassfish.grizzly.http.server.NetworkListener start
INFO: Started listener bound to [172.31.11.134:8082]
Oct 16, 2016 3:11:07 PM org.glassfish.grizzly.http.server.HttpServer start
INFO: [HttpServer] Started.
Oct 16, 2016 3:11:07 PM edu.stevens.cs549.dhts.main.Main info
INFO: DHT Web service started with WADL available at http://172.31.11.134:8082/a
pplication.wadl
Try out http://172.31.11.134:8082/dht
Entering command-line interface...
dht<37> bindings
No entries.
dht<37> join http://172.31.11.135:8081/dht
dht<37> add foo first
dht<37> add foo2 second
dht<37> bindings
No entries.
dht<37>
```

```
Terminal
ec2-user@ip-172-31-11-133:~/tmp/cs549/dht-test
Oct 16, 2016 3:09:43 PM org.glassfish.grizzly.http.server.NetworkListener start
INFO: Started listener bound to [172.31.11.133:8080]
Oct 16, 2016 3:09:43 PM org.glassfish.grizzly.http.server.HttpServer start
INFO: [HttpServer] Started.
Oct 16, 2016 3:09:43 PM edu.stevens.cs549.dhts.main.Main info
INFO: DHT Web service started with WADL available at http://172.31.11.133:8080/a
pplication.wadl
Try out http://172.31.11.133:8080/dht
Entering command-line interface...
dht<23> bindings
No entries.
dht<23> join http://172.31.11.135:8081/dht
dht<23> bindings
KEYSTRING ID VALUES
foo 6 {first}
dht<23> bindings
KEYSTRING ID VALUES
baz2 55 {fourth}
foo 6 {first}
dht<23> get foo2
(second)
dht<23>

ec2-user@ip-172-31-11-134:~/tmp/cs549/dht-test
Oct 16, 2016 3:11:07 PM org.glassfish.grizzly.http.server.NetworkListener start
INFO: Started listener bound to [172.31.11.134:8082]
Oct 16, 2016 3:11:07 PM org.glassfish.grizzly.http.server.HttpServer start
INFO: [HttpServer] Started.
Oct 16, 2016 3:11:07 PM edu.stevens.cs549.dhts.main.Main info
INFO: DHT Web service started with WADL available at http://172.31.11.134:8082/a
pplication.wadl
Try out http://172.31.11.134:8082/dht
Entering command-line interface...
dht<37> bindings
No entries.
dht<37> join http://172.31.11.135:8081/dht
dht<37> add foo first
dht<37> add foo2 second
dht<37> bindings
No entries.
dht<37> bindings
KEYSTRING ID VALUES
baz 27 {third}
dht<37>

ec2-user@ip-172-31-11-135:~/tmp/cs549/dht-test
Oct 16, 2016 3:10:42 PM edu.stevens.cs549.dhts.main.Main info
INFO: State server bound.
Oct 16, 2016 3:10:42 PM edu.stevens.cs549.dhts.main.Main info
INFO: Starting HTTP server.
Oct 16, 2016 3:10:45 PM org.glassfish.grizzly.http.server.NetworkListener start
INFO: Started listener bound to [172.31.11.135:8081]
Oct 16, 2016 3:10:45 PM org.glassfish.grizzly.http.server.HttpServer start
INFO: [HttpServer] Started.
Oct 16, 2016 3:10:45 PM edu.stevens.cs549.dhts.main.Main info
INFO: DHT Web service started with WADL available at http://172.31.11.135:8081/a
pplication.wadl
Try out http://172.31.11.135:8081/dht
Entering command-line interface...
dht<45> bindings
No entries.
dht<45> bindings
KEYSTRING ID VALUES
foo2 44 {second}
dht<45> add baz third
dht<45> add baz2 fourth
dht<45> bindings
KEYSTRING ID VALUES
foo2 44 {second}
dht<45>
```



```
Terminal
ec2-user@ip-172-31-11-133:~/tmp/cs549/dht-test
foo 6 {first}
dht<23> get foo2
{second}
dht<23> get baz
{third}
dht<23> bindings
KEYSTRING ID VALUES
baz2 55 {fourth}
foo 6 {first}
dht<23> routes
Predecessor: [id=45,addr=http://172.31.11.135:8081/dht]
Successor : [id=37,addr=http://172.31.11.134:8082/dht]
Fingers:
Formula Key Succ
-----
23+2^0 24 [id=37,url=http://172.31.11.134:8082/dht]
23+2^1 25 [id=37,url=http://172.31.11.134:8082/dht]
23+2^2 27 [id=37,url=http://172.31.11.134:8082/dht]
23+2^3 31 [id=37,url=http://172.31.11.134:8082/dht]
23+2^4 39 [id=45,url=http://172.31.11.135:8081/dht]
23+2^5 55 [id=23,url=http://172.31.11.133:8080/dht]
dht<23>

ec2-user@ip-172-31-11-134:~/tmp/cs549/dht-test
dht<37> bindings
No entries.
dht<37> bindings
KEYSTRING ID VALUES
baz 27 {third}
dht<37> get foo2
{second}
dht<37> routes
Predecessor: [id=23,addr=http://172.31.11.133:8080/dht]
Successor : [id=45,addr=http://172.31.11.135:8081/dht]
Fingers:
Formula Key Succ
-----
37+2^0 38 [id=45,url=http://172.31.11.135:8081/dht]
37+2^1 39 [id=45,url=http://172.31.11.135:8081/dht]
37+2^2 41 [id=45,url=http://172.31.11.135:8081/dht]
37+2^3 45 [id=45,url=http://172.31.11.135:8081/dht]
37+2^4 53 [id=23,url=http://172.31.11.133:8080/dht]
37+2^5 5 [id=23,url=http://172.31.11.133:8080/dht]
dht<37>
```

```
ec2-user@ip-172-31-11-135:~/tmp/cs549/dht-test
No entries.
dht<45> bindings
KEYSTRING ID VALUES
foo2 44 {second}
dht<45> add baz third
dht<45> add baz2 fourth
dht<45> bindings
KEYSTRING ID VALUES
foo2 44 {second}
dht<45> get foo
{first}
dht<45> routes
Predecessor: [id=37,addr=http://172.31.11.134:8082/dht]
Successor : [id=23,addr=http://172.31.11.133:8080/dht]
Fingers:
Formula Key Succ
-----
45+2^0 46 [id=23,url=http://172.31.11.133:8080/dht]
45+2^1 47 [id=23,url=http://172.31.11.133:8080/dht]
45+2^2 49 [id=23,url=http://172.31.11.133:8080/dht]
45+2^3 53 [id=23,url=http://172.31.11.133:8080/dht]
45+2^4 61 [id=23,url=http://172.31.11.133:8080/dht]
45+2^5 13 [id=23,url=http://172.31.11.133:8080/dht]
dht<45>
```

```
Terminal
ec2-user@ip-172-31-11-133:~/tmp/cs549/dht-test
foo 6 {first}
dht<23> get foo2
{second}
dht<23> get baz
{third}
dht<23> bindings
KEYSTRING ID VALUES
baz2 55 {fourth}
foo 6 {first}
dht<23> routes
Predecessor: [id=45,addr=http://172.31.11.135:8081/dht]
Successor : [id=37,addr=http://172.31.11.134:8082/dht]
Fingers:
Formula Key Succ
-----
23+2^0 24 [id=37,url=http://172.31.11.134:8082/dht]
23+2^1 25 [id=37,url=http://172.31.11.134:8082/dht]
23+2^2 27 [id=37,url=http://172.31.11.134:8082/dht]
23+2^3 31 [id=37,url=http://172.31.11.134:8082/dht]
23+2^4 39 [id=45,url=http://172.31.11.135:8081/dht]
23+2^5 55 [id=23,url=http://172.31.11.133:8080/dht]
dht<23>

ec2-user@ip-172-31-11-134:~/tmp/cs549/dht-test
dht<37> bindings
No entries.
dht<37> bindings
KEYSTRING ID VALUES
baz 27 {third}
dht<37> get foo2
{second}
dht<37> routes
Predecessor: [id=23,addr=http://172.31.11.133:8080/dht]
Successor : [id=45,addr=http://172.31.11.135:8081/dht]
Fingers:
Formula Key Succ
-----
37+2^0 38 [id=45,url=http://172.31.11.135:8081/dht]
37+2^1 39 [id=45,url=http://172.31.11.135:8081/dht]
37+2^2 41 [id=45,url=http://172.31.11.135:8081/dht]
37+2^3 45 [id=45,url=http://172.31.11.135:8081/dht]
37+2^4 53 [id=23,url=http://172.31.11.133:8080/dht]
37+2^5 5 [id=23,url=http://172.31.11.133:8080/dht]
dht<37> ge

ec2-user@ip-172-31-11-135:~/tmp/cs549/dht-test
dht<45> add baz2 fourth
dht<45> bindings
KEYSTRING ID VALUES
foo2 44 {second}
dht<45> get foo
{first}
dht<45> routes
Predecessor: [id=37,addr=http://172.31.11.134:8082/dht]
Successor : [id=23,addr=http://172.31.11.133:8080/dht]
Fingers:
Formula Key Succ
-----
45+2^0 46 [id=23,url=http://172.31.11.133:8080/dht]
45+2^1 47 [id=23,url=http://172.31.11.133:8080/dht]
45+2^2 49 [id=23,url=http://172.31.11.133:8080/dht]
45+2^3 53 [id=23,url=http://172.31.11.133:8080/dht]
45+2^4 61 [id=23,url=http://172.31.11.133:8080/dht]
45+2^5 13 [id=23,url=http://172.31.11.133:8080/dht]
dht<45> del foo first
Oct 16, 2016 3:15:29 PM edu.stevens.cs549.dhts.main.WebClient error
SEVERE: Exception during PUT request: java.lang.NullPointerException
dht<45> get foo
{}
dht<45>
```