

COP5615 - DISTRIBUTED MULTIMEDIA SYSTEMS

PROJECT #1

GOAL

The objective of this project is to use functional programming language and the Akka Actor Model to build a good solution to the Bitcoin Mining problem using a distributed system that runs well on multi-core machines.

AUTHORS

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THE SIZE OF THE WORK UNIT

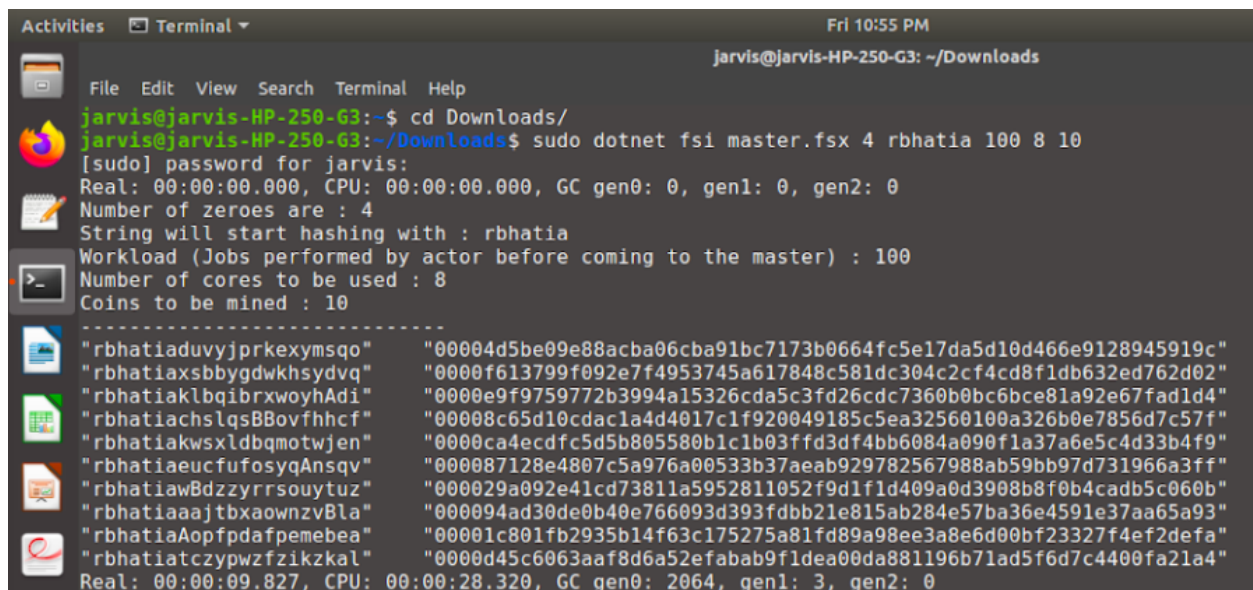
In the program, the worker receives a request for mining with the number of coins to be mined given as input by the user using the command line. Since the number of cores in the client machine is 4, we used 8 actors to be spawned on a single machine with each actor performing 100 iterations before asking for a new job from the master.

RESULT FOR RUNNING THE PROGRAM WITH 4 LEADING ZEROES

a) Sample Output

The following output was generated for command with 4 zeroes as input, “rbhatia” as the gator id, 100 as the number of iterations the actor will perform before requesting the master for a new coin, 8 as the number of actors to be spawned by a master over a single machine, 10 as the number of coins to be mined :

i) Working Locally



```
jarvis@jarvis-HP-250-G3: ~/Downloads
[sudo] password for jarvis:
Real: 00:00:00.000, CPU: 00:00:00.000, GC gen0: 0, gen1: 0, gen2: 0
Number of zeroes are : 4
String will start hashing with : rbhatia
Workload (Jobs performed by actor before coming to the master) : 100
Number of cores to be used : 8
Coins to be mined : 10
-----
"rbhatiaduvyjjrkexymsqo" "00004d5be09e88acba06cba91bc7173b0664fc5e17da5d10d466e9128945919c"
"rbhatiaxsbbvgdwkhsydvq" "0000f613799f092e7f4953745a617848c581dc304c2cf4cd8f1db632ed762d02"
"rbhatiaklbqibrxwoyhAdi" "0000e9f9759772b3994a15326cda5c3fd26cdc7360b0bc6bce81a92e67fad1d4"
"rbhatiachslqsBBovfhcf" "00008c65d10cdacla4d4017c1f920049185c5ea32560100a326b0e7856d7c57f"
"rbhatiakwslqdbqmotwjn" "0000ca4ecdffc5d5b805580b1c1b03ffd3df4bb6084a090f1a37a6e5c4d33b4f9"
"rbhatiaaucufufosyqAnsqv" "000087128e4807c5a976a00533b37aeab929782567988ab59bb97d731966a3ff"
"rbhatiawBdzzyrrsouytuz" "000029a092e41cd73811a5952811052f9d1fd409a0d3908b8f0b4cadb5c060b"
"rbhatiaaajtbxaownzvBla" "000094ad30de0b40e766093d393fddb21e815ab284e57ba36e4591e37aa65a93"
"rbhatiaAopfdaafpemebea" "00001c801fb2935b14f63c175275a81fd89a98ee3a8e6d00bf23327f4ef2defa"
"rbhatiatczypwzfzikzkal" "0000d45c6063aaf8d6a52efabab9f1dea00da881196b71ad5f6d7c4400fa21a4"
Real: 00:00:09.827, CPU: 00:00:28.320, GC gen0: 2064, gen1: 3, gen2: 0
```

ii) Working Remotely

master.fsx

```
jarvis@jarvis-HP-250-G3:~/Downloads$ sudo dotnet fsi master.fsx 4 rbhatia 100 8 10
Real: 00:00:00.000, CPU: 00:00:00.000, GC gen0: 0, gen1: 0, gen2: 0
Number of zeroes are : 4
String will start hashing with : rbhatia
Workload (Jobs performed by actor before coming to the master) : 100
Number of cores to be used : 8
Coins to be mined : 10
-----
"rbhatiaxqhwabiAcglscqB" "00007c823c7dfa66986d332a4112887aeff74fc34516170090131e058e7d863b"
"rbhatiaptgfdagntfstjpp" "0000c1c2d52e1f9e4bd67bfa539214a08f589319e445ab30a0a55c024fc1872f"
"rbhatiaacygaqaopiumzof" "0000fd8fa6b21dfb05e02a67d240a44d6be96e04a6bc72aad0aae5bafa9587df"
"rbhatialqubwxuzukmbtw" "000078c19e8afb663d15fd378b0bfd9f479c6b7425b983ee839889720ed5ac0c"
"rbhatiakfiegyougnwxvbe" "0000c9a177f37977c79eaaaf446f85f63a7b86be186c124638c27791a8993a261"
"rbhatiaABycmpAsbrCBpAc" "0000aeb164fcb38d738338983c72f3cb1b9476c3109b105538e3151042b71d3"
RemoteCoinRequest
Request from Remote Miners
Received Mining Request from "[akka.tcp://ClientFsharp@10.20.89.8:8888/user/client#39070881]"
RemoteCoinRequest
Request from Remote Miners
Received Mining Request from "[akka.tcp://ClientFsharp@10.20.89.5:8888/user/client#1816580083]"
rbhatiaxewknoAeAgvAlgm,0000225b50ec77bcee7dce87b1aa6fcda1016c72e227e492cd4ff1406079ab4f
Success from Remote Miner!
"rbhatiaxewknoAeAgvAlgm" "0000225b50ec77bcee7dce87b1aa6fcda1016c72e227e492cd4ff1406079ab4f"
Real: 00:00:06.970, CPU: 00:00:19.340, GC gen0: 1322, gen1: 5, gen2: 1
jarvis@jarvis-HP-250-G3:~/Downloads$
```

client1.fsx

```
Bitcoin_Mining -- zsh -- 139x33
simran@Simrans-MacBook-Air Bitcoin_Mining % dotnet fsi client.fsx 10.20.89.6
Local IP : 10.20.89.8
Server IP : 10.20.89.6
[INFO][09/25/2021 02:57:02][Thread 0001][remoting (akka://ClientFsharp)] Starting remoting
[INFO][09/25/2021 02:57:03][Thread 0001][remoting (akka://ClientFsharp)] Remoting started; listening on addresses : [akka.tcp://ClientFsharp@10.20.89.8:8888]
[INFO][09/25/2021 02:57:03][Thread 0001][remoting (akka://ClientFsharp)] Remoting now listens on addresses: [akka.tcp://ClientFsharp@10.20.89.8:8888]
ActorSelection[Anchor(akka.tcp://RemoteFSharp@10.20.89.6:9001/), Path(/user/server)]
**
"rbhatiaxewknoAeAgvAlgm" "0000225b50ec77bcee7dce87b1aa6fcda1016c72e227e492cd4ff1406079ab4f"
Terminating
[INFO][09/25/2021 02:57:03][Thread 0015][remoting-terminator] Shutting down remote daemon.
[INFO][09/25/2021 02:57:03][Thread 0015][remoting-terminator] Remote daemon shut down; proceeding with flushing remote transports.
[INFO][09/25/2021 02:57:03][Thread 0016][akka.tcp://ClientFsharp@10.20.89.8:8888/system/endpointManager/reliableEndpointWriter-akka.tcp%3A%2F%2FRemoteFSharp%4010.20.89.6%3A9001-1] Removing receive buffers for [akka.tcp://ClientFsharp@10.20.89.8:8888]->[akka.tcp://RemoteFSharp@10.20.89.6:9001]
[INFO][09/25/2021 02:57:03][Thread 0005][remoting (akka://ClientFsharp)] Remoting shut down
[INFO][09/25/2021 02:57:03][Thread 0017][remoting-terminator] Remoting shut down.
simran@Simrans-MacBook-Air Bitcoin_Mining %
[INFO][09/25/2021 02:57:03][Thread 0001][remoting (akka://ClientFsharp)] Remoting started; listening on addresses : [akka.tcp://ClientFsharp@10.20.89.8:8888]
[INFO][09/25/2021 02:57:03][Thread 0001][remoting (akka://ClientFsharp)] Remoting now listens on addresses: [akka.tcp://ClientFsharp@10.20.89.8:8888]
ActorSelection[Anchor(akka.tcp://RemoteFSharp@10.20.89.6:9001/), Path(/user/server)]
**
"rbhatiaxewknoAeAgvAlgm" "0000225b50ec77bcee7dce87b1aa6fcda1016c72e227e492cd4ff1406079ab4f"
Terminating
[INFO][09/25/2021 02:57:03][Thread 0015][remoting-terminator] Shutting down remote daemon.
[INFO][09/25/2021 02:57:03][Thread 0015][remoting-terminator] Remote daemon shut down; proceeding with flushing remote transports.
[INFO][09/25/2021 02:57:03][Thread 0016][akka.tcp://ClientFsharp@10.20.89.8:8888/system/endpointManager/reliableEndpointWriter-akka.tcp%3A%2F%2FRemoteFSharp%4010.20.89.6%3A9001-1] Removing receive buffers for [akka.tcp://ClientFsharp@10.20.89.8:8888]->[akka.tcp://RemoteFSharp@10.20.89.6:9001]
[INFO][09/25/2021 02:57:03][Thread 0005][remoting (akka://ClientFsharp)] Remoting shut down
[INFO][09/25/2021 02:57:03][Thread 0017][remoting-terminator] Remoting shut down.
simran@Simrans-MacBook-Air Bitcoin_Mining %
```

client2.fsx

```
Desktop -- zsh -- 161x46
(base) anjali@Anjali-MacBook-Air Desktop % dotnet fsi client.fsx 10.20.89.6
Local IP : 10.20.89.5
Server IP : 10.20.89.6
[INFO][9/25/2021 2:57:02 AM][Thread 0001][remoting (akka://ClientFsharp)] Starting remoting
[INFO][9/25/2021 2:57:02 AM][Thread 0001][remoting (akka://ClientFsharp)] Remoting started; listening on addresses : [akka.tcp://ClientFsharp@10.20.89.5:8888]
[INFO][9/25/2021 2:57:02 AM][Thread 0001][remoting (akka://ClientFsharp)] Remoting now listens on addresses: [akka.tcp://ClientFsharp@10.20.89.5:8888]
ActorSelection[Anchor(akka.tcp://RemoteFSharp@10.20.89.6:9001/), Path(/user/server)]
Terminating
[INFO][9/25/2021 2:57:04 AM][Thread 0022][akka.tcp://ClientFsharp@10.20.89.5:8888/system/endpointManager/reliableEndpointWriter-akka.tcp%3A%2F%2FRemoteFSharp%4010.20.89.6%3A9001-1] Removing receive buffers for [akka.tcp://ClientFsharp@10.20.89.5:8888]->[akka.tcp://RemoteFSharp@10.20.89.6:9001]
[INFO][9/25/2021 2:57:04 AM][Thread 0005][akka://ClientFsharp/system/endpointManager/reliableEndpointWriter-akka.tcp%3A%2F%2FRemoteFSharp%4010.20.89.6%3A9001-1/endpointWriter] Message [AckIdleCheckTimer] from [akka://ClientFsharp/system/endpointManager/reliableEndpointWriter-akka.tcp%3A%2F%2FRemoteFSharp%4010.20.89.6%3A9001-1/endpointWriter#1218330178] to [akka://ClientFsharp/system/endpointManager/reliableEndpointWriter-akka.tcp%3A%2F%2FRemoteFSharp%4010.20.89.6%3A9001-1/endpointWriter#1218330178] was not delivered. [1] dead letters encountered. If this is not an expected behavior then [akka://ClientFsharp/system/endpointManager/reliableEndpointWriter-akka.tcp%3A%2F%2FRemoteFSharp%4010.20.89.6%3A9001-1/endpointWriter#1218330178] may have terminated unexpectedly. This logging can be turned off or adjusted with configuration settings 'akka.log-dead-letters' and 'akka.log-dead-letters-during-shutdown'.
[INFO][9/25/2021 2:57:04 AM][Thread 0025][remoting-terminator] Shutting down remote daemon.
[INFO][9/25/2021 2:57:04 AM][Thread 0025][remoting-terminator] Remote daemon shut down; proceeding with flushing remote transports.
[INFO][9/25/2021 2:57:04 AM][Thread 0010][remoting (akka://ClientFsharp)] Remoting shut down
[INFO][9/25/2021 2:57:04 AM][Thread 0020][remoting-terminator] Remoting shut down.
(base) anjali@Anjali-MacBook-Air Desktop %
```

There is always a trade-off between the time consumed by the worker and the master to communicate for the request and delegation of jobs and the time used by miners to mine the coin. So, after trying multiple permutations and combinations between the input parameters, the above mentioned parameters achieved the best parallelism of nearly 2.7x.

b) Running Time

real-time → 00:00:19.340
CPU time → 00:00:06.970
Ratio → 2.774

COINS WITH MOST NUMBER OF ZEROES (7)

One of the bitcoins which hashes to 7 leading zeroes is “**rbhatiaacghpzjqpjtrBn**”. We achieved this by distributing the job over 5 machines.

“rbhatiaacghpzjqpjtrBn” “000000036c9281dd36ff5abc5286e42b240f76c7ea77aa80eb5c7913ad4c3301”

Attached below is a snapshot for the output obtained by the master as mentioned above :

```
Activities Terminal Fri 9:43 PM jarvis@jarvis-HP-250-G3: ~/Downloads
File Edit View Search Terminal Help
Workload (Jobs performed by actor before coming to the master) : 100
Number of cores to be used : 8
Coins to be mined : 1
-----
RemoteCoinRequest
Request from Remote Miners
Received Mining Request from "[akka.tcp://ClientFsharp@10.20.89.8:8888/user/client#538205128]"
RemoteCoinRequest
Request from Remote Miners
Received Mining Request from "[akka.tcp://ClientFsharp@10.20.89.10:8888/user/client#2032938822]"
RemoteCoinRequest
Request from Remote Miners
Received Mining Request from "[akka.tcp://ClientFsharp@10.20.89.5:8888/user/client#876032855]"
jarvis@jarvis-HP-250-G3:~/Downloads$ ^C
jarvis@jarvis-HP-250-G3:~/Downloads$ sudo dotnet fsi master.fsx 7 rbhatia 100 8 1
Real: 00:00:00.000, CPU: 00:00:00.000, GC gen0: 0, gen1: 0, gen2: 0
Number of zeroes are : 7
String will start hashing with : rbhatia
Workload (Jobs performed by actor before coming to the master) : 100
Number of cores to be used : 8
Coins to be mined : 1
-----
RemoteCoinRequest
Request from Remote Miners
Received Mining Request from "[akka.tcp://ClientFsharp@10.20.89.8:8888/user/client#1458800921]"
RemoteCoinRequest
Request from Remote Miners
Received Mining Request from "[akka.tcp://ClientFsharp@10.20.89.10:8888/user/client#1907543895]"
RemoteCoinRequest
Request from Remote Miners
Received Mining Request from "[akka.tcp://ClientFsharp@10.20.89.5:8888/user/client#243274450]"
rbhatiaaclghpzjqjtrBn.000000036c9281dd36ff5abc5286e42b240f76c7ea77aa80eb5c7913ad4c3301
Success from Remote Miner!
"rbhatiaaclghpzjqjtrBn" "000000036c9281dd36ff5abc5286e42b240f76c7ea77aa80eb5c7913ad4c3301"
Real: 00:04:56.489, CPU: 00:14:52.450, GC gen0: 73663, gen1: 36, gen2: 3
jarvis@jarvis-HP-250-G3:~/Downloads$
```

The ratio of CPU time to real-time is approximately $14m / 4m \sim 3.2$.

The following is the Xorbin snippet for the above bitcoin as verification :

SHA-256 hash calculator

SHA-256 produces a 256-bit (32-byte) hash value.

Data

rbhatiaaclghpzjqjtrBn

SHA-256 hash

000000036c9281dd36ff5abc5286e42b240f76c7ea77aa80eb5c7913ad4c3301

Hash added to your clipboard. Simply press ⌘+V, CTRL+V to paste.

Calculate SHA256 hash

LARGEST NUMBER OF WORKING MACHINES ON WHICH THE CODE WAS RUN

The code was simultaneously run on 5 machines with one functioning as a server and the other 4 as workers. The configuration of the machines are as follows :

1. **Master/Server:** 8 core Intel i3, running over Linux OS.
2. **Client 1:** Macbook Pro M1 chip, 8 core.
3. **Client 2:** Macbook Air M1 chip, 8 core.
4. **Client 3:** Macbook Air 2017 Intel chip, 4 core.
5. **Client 4:** Macbook Pro M1 chip, 8 core.

INSTRUCTIONS TO RUN THE PROJECT

1. Go to the directory containing master.fsx and client.fsx.
2. Install Akka and its packages using the following command :
dotnet add package Akka."package_name" --version 1.4.25
3. To run the project locally, enter your machine's IP address in the "master.fsx" file where the field "hostname" is mentioned in the Configuration and execute the file using the command :
"dotnet fsi master.fsx number_of_zeroes gator_id workload number_of_actors number_of_coins"
4. To run the project remotely, execute the client.fsx file using the command :
"dotnet fsi client.fsx server_ip" in the client machine and the above mentioned command in the server machine.