

Configuration Manual

MSc Research Project Cloud Computing

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Dynamic Prewarming Strategy using Reinforcement Learning and LSTM for Cold Start Mitigation in Serverless Computing

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1 Introduction

This document offers detailed instructions for configuring and carrying out the project's research tests on t2.large AWS EC2 instances. It lists the platforms and software required for the experiments to be implemented successfully. The principal aim of the study was to evaluate the solution's capacity to improve cold start latency, specifically focusing on the Apache OpenWhisk serverless framework. Table 1 provides an overview of the essential instruments and systems required for the study, providing information about the technological basis of the tests. Simultaneously, Table 2 lists the particular software packages and libraries that were used during the study, offering a thorough summary of all the computer resources that were used for the project.

Туре	Tool/Platform					
Operating System	Linux Ubuntu Server 18.04 LTS (HVM)					
Virtual Machines	Amazon Web Services (AWS) EC2					
Machine Learning	Keras Tensorflow 2.15.0					
Serverless Platform	Apache OpenWhisk 1.0.0 (open-source)					
Container Technology	Docker 20.10.17 CE					
Programming Language	Python 3.11.5					
Performance/Load Testing	Java (openjdk-11) & Apache JMeter 5.6.2					

Table 1: Used Platforms and Tools

Python	matplotlib, numpy andpandas
Bash	gnupg, curl, make, containerd, npm, ca-certificates, zip, lsb-release, docker-compose 1.21.2, python-pip, docker-ce-cli and wsk (openwhisk cli v1)

Table 2: Pre-requisites software

2 Experiment

2.1 Setting Up Amazon Resources

- 1. Open the Amazon Web Services Portal and log in.
- 2. Search for the EC2 service and start it.

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Figure 1: EC2 service.

3. Along the left panel, in the Network and Security group, select Open Key Pairs.

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aws III Services Q Search	ĥ	[Option+S]	▶ ♦ Ø Ø Ire	land ▼ MSCCLOUD/x21219141@student.ncirl.ie ▼			
EC2 Dashboard X	Key pairs (986) Info			C Actions ▼ Create key pair 1 2 3 4 5 6 7 20 > 🕥			
Events	Name	▼ Type ▼ Created	▼ Fingerprint	ID V			
▼ Instances	x21153213research	rsa 2022/10/21 18:32 GMT+1	d2:de:d7:2e:94:b3:9d:82:	3b:47:7 key-05e2ea82753bf0384			
Instances	Aman_Key	rsa 2022/10/23 18:08 GMT+1	69:38:ba:44:c1:90:1b:eb:5	58:13:2 key-0b0c3d2614bfc3626			
Instance Types	x21128197_CA_Lab1_Sept	rsa 2022/10/24 10:36 GMT+1	Of:fa:5b:83:38:6e:95:92:8	2:a0:05 key-028b4967dcb6773ac			
Launch Templates	pstr-x20223722-keypair-nci	rsa 2022/10/24 11:49 GMT+1	9f:e0:78:bd:ac:98:e7:4c:fd	1:88:9e: key-05cbf0c4581fa7665			
Spot Requests	x21219095Devops	rsa 2022/10/25 20:35 GMT+1	f7:4e:44:cb:a4:0f:d5:c1:d2	2:84:8e: key-09e698a063962d84b			
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Reserved Instances	x21164967-MScProject	rsa 2022/10/26 14:08 GMT+1	3f:e5:60:90:a6:79:13:a0:d	l2:ef:7d key-0b5ab53650ca0fdc9			
Dedicated Hosts	sample keypair	rsa 2022/10/26 17:57 GMT+1	80:e1:d4:1e:1e:71:eb:e8:1	3:da:fd key-0d6ab2e3a2719c523			
Capacity Reservations New	nci-general-ec2-lab-keypair	rsa 2022/10/27 14:13 GMT+1	9f:0c:52:cc:4c:a0:3f:b3:a5	:f2:42: key-0b517b5057ecc7641			
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AMIs	Jenkins	rsa 2022/10/27 14:36 GMT+1	54:7e:47:4f:d6:dc:71:56:0	b:96:7 key-0d63110da4ede4881			
AMI Catalog	DevSecOps	rsa 2022/10/27 14:46 GMT+1	cf:98:c0:af:86:1a:ed:9c:24	:bd:4b: key-077e718333c0f0f3b			
Elastic Block Store	x21120242-jenkins	rsa 2022/10/27 15:04 GMT+1	f4:51:14:b4:b7:b1:fd:ed:8	4:57:b key-0bf77330917776697			
Volumes	x21242887-sonarcube-key	rsa 2022/10/27 15:09 GMT+1	67:0a:64:04:a2:12:b9:7e:	1d:5e:9 key-02ff21175529c8238			
Snapshots	devops-jenkins	rsa 2022/10/27 15:26 GMT+1	1d:c2:d5:52:73:24:fd:4b:7	77:f1:0c key-01e7a6d2bea1caa31			
Lifecycle Manager	x21242887-devops-sonar	rsa 2022/10/27 15:53 GMT+1	c9:42:6e:d6:79:e4:f5:08:4	6:d7:0c key-08a428f70924c0550			
Thetwork & Security	nfs nfs	rsa 2022/10/29 15:17 GMT+1	07:bf:ac:eb:19:91:e8:b5:cl	b:24:19 key-05703f75b59693b75			
CloudShell Feedback			© 2023, Amazon Web Services, Inc. or it	ts affiliates. Privacy Terms Cookie preferences			

Figure 2: Key Pairs.

4. Using the name, the default RSA type, and exporting as a.pem file format, create a key pair.

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		VCI Cloud Services	11 Cloud Services 🛛 😝 Amazon Web Services (AWS)						🎁 Create	ite key pair EC2 eu-west-1		
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=	EC2 > Key	pairs 〉 Create key pair										
	Create	key pair Info										
	Key pai A key pair, c an instance.	F onsisting of a private key and a public	key, is a set of se	unity credentials that you use to prove your identity when connecting to								
	Name Enter key	pair name										
	The name of	an include up to 255 ASCII characters.	t can't include le	iding or trailing spaces.								
	Key pair ty RSA	rpe Info	○ ED25	519								
	 .pem For use .ppk 	with OpenSSH										

Figure 3: Create a Key Pairs.

- 5. To open a new instance, navigate to Instances and click.
- 6. Assign virtual machines with proper name.
- 7. Browse for and choose the 64-bit "Ubuntu Server 20.04 LTS (HVM), SSD Volume Type.
- 8. If you don't change the instance type to t2.large (2vCPUs/8GB RAM), the experiments will not succeed make sure that t2.large (2vCPUs/8GB RAM) is selected.
- 9. Choose the key pair that was previously produced.
- 10. Increase the virtual machines' storage space to 16 gigabit.
- 11. Start the instances.

2.2 How to connect to Instance

It is not mandatory but After the instances are up and running, append "studentid" or anything which you can remember to the end of the VM names to differentiate them from one another.

- 1. For easy access, copy the public IPv4 DNS from each instance's information tab to your clipboard or another location.
- 2. From your client, launch a terminal session (for convenience, in the same directory as your.pem file).
- 3. Open an SSH session to the EC2 instances by entering. ubuntu@YOUR_EC2_PUBLIC_IP_DNS ssh -i "YOUR_KEYPAIR.pem".

2.3 Executing the Installation

1. Use the command git –version to confirm that git is installed on the virtual machine (which it should be). If git isn't installed already, use sudo apt install git.



Figure 4: This is Apache Jmeter version output.

- 2. Use the following command to clone the project's codebase from the Github repository: sudo git clone https://github.com:sameer05jain/projectprewarm.git.
- 3. The install.sh bash file automates the download and installation of necessary software tools and dependencies. Enter sudo bash /openwhisk/install.sh to launch this file. Please wait till the installation gets complited
- 4. Verify the installation of both Docker and OpenWhisk by watching the containers that are now running sudo docker ps --format '{{.Names}}'.
- 5. Verify that the Jmeter work-load sudo wsk -i action list has the necessary Openwhisk actions created.
- 6. To enable JMeter to execute sudo unzip, use the following commands to relocate the downloaded executables and JMeter files to the proper location on the server. It is sudo unzip ~/apache-jmeter-5.4.3.zip. To move the Apache JMeter installation directory, use the following command: sudo mv ~/apache-jmeter-5.4.3 ~/jmeter. To move the JMeter directory to the '/tmp' directory, use the following command: sudo mv ~/jmeter /tmp. To add JMeter to the system's PATH, use the following command: echo 'export PATH="\$PATH:/tmp/jmeter/bin"' >> ~/.bashrc. To apply the changes to the current terminal session, use the following command: source ~/.bashrc.
- To check the JMeter version, use the following command: sudo /tmp/jmeter/bin/jmeter.sh --version.

Figure 4 presents a **full-size** plot.

2.4 Running the Validation in Test Infrastructure

Run with no Machine learning predictions

Step 1 : Make sure you're in the home directory cd / Step 2 : Run the Jmeter test plan against function_gateway with this command sudo nohup /tmp/jmeter/bin/jmeter.sh

```
ubuntu@ip-172-31-35-69:~$ sudo nohup python ~/project_prewarm/function_gateway.py lstm & /tmp/jmeter/bin/jmeter.sh -n -t "~/project_prewarm/ml
_experiments/ml_lstm//Jmeter_testplan_lstm.jmx" -l "~/project_prewarm/ml_experiments/ml_lstm/Jmeter_run_logs_lstm.csv " > ~/project_prewarm/ml
_experiments/ml_lstm/Jmeter_run_logs_lstm.log &
[1] 3452306
[2] 3452307
```

Figure 5: This is console output while running the script.

```
-n -t
"~/project_prewarm/ml_experiments/ml_default/Jmeter_testplan_default.jmx"
-1
"~/project_prewarm/ml_experiments/ml_default/Jmeter_run_logs_default.csv"
>
"~/project_prewarm/ml_experiments/ml_default/Jmeter_run_logs_default.log"
&
```

Run with LSTM Machine learning predictions

Step 1 : Make sure you're in the home directory cd / Step 2 :sudo nohup python
~/project_prewarm/function_gateway.py
lstm & /tmp/jmeter/bin/jmeter.sh -n -t
"~/project_prewarm/ml_experiments/ml_lstm/Jmeter_testplan_lstm.jmx" -l
"~/project_prewarm/ml_experiments/ml_lstm/Jmeter_run_logs_lstm.csv" >
"~/project_prewarm/ml_experiments/ml_lstm/ml_experiments/ml_prewarm/ml_experiments/ml_prewarm/ml_experiments/ml_prewarm/ml_experiments/ml_prewarm/ml_experiments/ml_prewarm/ml_experiments/ml_prewarm/ml_experiments/ml_prewarm/ml_experiments/ml_prewarm/ml_experiments/ml_prewarm/ml_experiments/ml_prewarm/ml_experiments/ml_prewarm/ml_prewarm/ml_experiments/ml_prewarm/ml_experiments/ml_prewarm/ml_prewarm/ml_experiments/ml_prewarm/ml_experiments/ml_prewarm/ml_experiments/ml_prewarm/ml_p

"~/project_prewarm/ml_experiments/ml_lstm/Jmeter_run_logs_lstm.log" &

Run with QLearning Machine learning predictions

Step 1 : Make sure you're in the home directory cd / Step 2 : sudo nohup python
~/project_prewarm/function_gateway.py qlearning & /tmp/jmeter/bin/jmeter.sh
-n -t

"~/project_prewarm/ml_experiments/ml_qlearning/Jmeter_testplan_qlearning.jmx" -1

```
"~/project_prewarm/ml_experiments/ml_qlearning/Jmeter_run_logs_qlearning.csv" >
```

"~/project_prewarm/ml_experiments/ml_qlearning/Jmeter_run_logs_qlearning.log" &

2.5 Result Analysis

Logs files will be generated in ~/project_prewarm/ml_experiments under the corresponding ML folder. This can be used in the Jupyter notebooks provided to visualize and verify the results.

For example :

~/project_prewarm/ml_experiments/ml_qlearning/Jmeter_run_logs_qlearning.csv. Azure (n.d.a) Azure (n.d.b)

References

- Azure (n.d.a). Azurepublicdataset/azurefunctionsinvocationtrace2021.md, https://github.com/Azure/AzurePublicDataset/blob/master/ AzureFunctionsInvocationTrace2021.md. GitHub.
- Azure (n.d.b). Azurepublicdataset/license, https://github.com/Azure/ AzurePublicDataset/blob/master/LICENSE. GitHub.