

Cloud Computing with AWS

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Chapter 1

Glossary

- **ACL** — Access Control List
- **ACM** — AWS Certificate Manager
- **AMI** — Amazon Machine Images
- **App** — Application
- **AWS** — Amazon Web Services
- **AZ** — Availability Zone
- **CA** — Certificate Authority
- **CDS** — Content Delivery Network
- **CPU** — Central Processing Unit
- **DB** — Database
- **DIG** — Domain Information Groper
- **EC2** — Elastic Cloud Compute
- **ELB** — Elastic Load Balancing
- **.env** — Environment File Extension
- **GB** — Gigabyte
- **HTTP** — HyperText Transfer Protocol
- **HTTPS** — HyperText Transfer Protocol Secure
- **IAM** — Identity and Access Management
- **IEEE** — Institute of Electrical and Electronics Engineers
- **IP** — Internet Protocol
- **IPv4** — Internet Protocol Version 4
- **LAMP** — Linux, Apache, MySQL, PHP

- **ML** — Machine Learning
- **nslookup** — Name Server Lookup
- **OS** — Operating System
- **.pem** — Privacy Enhanced Mail File Extension
- **PHP** — PHP: Hypertext Preprocessor
- **RAM** — Random Access Memory
- **S3** — Simple Storage Service
- **RAM** — Random Access Memory
- **RDBMS** — Relational Database Management System
- **RDS** — Relational Database Service
- **SNS** — Simple Notification Service
- **SQL** — Structured Query Language
- **SSH** — Secure Shell
- **VPC** — Virtual Private Cloud
- **VPN** — Virtual Private Network

Chapter 2

Introduction

This report details the process of designing, developing, and deploying a cloud application onto Amazon Web Services (AWS). The application is called *Digital Ink* and allows users to create, edit, and delete their own short stories. Users can then view their own short stories and other users' short stories. It was first developed locally using a LAMP stack. This consisted of Linux - hosted through Docker - for the operating system, an Apache HTTP Server, MySQL for the relational database management, and PHP as the programming language.

After the application was built locally, it was gradually integrated onto AWS. This involved implementing several AWS cloud features to enhance the application, ensure application security, and increase availability. This was accomplished by using Simple Storage Service (S3), Elastic Compute Cloud (EC2), ELB (Elastic Load Balancing), and more. The process of implementing these cloud features will be discussed throughout the report.

After the application was integrated onto AWS, an evaluation of the process was conducted. This includes a discussion of the security practices used, estimated costs for different user scales, and thorough testing. Lastly, several enhancements which could be made to the application in the future will be discussed.

Chapter 3

Web App

This chapter of the report will detail the local design and development of the *Digital Ink* web application. We will first discuss the software stack used to develop the app, then the design of the database used, and, lastly, the design of the user interface.

3.1 Software Stack

Digital Ink was first developed locally using a LAMP stack. LAMP refers to a generic software stack, where each letter in the acronym stands for one the following open source building blocks: Linux, Apache HTTP Server, MySQL, and PHP (Lee and Ware, 2003). The web app is hosted within a Docker container (Anderson, 2015) which runs a minified version of the Linux operating system. Apache is an open-source web server software which is used to host the app on the web (Fielding and Kaiser, 1997). MySQL is an open-source relational database management system (Widenius, Axmark, and Arno, 2002) which is used to store all the data used within the app, including user details and story details. PHP is a programming language aimed towards web development, chosen due to its stability and reliability (Lerdorf et al., 2002). Additionally, all developers involved have prior experience with PHP.

3.2 Database Design

As mentioned before, the web app uses the MySQL relational database management system to store its data. MySQL is a relational database management system (RDBMS) which stores data in the form of tables, where Structured Query Language (SQL) is used to access the database. As shown in Figure 3.1, the database which this web app uses consists of three tables: `users`, `stories`, and `migrations`.

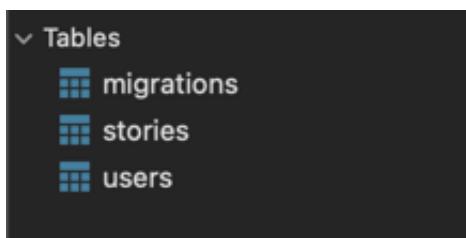


Figure 3.1: Database tables overview.

The `migrations` table (see Figure 3.2) contains records which correspond to the migrations within the Laravel web app. These migrations contain the scripts required to automatically generate the `users` and `stories` tables in SQL. It contains the following three columns:

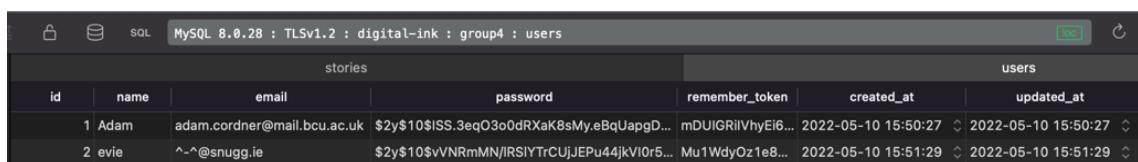
- `id`: the unique ID for each migration.
- `migration`: points to the scripts used to create tables.
- `batch`: how many times the script has been ran.

| <code>id</code> | <code>migration</code> | <code>batch</code> |
|-----------------|---|--------------------|
| 1 | <code>2014_10_12_000000_create_users_table</code> | 1 |
| 4 | <code>2020_03_13_105916_create_stories_table</code> | 1 |

Figure 3.2: `migrations` table.

The `users` table (see Figure 3.3) contains all the information about user accounts, and it contains the following seven columns:

- `id`: the unique ID for each user account.
- `name`: the name associated with user account.
- `email`: the unique email used to log in.
- `password`: the password used to log in, encrypted with 184 bit hashing by Bcrypt (Laravel, 2022b).
- `remember_token`: keeps the user logged in if they select "Remember me".
- `created_at`: records what date and time the user account was first created at.
- `updated_at`: records what date and time the user account was last updated at.



The screenshot shows the MySQL Workbench interface with a database named 'digital-ink' and a schema named 'group4'. The 'users' table is selected. The table has the following structure:

| stories | | users | | | | |
|-----------------|-------------------|-----------------------------|---|-----------------------------|-------------------------|-------------------------|
| <code>id</code> | <code>name</code> | <code>email</code> | <code>password</code> | <code>remember_token</code> | <code>created_at</code> | <code>updated_at</code> |
| 1 | Adam | adam.cordner@mail.bcu.ac.uk | \$2y\$10\$ISS.3eqO3o0dRXaK8sMy.eBqUapgD... | mDUIGRilVhyEi6... | 2022-05-10 15:50:27 | 2022-05-10 15:50:27 |
| 2 | evie | ^~@snugg.ie | \$2y\$10\$vVRmMN/lRSIYTrCUjJEPu44jkVI0r5... | Mu1WdyOz1e8... | 2022-05-10 15:51:29 | 2022-05-10 15:51:29 |

Figure 3.3: `users` table.

The `stories` table (see Figure 3.4) contains all the information about user-created stories, and it contains the following 11 columns:

- `id`: the unique ID for each story.
- `author_id`: the unique ID associated with the user who created the story.
- `title`: the title associated with the story.
- `genre`: the genre associated with the story, which can be one of eight different genres.
- `blurb`: a brief description of the story.
- `content`: the full content of the story.
- `cover_image`: a thumbnail image for the story.
- `file_upload`: an optional PDF upload of the story.
- `published`: 1 if the story has been made public, or 0 if it is a draft.
- `created_at`: records what date and time the story was first created at.
- `updated_at`: records what date and time the story was last updated at.

| <code>id</code> | <code>author_id</code> | <code>title</code> | <code>genre</code> | <code>blurb</code> | <code>content</code> |
|-----------------|------------------------|---|--------------------------------------|---|---|
| | | | | | |
| | | <code>cover_image</code> | <code>file_upload</code> | <code>published</code> | <code>created_at</code> |
| 2 | 1 → Group 4 Loves AWS | Romance | Meet Group 4 and their love for AWS! | Group 4 loves using AWS' cloud features to host Di... | |
| 3 | 2 → cheese savoury | Action and Adventure | nice and simple | on malted granary | |
| | | ./storage/cover_images/7537329101652200606.j... | NULL | 1 | 2022-05-10 16:36:46 ⏺ 2022-05-10 16:36:46 ⏺ |
| | | images/digital-ink-logo.png | NULL | 1 | 2022-05-10 16:38:51 ⏺ 2022-05-10 16:38:51 ⏺ |

Figure 3.4: `stories` table.

3.3 Interface Design

The design of the web app was created using Blade, a powerful templating engine (Laravel, 2022a). When the user initially accesses the web app, they are able to log in or sign up. This can be seen in Figure 3.5. When a user has created an account, a record is written to the `users` table in the database.



The image shows the Digital Ink home page with two forms: a login form at the top and a sign-up form below it. The login form has fields for Email and Password, a 'Remember me' checkbox, and a 'Login' button. The sign-up form has fields for Name, Email, Password, Repeat Password, and a 'Sign Up' button. Both forms have placeholder text in the input fields.

Stories Create About Account

Email
Enter Email

Password
Enter Password

Remember me

Login

Don't have an account already? Why not sign up?

Sign Up

Name
Enter Name

Email
Enter Email

Password
Enter Password

Repeat Password
Repeat Password

Sign Up

Figure 3.5: *Digital-Ink* home page log in and sign up forms.

Once a user is signed in, they can create a story. Creating a story requires the user to enter a title, a genre, the story itself, a blurb, and, optionally, a thumbnail image. This can be seen in Figure 3.6. Once a story has been created, it is written to the `stories` table.

Create your story!



The figure shows a three-panel interface for creating a story. The top panel is titled 'Create your story!' and contains fields for 'Author Reference Number' (with value '1'), 'Title' (with placeholder 'Every story needs a good title!' and value 'Group 4 Loves AWS'), and 'Genre' (with placeholder 'What type of story are you creating?' and value 'Romance'). The middle panel is titled 'Your Story:' and contains a text area with placeholder text 'Group 4 loves using AWS' cloud features to host Digital Ink.' and a file selection button 'Browse...' showing 'No file selected.'. The bottom panel is titled 'Blurb:' and contains a text area with placeholder text 'Meet Group 4 and their love for AWS!' and a file selection button 'Browse...' showing 'index.jpg'. It also includes a section titled 'Nearly finished! *' with a question 'Do you want to save your story as a draft or publish it onto our site?' and two options: 'Save as a Draft' (unchecked) and 'Upload' (checked). A 'Complete' button is located at the bottom right of the bottom panel.

Author Reference Number: *

1

Title: *

Every story needs a good title!

Group 4 Loves AWS

Genre: *

What type of story are you creating?

Romance

Your Story: *

Add the content of your story below.

Group 4 loves using AWS' cloud features to host Digital Ink.

Browse... No file selected.

Blurb: *

Add a short description of your story!

Meet Group 4 and their love for AWS!

Browse... index.jpg

Nearly finished! *

Do you want to save your story as a draft or publish it onto our site?

Save as a Draft

Upload

Complete

Figure 3.6: *Digital-Ink* story creation form.

After this, the user can see all of their uploaded stories on their account page. This can be seen in Figure 3.7. From here, a story can be edited or deleted, which either updates a record in the `stories` table or removes a record from it.

The screenshot shows a user interface for managing published stories. At the top, a green header bar displays the message "Yay! Your story has been published!". Below this, a heading says "Here are your published stories:". A table follows, with columns for TITLE, GENRE, and ACTIONS. The first row shows a story titled "Group 4 Loves AWS" in the Romance genre. The "Actions" column contains two buttons: "Edit" (highlighted with a green oval) and "Delete" (highlighted with a red oval).

| TITLE | GENRE | ACTIONS |
|-------------------|---------|---|
| Group 4 Loves AWS | Romance | Edit Delete |

Figure 3.7: *Digital-Ink* account page.

Lastly, on the Stories page, a user can view and search through all uploaded stories across all users. Each story's title, genre, and blurb is shown in a list view. A user can click into one of these stories to see the thumbnail image and read the full story. These pages can be seen in Figure 3.8.

The screenshot shows the "Stories" page and a detailed view of a specific story. The top navigation bar includes a search bar with placeholder text "Enter a title to search" and a "Search" button. The main content area displays a table of stories with columns for AUTHOR ID, TITLE, GENRE, and BLURB. Two stories are listed: "Group 4 Loves AWS" (AUTHOR ID 1, Romance, blurb "Meet Group 4 and their love for AWS!") and "cheese savoury" (AUTHOR ID 2, Action and Adventure, blurb "nice and simple"). Below the table, a story card for "Group 4 Loves AWS" is shown. It features a thumbnail image of a person, the title "Group 4 Loves AWS", the author ID "1", the genre "Romance", and a blurb: "Group 4 loves using AWS' cloud features to host Digital Ink.". A "Back" button is located at the bottom left of the story card.

| AUTHOR ID | TITLE | GENRE | BLURB |
|-----------|-------------------|----------------------|--------------------------------------|
| 1 | Group 4 Loves AWS | Romance | Meet Group 4 and their love for AWS! |
| 2 | cheese savoury | Action and Adventure | nice and simple |

Figure 3.8: *Digital-Ink* stories page and story view.

Chapter 4

Virtual Private Cloud and Subnets

Amazon Virtual Private Cloud (VPC) allows for AWS resources to be launched in a virtual network that has been custom defined and configured. This virtual network is similar to a traditional network which operates within your own physical data center, with the added benefits of the scalable AWS infrastructure (Amazon Web Services (AWS), 2022b). A VPC can have multiple assigned subnets, which are a range of IP addresses accessible in the VPC.

Chapter 5

Elastic Cloud Compute

5.1 AWS Setup

After the VPC and subnets were configured, the initial deployment of the web app began with setting up EC2. This AWS service allows for scalable computing capacity through the use of a virtual computing environment hosted in the cloud (Amazon Web Services (AWS), 2022a). The web app will be stored on an EC2 instance of Amazon Linux, known as Amazon Machine Image (AMI), which will then be launched through a docker container stored on the app.

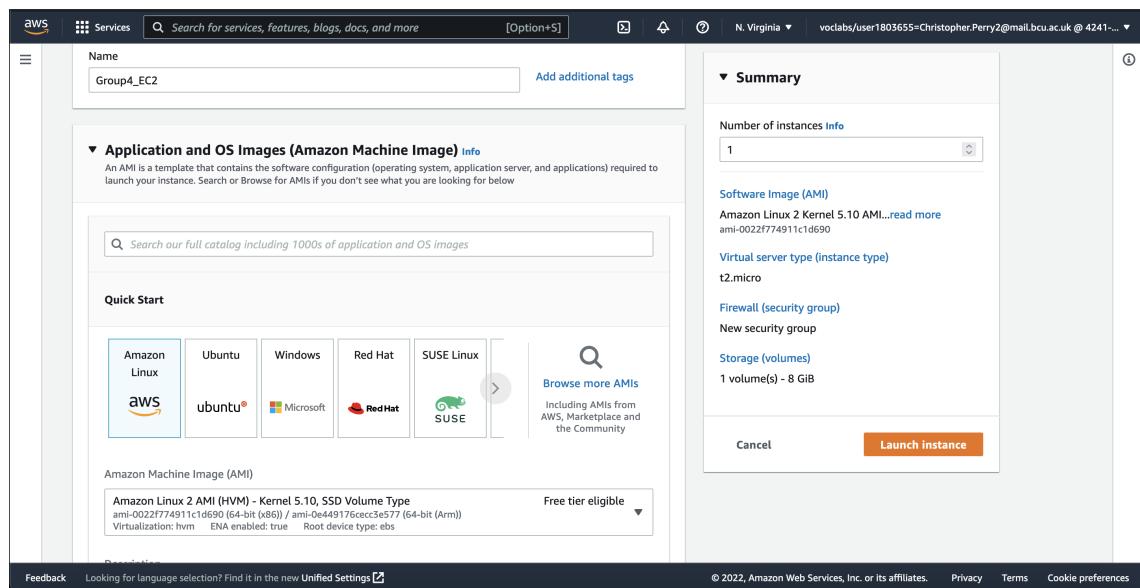


Figure 5.1: Selection of EC2 OS Image.

Figure 5.1 details the selection of the Operating System (OS) that will be used for the EC2 instance. The *Amazon Linux 2 AMI* was selected, as it is already configured with Linux and does not need any more setup.

Now that an AMI has been chosen, the specific instance type that will be used within this AMI can be selected. It was decided that the instance type of *t2.micro* would be used, as it contains only 1GB of Random Access Memory (RAM). The selection of this can be found in Figure 5.2.

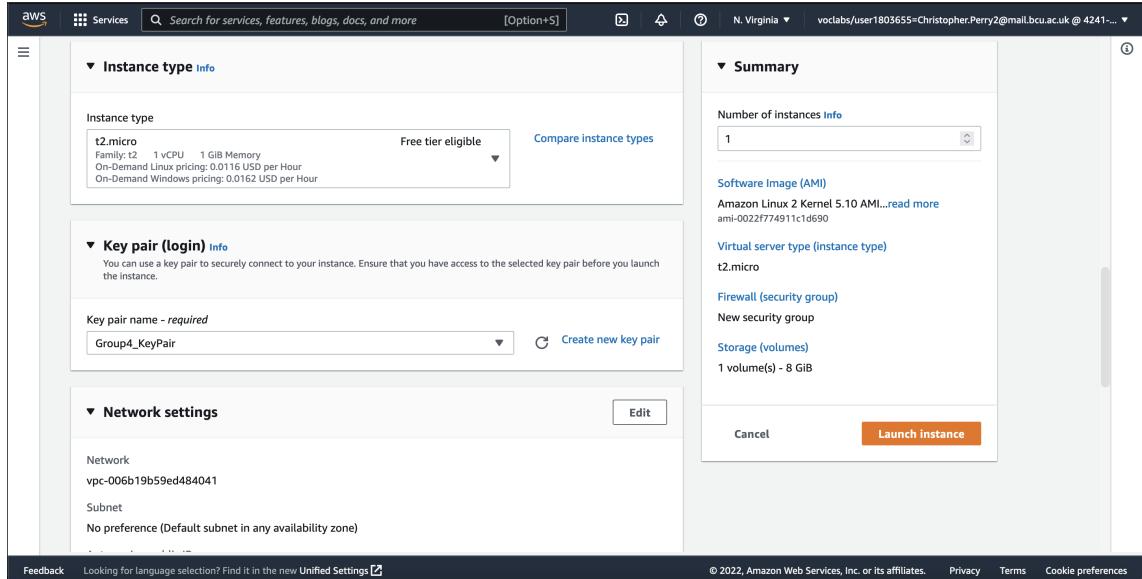


Figure 5.2: Selection of EC2 Instance.

A key pair will allow for the ability to sign in to the EC2 instance with a unique set of login credentials, heightening the security of the project.

The next stage of the setup process was to set up networking for the EC2 instance, in order for the web app to work with Docker to download relevant containers from DockerHub, which will allow a Laravel instance to be initialised, as discussed in Section 3.

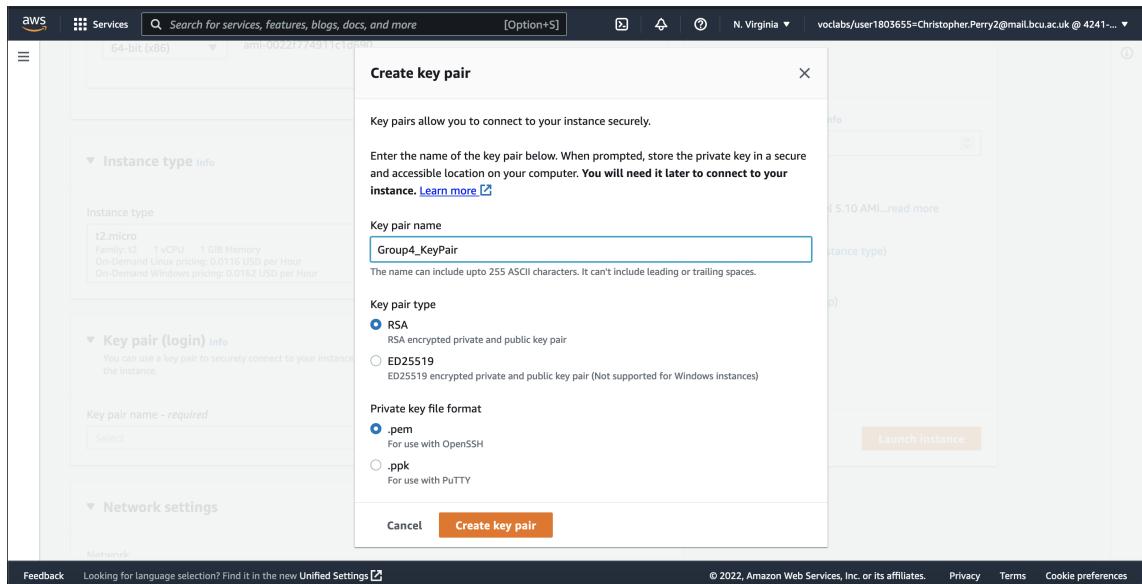


Figure 5.3: Selection of EC2 Keypair.

This process can be seen in Figure 5.3.

The instance is assigned the VPC created in Section 4, where it is assigned a subnet in the same availability zone of us-east-1.

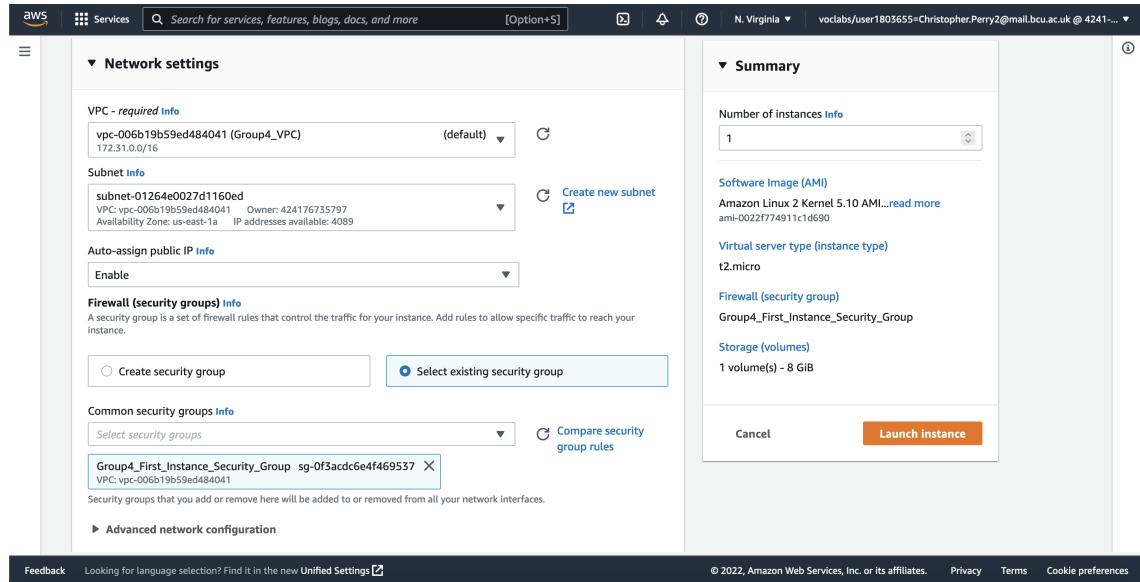


Figure 5.4: Selection of EC2 Networking options.

A screenshot of a terminal window titled 'chris@Christophers-MacBook-Pro:~/Desktop/Keypair'. The command 'ssh -i Group4_KeyPair.pem ec2-user@52.45.13.111' is run, and the output shows the keypair has been generated at 17:47:52.

Figure 5.5: Generated EC2 Keypair in the .pem format.

This setup can be seen in Figure 5.4. An EC2 keypair is then generated in the .pem format.

This is enough to comfortably run the web app without any issues. Storage for the AMI was subsequently chosen. It was decided that 8GB of storage would be used, as this is enough to run the web app and still provide leftover storage for any system-critical tasks.

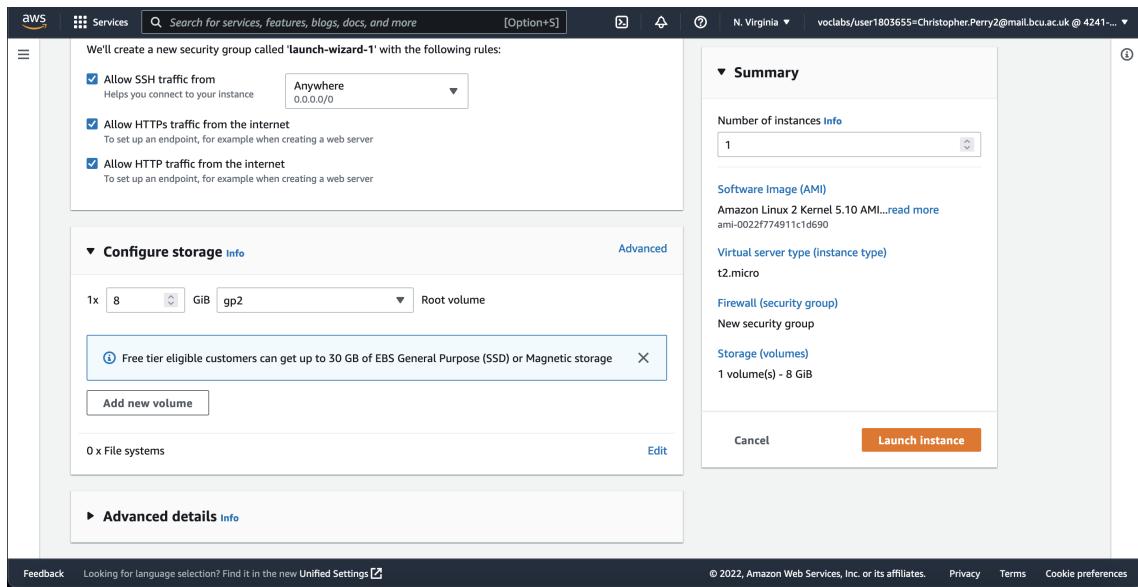


Figure 5.6: Selection of EC2 Storage Configuration.

The selection of these options can be found in Figure 5.6. In addition to this, the chosen options are eligible for "Free Tier", which means that it will use a limited amount of the \$100 budget allocated for the project.

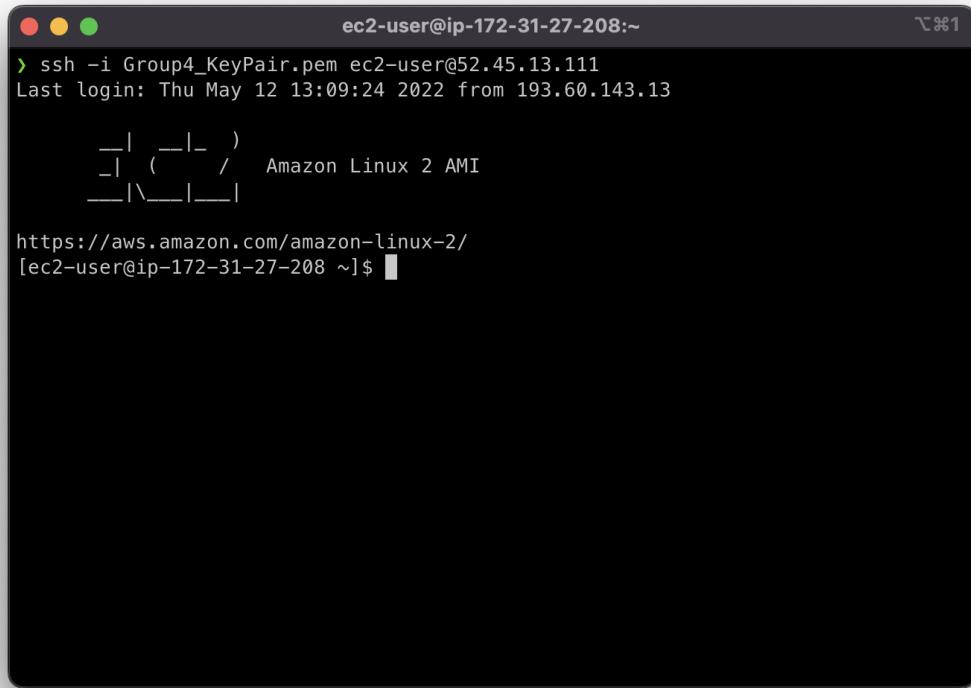
5.2 EC2 Login

The EC2 instance `group4-ec2` is now live, and the webapp can be loaded onto it. The instance is first logged in to through the use of the `ssh` command, followed by the `-i` argument to specify an identify file, which was generated earlier, and then the public ipv4 address of the instance.

```
ssh -i ~/Desktop/Group4_KeyPair.pem ec2-user@52.45.13.111
```

Figure 5.7: SSH command to log into EC2 instance.

This command can seen being executed in Figure 5.7.



A screenshot of a terminal window titled "ec2-user@ip-172-31-27-208:~". The window shows the command `ssh -i Group4_KeyPair.pem ec2-user@52.45.13.111` being run, followed by the output: "Last login: Thu May 12 13:09:24 2022 from 193.60.143.13". Below this, the Amazon Linux 2 AMI logo is displayed, consisting of a stylized tree or root system icon. The final line of output is `https://aws.amazon.com/amazon-linux-2/ [ec2-user@ip-172-31-27-208 ~]$`.

Figure 5.8: Logging into EC2 instance.

The logged in EC2 instance can be seen in Figure 5.8.

5.3 Package Setup

The web app is stored on GitHub, and the AMI does not come with GitHub by default. Git is subsequently installed via `yum install git`.

```
git-core           x86_64      2.32.0-1.amzn2.0.1          amzn2-core          4.8 M
git-core-doc      noarch      2.32.0-1.amzn2.0.1          amzn2-core          2.7 M
perl-L-Error      noarch      1:0.17020-2.amzn2          amzn2-core          32 k
perl-Git          noarch      2.32.0-1.amzn2.0.1          amzn2-core          43 k
perl-TermReadKey x86_64      2.30-20.amzn2.0.2          amzn2-core          31 k
Transaction Summary
=====
Install 1 Package (+6 Dependent packages)

Total download size: 7.8 M
Installed size: 38 M
Is this ok [y/N]: y
Downloading packages:
(1/7): emacs-filesystem-27.2-4.amzn2.0.1.noarch.rpm | 67 kB 00:00:00
(2/7): git-2.32.0-1.amzn2.0.1.x86_64.rpm | 126 kB 00:00:00
(3/7): git-core-doc-2.32.0-1.amzn2.0.1.noarch.rpm | 2.7 MB 00:00:00
(4/7): perl-Error-0.17020-2.amzn2.noarch.rpm | 32 kB 00:00:00
(5/7): perl-Git-2.32.0-1.amzn2.0.1.noarch.rpm | 43 kB 00:00:00
(6/7): git-core-2.32.0-1.amzn2.0.1.x86_64.rpm | 4.8 MB 00:00:00
(7/7): perl-TermReadKey-2.30-20.amzn2.0.2.x86_64.rpm | 31 kB 00:00:00
Total                                         29 MB/s | 7.8 MB 00:00:00
Running transaction check
Running transaction test
Transaction test succeeded
Running transaction
  Installing : git-core-2.32.0-1.amzn2.0.1.x86_64          1/7
  Installing : git-core-doc-2.32.0-1.amzn2.0.1.noarch        2/7
  Installing : 1:perl-Error-0.17020-2.amzn2.noarch         3/7
  Installing : 1:emacs-filesystem-27.2-4.amzn2.0.1.noarch   4/7
  Installing : perl-TermReadKey-2.30-20.amzn2.0.2.x86_64    5/7
  Installing : git-2.32.0-1.amzn2.0.1.x86_64               6/7
  Verifying  : perl-Error-0.17020-2.amzn2.0.1.noarch         7/7
  Verifying  : git-core-2.32.0-1.amzn2.0.1.noarch           1/7
  Verifying  : perl-Git-2.32.0-1.amzn2.0.1.noarch           2/7
  Verifying  : 1:emacs-filesystem-27.2-4.amzn2.0.1.noarch     3/7
  Verifying  : git-2.32.0-1.amzn2.0.1.x86_64                4/7
  Verifying  : git-core-2.32.0-1.amzn2.0.1.x86_64           5/7
  Verifying  : 1:perl-TermReadKey-2.30-20.amzn2.noarch       6/7
  Verifying  : git-2.32.0-1.amzn2.0.1.x86_64                7/7
Installed:
  git.x86_64 0:2.32.0-1.amzn2.0.1

Dependency Installed:
  emacs-filesystem.noarch 1:27.2-4.amzn2.0.1  git-core.x86_64 0:2.32.0-1.amzn2.0.1  git-core-doc.noarch 0:2.32.0-1.amzn2.0.1  perl-Error.noarch 1:0.17020-2.amzn2  perl-Git.noarch 0:2.32.0-1.amzn2.0.1
  perl-TermReadKey.x86_64 0:2.30-20.amzn2.0.2

Complete!
[ec2-user@ip-172-31-27-208 ~]$
```

Figure 5.9: Installing Git.

The web app also requires docker, and `yum install docker` is executed to install Docker as a result.

```
[ec2-user@ip-172-31-27-208 ~]$ sudo yum update
Loaded plugins: extras_suggestions, langpacks, priorities, update-motd
amzn2-core
No packages marked for update
[ec2-user@ip-172-31-27-208 ~]$ sudo yum install docker docker-compose
Loaded plugins: extras_suggestions, langpacks, priorities, update-motd
No package docker-compose available.
Resolving Dependencies
--> Running transaction check
--> Package docker x86_64 0:20.10.13-2.amzn2 will be installed
--> Processing Dependency: runc >= 1.0.0 for package: docker-20.10.13-2.amzn2.x86_64
--> Processing Dependency: libcgroup >= 0.40.rcl5.15 for package: docker-20.10.13-2.amzn2.x86_64
--> Processing Dependency: containerd >= 1.3.2 for package: docker-20.10.13-2.amzn2.x86_64
--> Processing Dependency: pigz for package: docker-20.10.13-2.amzn2.x86_64
--> Running transaction check
-->> Package containerd.x86_64 0:1.4.13-2.amzn2.0.1 will be installed
-->> Package libcgroup.x86_64 0:0.41-21.amzn2 will be installed
-->> Package pigz.x86_64 0:2.3.4-1.amzn2.0.1 will be installed
-->> Package runc.x86_64 0:1.0.3-2.amzn2 will be installed
--> Finished Dependency Resolution

Dependencies Resolved

---- Package Arch Version Repository Size
Installing:
docker x86_64 20.10.13-2.amzn2 amzn2extra-docker 40 M
Installing for dependencies:
containerd x86_64 1.4.13-2.amzn2.0.1 amzn2extra-docker 23 M
libcgroup x86_64 0.41-21.amzn2 amzn2-core 66 k
pigz x86_64 2.3.4-1.amzn2.0.1 amzn2-core 81 k
runc x86_64 1.0.3-2.amzn2 amzn2extra-docker 3.0 M

Transaction Summary
----
Install 1 Package (+4 Dependent packages)

Total download size: 67 M
Installed size: 280 M
Is this ok [y/N]: [■]

snugle | ↵ | □ ~ | ls ssh × fish × bash × zsh × fish × fish × fish × -fish | spacedust | 54% ↗ 5.2 GB ↗ 18% ↗ 5-04, 1:31 PM
```

Figure 5.10: Installing Docker.

5.4 Web App Setup

The web app is firstly cloned from its repository via the `git clone` command, and a new `digital-ink` folder is made to store the contents.

```
ec2-user@ip-172-31-27-208:~$ git clone https://github.com/ChrisP99/digital-ink
.bash: git: command not found
[ec2-user@ip-172-31-27-208 ~]$ git clone https://github.com/ChrisP99/digital-ink
.git
Cloning into 'digital-ink'...
remote: Enumerating objects: 959, done.
remote: Counting objects: 100% (959/959), done.
remote: Compressing objects: 100% (324/324), done.
remote: Total 959 (delta 593), reused 959 (delta 593), pack-reused 0
Receiving objects: 100% (959/959), 3.32 MiB | 19.01 MiB/s, done.
Resolving deltas: 100% (593/593), done.
[ec2-user@ip-172-31-27-208 ~]$ [■]
```

Figure 5.11: Cloning the web app from Github.

The `cd` command is used to move into the digital-ink folder, and the web app is subsequently launched through the `docker-compose up -d` to launch the web app as a detached Docker container. Relevant containers that are required to be downloaded from the `dockerfile` are then pulled.

```
ec2-user@ip-172-31-27-208:~/digital-ink
```

```
: phippyadmin Pulling
: 5eb5b503b376 Extracting      27.53MB/31.37MB          5.95
: 8b1a084cf101 Download complete                         5.75
: 38c937adeb7 Download complete                         5.75
: 6a2f1dc96e59 Download complete                         5.75
: f8c3f82c39d4 Download complete                         5.78
: 90fcf462bd8e Download complete                         5.78
:[+] Running 7/319 Download complete                     5.75
:[+] phippyadmin Pulling
: 5eb5b503b376 Extracting      27.53MB/31.37MB          6.05
: 8b1a084cf101 Download complete                         5.85
: 38c937adeb7 Download complete                         5.85
: 6a2f1dc96e59 Download complete                         5.85
: f8c3f82c39d4 Download complete                         5.85
: 90fcf462bd8e Download complete                         5.85
:[+] Running 7/319 Download complete                     5.85
:[+] phippyadmin Pulling
: 5eb5b503b376 Pull complete                           13.05
: 8b1a084cf101 Pull complete                           7.65
: 38c937adeb7 Extracting     [=====] 32.31MB/91.6MB   7.95
: 6a2f1dc96e59 Download complete                         12.85
: f8c3f82c39d4 Download complete                         12.85
: 90fcf462bd8e Download complete                         12.85
: c670d99116c9 Download complete                         12.85
: 268554d6fe96 Download complete                         12.85
: 6c29fa0d4492 Download complete                         12.85
: 73e23c50a259 Download complete                         12.85
: 61ac13c96fc2 Download complete                         12.85
: b60a3e6c23949 Download complete                         12.85
: dac5dd677df59 Download complete                         12.85
: fdd46866d9c36 Download complete                         12.85
: 443ab08ef4c80 Download complete                         12.85
: 5ed049224f95 Download complete                         12.85
: 213e6ccdf5f6 Download complete                         12.85
: 989a04010108 Download complete                         12.85
:[+] db Pulling
: 5e31516562 Pull complete                           13.05
: 96c2eb27a3b Pull complete                           13.05
: 8aa3ac50866b Pull complete                           8.85
: ac7e524ffcc80 Pull complete                           9.45
: f6a88631064f Pull complete                           9.35
:[+] 15bb3ec3f5f0 Extracting     [=====] 13.11MB/14.00MB 10.15
: ae65d4c337dc0 Download complete                         12.75
: a4d4c43adff52 Download complete                         12.75
: c6cab33e8f91 Download complete                         12.75
: 2e1cd4f2c43f6 Download complete                         12.75
: 2e5ee322a4f48 Download complete                         12.75
```

Figure 5.12: Containers required for the web app being pulled from Docker Hub.

The result of this command launches 3 containers:

1. digital-ink: An instance of the web app which uses a custom Laravel container.
 2. mysql: An instance of a local database made in MySQL.
 3. phpmyadmin: A way to locally manage the database through a UI.

At the minute, the web app is live through the `digital-ink` container, and is using a local version of MySQL as a database, stored within the `mysqlDocker` container. The database has no tables, but can be populated through the use of Laravel. The container is firstly accessed through `docker exec app bash`, and the database is populated with tables with `php artisan migrate`. This then generates tables to store users and their stories.

```
[leci-2-user@ip-172-31-27-208 digital-in]# sudo /usr/local/bin/docker-compose exec app bash
root@de0e13abbd1f:/srv/app# php artisan migrate
Migrating: 2014_10_12_00000_create_users_table
Migrated: 2014_10_12_00000_create_users_table (0.00 seconds)
Migrating: 2014_10_12_000000_create_password_resets_table
Migrated: 2014_10_12_100000_create_failed_jobs_table (0.07 seconds)
Migrating: 2019_08_19_000000_create_failed_jobs_table
Migrated: 2019_08_19_000000_create_stories_table (0.04 seconds)
Migrating: 2020_03_13_105016_create_stories_table
Migrated: 2020_03_13_105016_create_stories_table (0.16 seconds)
root@de0e13abbd1f:/srv/app#
```

Figure 5.13: Creation of tables through `php artisan migrate` command.

The subsequent output of this command can be found in Figure 5.13. When the website is accessed at the public IPv4 address at , Digital Ink will now be shown.

Figure 5.14: Digital Ink shown when accessed through the

5.5 systemd Services

systemd is a service manager, which is a program that launches and monitors different services across the system. These systemd services was used to ensure the automatic starting of the digital-ink web application

EVIE FILL THIS OUT YOU SILLY LLAMA

Chapter 6

Simple Storage Service

Chapter 7

CloudFront

Chapter 8

CloudWatch

Chapter 9

CloudTrail

Chapter 10

Relational Database Service

Amazon RDS service allows a user to create a fully-featured and highly-available SQL database that is automatically replicated to another availability zone. (TODO: Oops, no multi-az) This means that if the primary database becomes unavailable, there is automatic failover providing redundancy for all the data stored within.

To create an Amazon RDS instance, a suitable name/identifier for the database is required before created as well as a selection for the resource limits for the virtual server. The database requires a username and passphrase, although for additional security there is the option to automatically generate a passphrase.

Afterwards, the type of SQL database required (such as MySQL, PostgreSQL, MariaDB or others) will be selected and then the database should begin provisioning.

Chapter 11

Availability Zones

Chapter 12

Elastic Load Balancing

Chapter 13

Security Practices

Chapter 14

Cost Breakdown

- 14.1 Estimated Costs**
- 14.2 Scaling Up to 10,000 Users**
- 14.3 Scaling Up to 1 Million Users**
- 14.4 Scaling Up to 10 Million Users**

Chapter 15

Testing

This chapter of the report will detail the testing conducted on the configured AWS services. This was done to determine the accuracy and efficiency of the configurations made during the deployment process. The testing was conducted by using Gherkin, a language used to define behaviour and test cases (Santos and Vilain, 2018). It is non-technical and is intended to be easily human-readable. Gherkin uses set keywords for structure and meaning: Given, When, and Then. An example of this structure can be seen in Figure ??.

```
Scenario: ...
  Given ...
  When ...
  Then ...
```

EC2, S3, CloudFront, RDS, CloudWatch, and CloudTrail were all tested using this approach. Screenshots are included to illustrate the results of these tests.

15.1 Testing EC2

```
Scenario: Accessing instance through SSH with .pem file private key.
```

```
  Given ...
  When ...
  Then ...
```

```
Scenario: Accessing web app through EC2 domain name.
```

```
  Given ...
  When ...
  Then ...
```

15.2 Testing S3

```
Scenario: Accessing web app image through S3 domain name.
```

```
  Given ...
  When ...
  Then ...
```

15.3 Testing CloudFront

15.4 Testing RDS

```
Scenario: Accessing web app image through CloudFront domain name.
  Given ...
  When ...
  Then ...

Scenario: Accessing web app image through CloudFront domain name in another region.
  Given ...
  When ...
  Then ...

Scenario: Accessing web app image through CloudFront domain name in another IP address.
  Given ... (NSLookup test)
  When ...
  Then ...

Scenario: Creating user information through the web app.
  Given ...
  When ...
  Then ...

Scenario: Creating story information through the web app.
  Given ...
  When ...
  Then ...

Scenario: Reading user information from the database into the web app.
  Given ...
  When ...
  Then ...

Scenario: Reading story information from the database into the web app.
  Given ...
  When ...
  Then ...

Scenario: Updating user information in the database through the web app.
  Given ...
  When ...
  Then ...

Scenario: Updating story information in the database through the web app.
  Given ...
  When ...
  Then ...

Scenario: Deleting user information in the database through the web app.
  Given ...
  When ...
  Then ...

Scenario: Deleting story information in the database through the web app.
  Given ...
  When ...
  Then ...
```

15.5 Testing CloudWatch

(One test for each of the metrics we set up.)

Scenario:

```
Given ...
When ...
Then ...
```

15.6 Testing CloudTrail

(One test for each of the metrics we set up.)

Scenario:

```
Given ...
When ...
Then ...
```

15.7 Testing ELB

(Test for turning off instance 1. Test for turning off instance 2.)

Chapter 16

Future Enhancements

Chapter 17

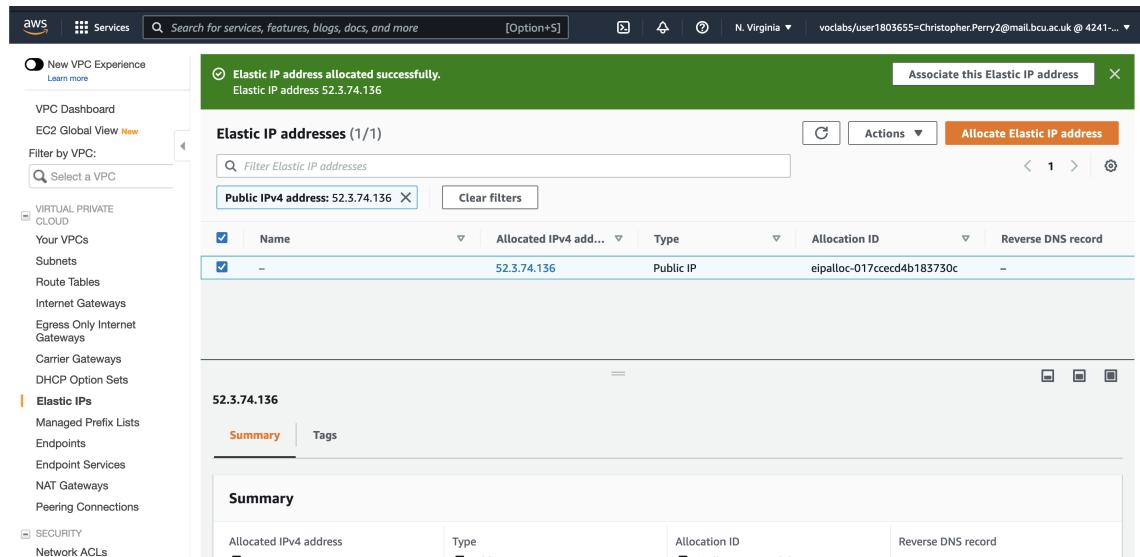
Conclusion

References

- Amazon Web Services (AWS) (2022a). *What is Amazon EC2?* AVAILABLE AT: <https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/concepts.html>.
- (2022b). *What is Amazon VPC?* AVAILABLE AT: <https://docs.aws.amazon.com/vpc/latest/userguide/what-is-amazon-vpc.html>.
- Anderson, C. (2015). “Docker [software engineering]”. In: *IEEE Software* 32.3, pp. 102–c3. AVAILABLE AT: <https://doi.org/10.1109/MS.2015.62>.
- Fielding, R. T. and G. Kaiser (1997). “The Apache HTTP server project”. In: *IEEE Internet Computing* 1.4, pp. 88–90. AVAILABLE AT: <https://doi.org/10.1109/4236.612229>.
- Laravel (2022a). *Blade Templates*. AVAILABLE AT: <https://laravel.com/docs/9.x/blade>.
- (2022b). *Hashing*. AVAILABLE AT: <https://laravel.com/docs/9.x/hashing>.
- Lee, J. and B. Ware (2003). *Open Source Web Development with LAMP: Using Linux, Apache, MySQL, Perl, and PHP*. Addison-Wesley Professional. AVAILABLE AT: <https://isbnsearch.org/isbn/9780201770612>.
- Lerdorf, R. et al. (2002). *Programming PHP*. " O'Reilly Media, Inc.". AVAILABLE AT: <https://isbnsearch.org/isbn/9781565926103>.
- Santos, E. C. dos and P. Vilain (2018). “Automated acceptance tests as software requirements: An experiment to compare the applicability of fit tables and gherkin language”. In: *International Conference on Agile Software Development*. Springer, pp. 104–119. AVAILABLE AT: https://doi.org/10.1007/978-3-319-91602-6_7.
- Widenius, M., D. Axmark, and K. Arno (2002). *MySQL reference manual: documentation from the source*. " O'Reilly Media, Inc.". AVAILABLE AT: <https://isbnsearch.org/isbn/9780596002657>.

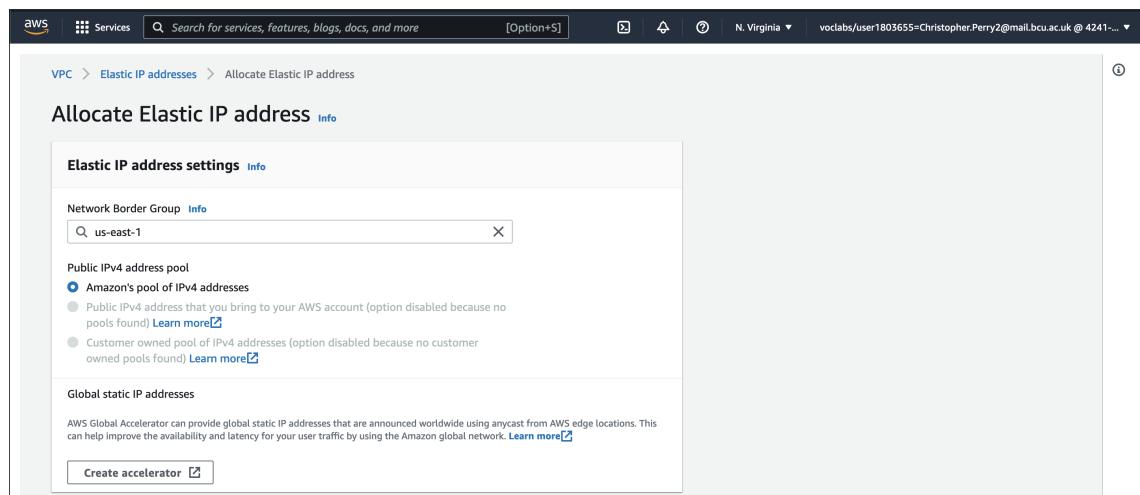
Appendix A: Screenshots

I am an appendix, please be kind.



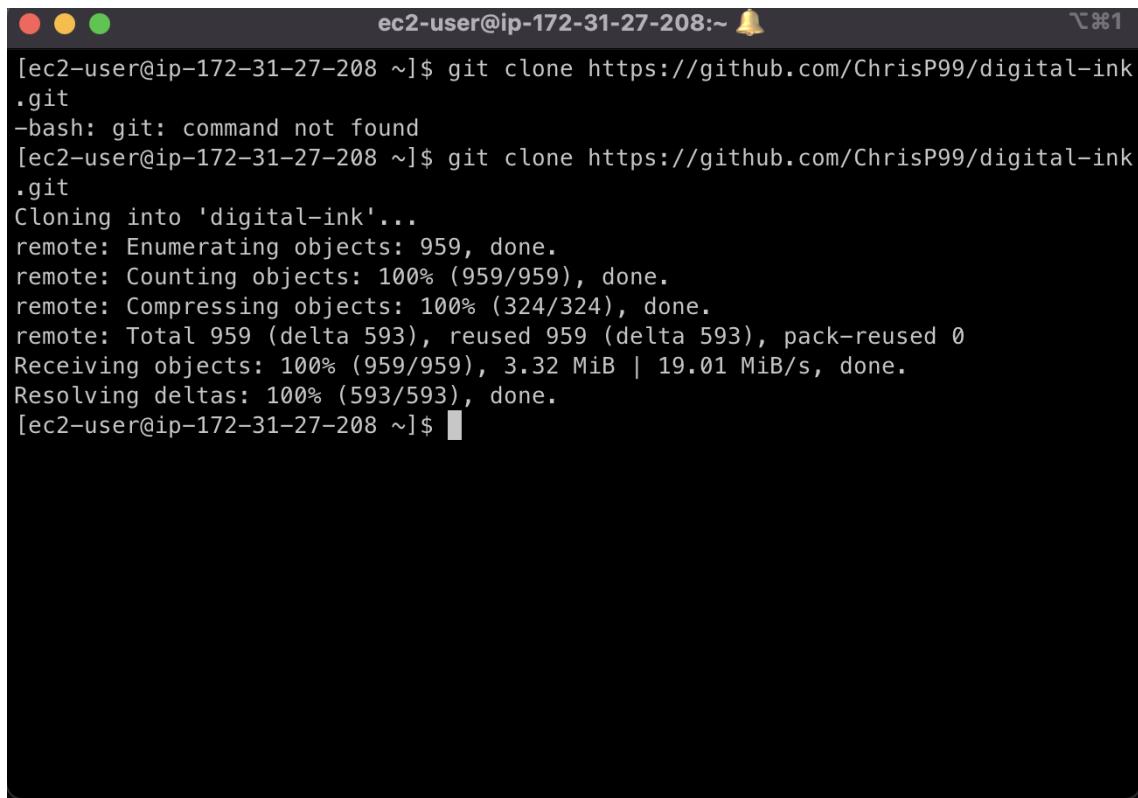
The screenshot shows the AWS VPC Elastic IP addresses page. At the top, a green banner displays the message "Elastic IP address allocated successfully." followed by the allocated IP address "52.3.74.136". Below the banner, the main interface shows a table of "Elastic IP addresses (1/1)". The table has columns for Name, Allocated IPv4 add..., Type, Allocation ID, and Reverse DNS record. One row is listed with the values: Name (checkbox checked), Allocated IPv4 add... (52.3.74.136), Type (Public IP), Allocation ID (eipalloc-017ccecd4b183730c), and Reverse DNS record (empty). Below the table, a summary card for the IP address 52.3.74.136 provides details such as Allocated IPv4 address, Type, Allocation ID, and Reverse DNS record.

Figure A.1: After Allocating Elastic IP Address



The screenshot shows the "Allocate Elastic IP address" settings page. The "Elastic IP address settings" section includes a "Network Border Group" dropdown set to "us-east-1". Under "Public IPv4 address pool", the "Amazon's pool of IPv4 addresses" option is selected. There is also a note about public IPv4 addresses being disabled because no pools were found. The "Global static IP addresses" section contains a note about AWS Global Accelerator and a "Create accelerator" button.

Figure A.2: Allocating Elastic IP Address



```
ec2-user@ip-172-31-27-208:~$ git clone https://github.com/ChrisP99/digital-ink.git
-bash: git: command not found
[ec2-user@ip-172-31-27-208 ~]$ git clone https://github.com/ChrisP99/digital-ink.git
Cloning into 'digital-ink'...
remote: Enumerating objects: 959, done.
remote: Counting objects: 100% (959/959), done.
remote: Compressing objects: 100% (324/324), done.
remote: Total 959 (delta 593), reused 959 (delta 593), pack-reused 0
Receiving objects: 100% (959/959), 3.32 MiB | 19.01 MiB/s, done.
Resolving deltas: 100% (593/593), done.
[ec2-user@ip-172-31-27-208 ~]$
```

Figure A.3: Cloning the App

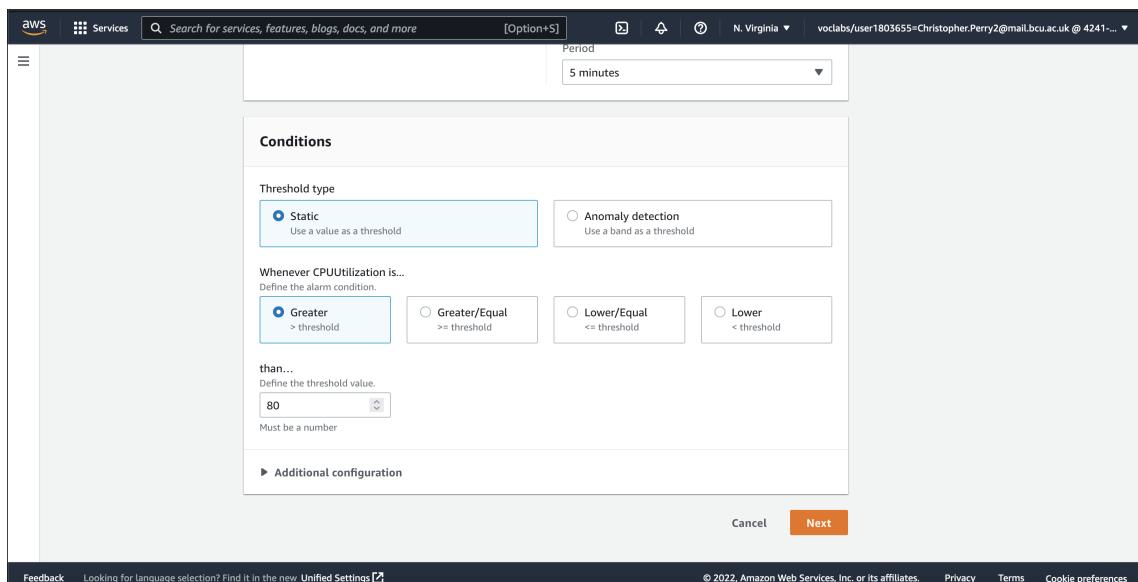


Figure A.4: CloudWatch Conditions

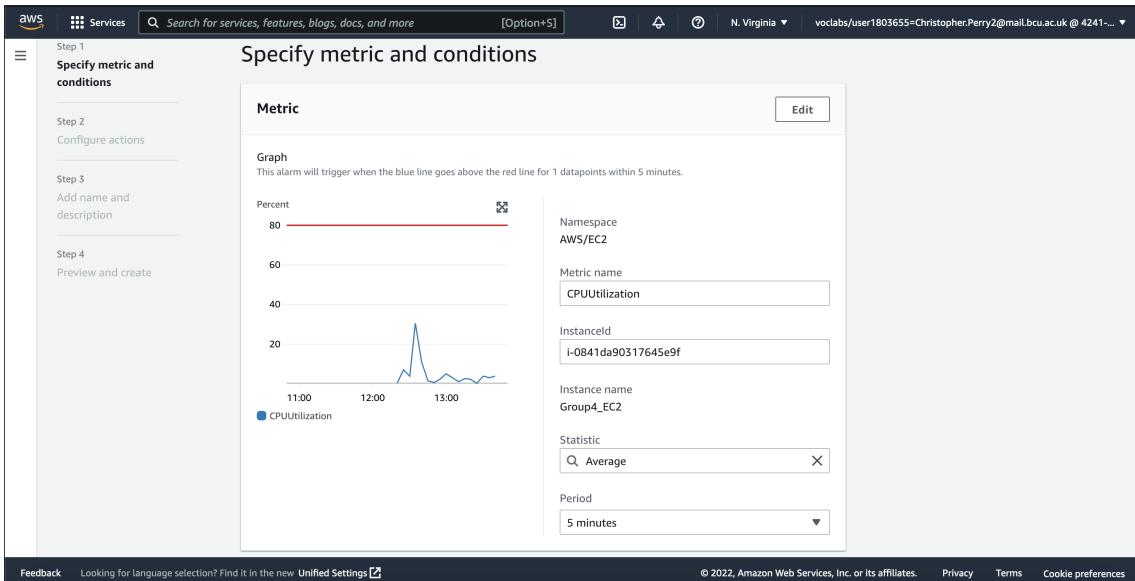


Figure A.5: CloudWatch Specify Metric

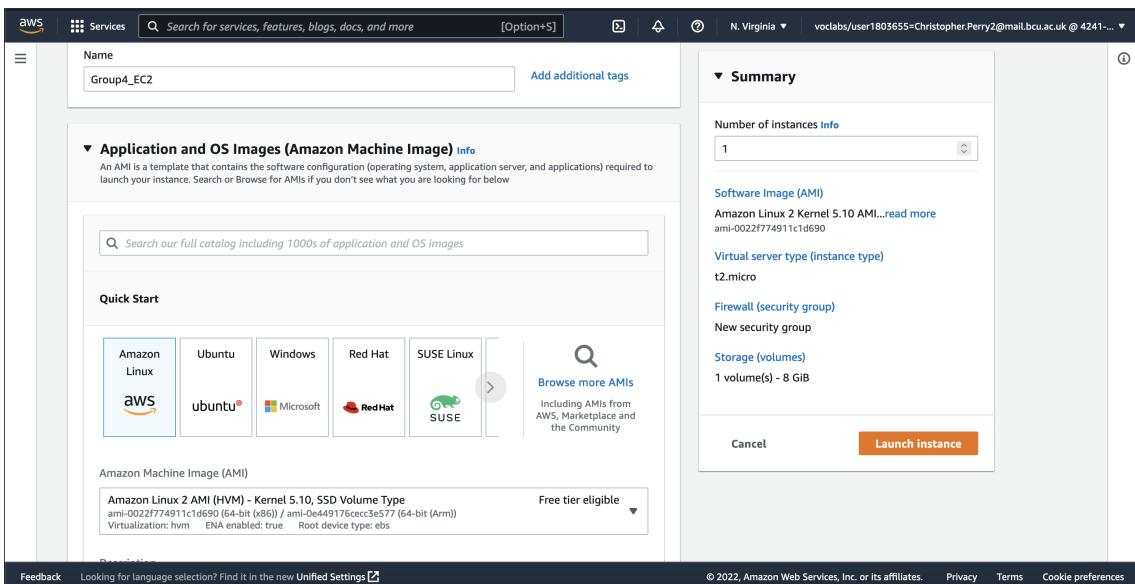


Figure A.6: Create Instance - Application and OS Images

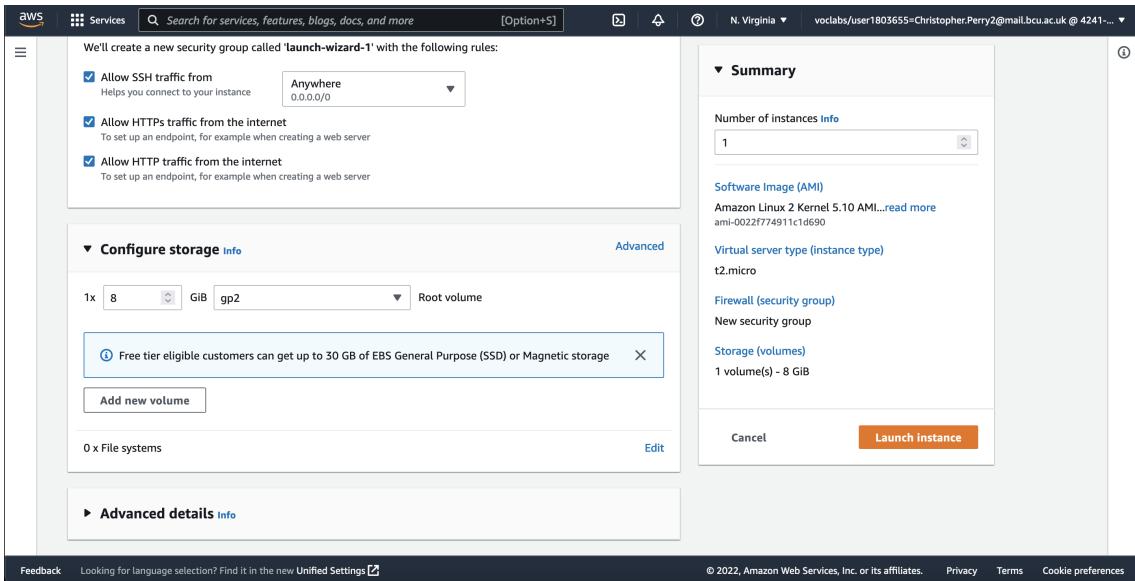


Figure A.7: Create Instance - Configure Storage

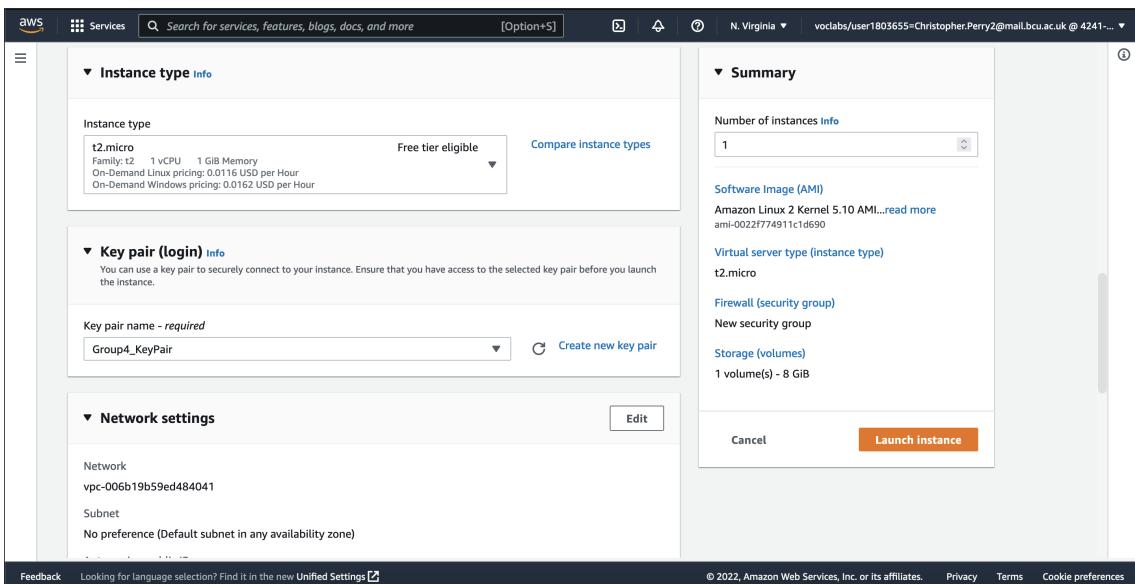


Figure A.8: Create Instance - Instance Type

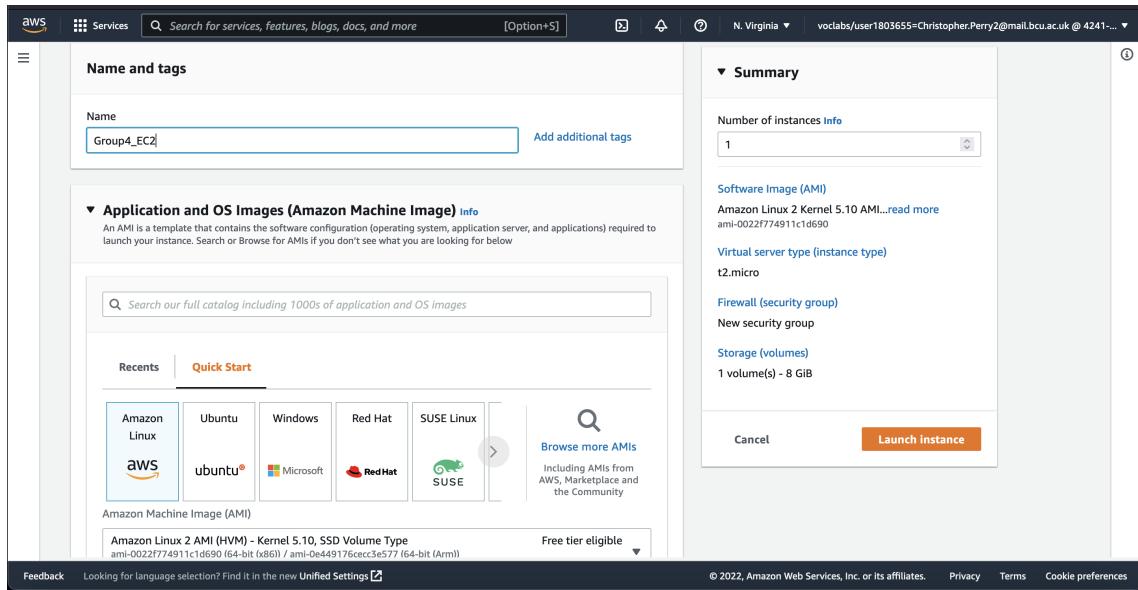


Figure A.9: Create Instance - Name & Tags

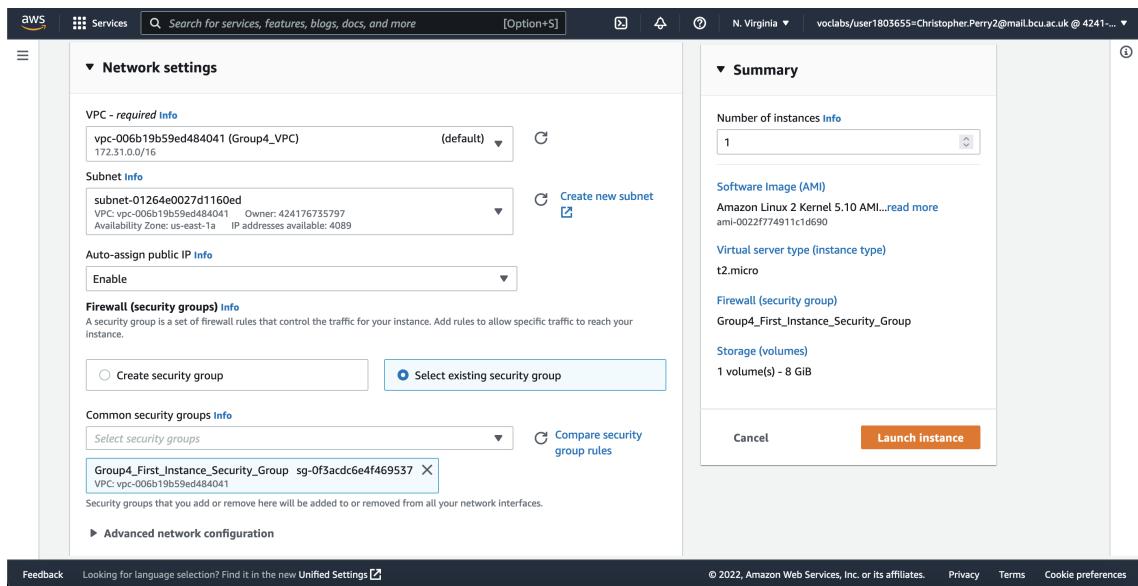


Figure A.10: Create Instance - Network Settings

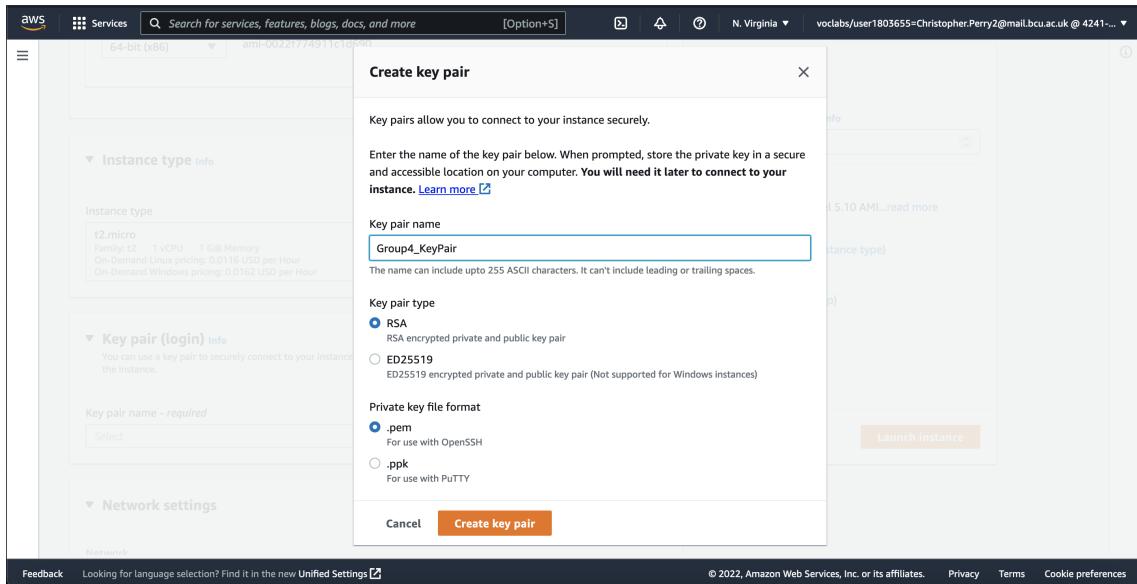


Figure A.11: Creating Key Pair

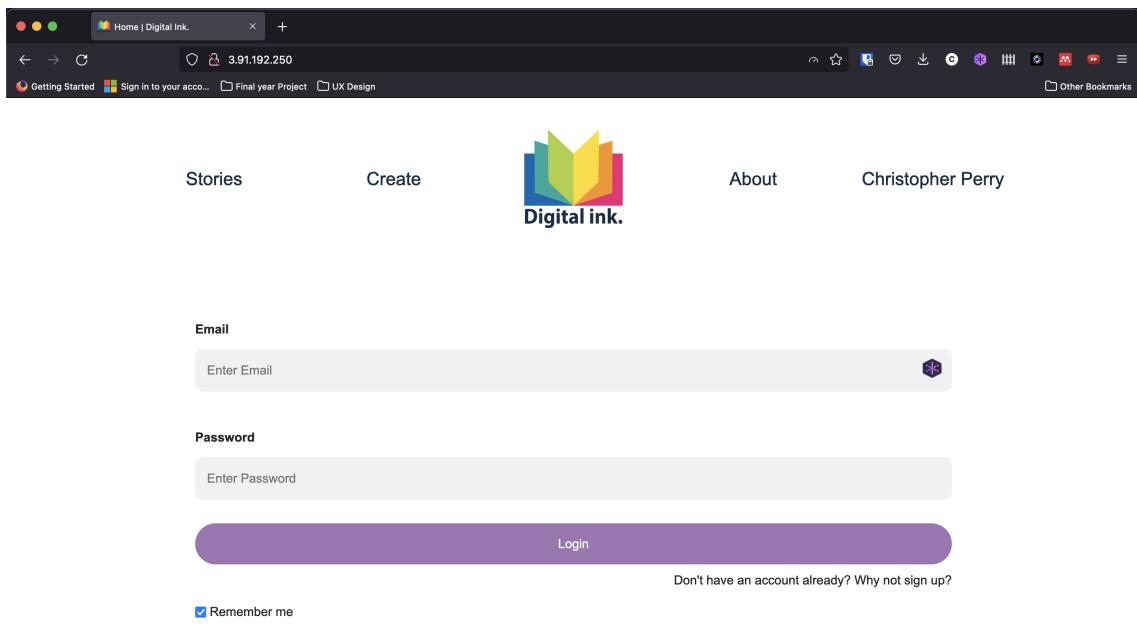


Figure A.12: Digital Ink

```
ec2-user@ip-172-31-27-208:~/digital-ink

: phpmypadmin Pulling
: 5eb5b503b376 Extracting    27.53MB/31.37MB      5.9s
: 8b1a0d84cf101 Download complete          5.7s
: 38c937addeb7 Download complete          5.7s
: 6a2f1dc96e59 Download complete          5.7s
: f8c3f82c39d4 Download complete          5.7s
: 90fc6462b088 Download complete          5.7s
[+] Running 0/319 Download complete      5.7s
: phpmypadmin Pulling
: 5eb5b503b376 Extracting    27.53MB/31.37MB      6.0s
: 8b1a0d84cf101 Download complete          5.8s
: 38c937addeb7 Download complete          5.8s
: 6a2f1dc96e59 Download complete          5.8s
: f8c3f82c39d4 Download complete          5.8s
: 90fc6462b088 Download complete          5.8s
[+] Running 7/319 Download complete      5.8s
: phpmypadmin Pulling
: 5eb5b503b376 Pull complete          7.6s
: 8b1a0d84cf101 Pull complete          7.9s
: 38c937addeb7 Extracting   [=====] 32.31MB/91.6MB      12.8s
: 6a2f1dc96e59 Download complete          12.8s
: f8c3f82c39d4 Download complete          12.8s
: 90fc6462b088 Download complete          12.8s
[+] Running 7/319 Download complete      12.8s
: phpmypadmin Pulling
: 5eb5b503b376 Pull complete          7.6s
: 8b1a0d84cf101 Pull complete          7.9s
: 38c937addeb7 Extracting   [=====] 32.31MB/91.6MB      12.8s
: 6a2f1dc96e59 Download complete          12.8s
: f8c3f82c39d4 Download complete          12.8s
: 90fc6462b088 Download complete          12.8s
: c670d99116c9 Download complete          12.8s
: 268554d6fe96 Download complete          12.8s
: 6c29fa0d4492 Download complete          12.8s
: 73c23c0a259 Download complete          12.8s
: 81ac13c96fc2 Download complete          12.8s
: b60a3e6c23949 Download complete          12.8s
: dac5dd67fd59 Download complete          12.8s
: fd46866d9c36 Download complete          12.8s
: 443a86ef4c80 Download complete          12.8s
: 5e0049224f95 Download complete          12.8s
: 213e66cdf7f56 Download complete          12.8s
: 9b9b44731108 Download complete          12.8s
[+] db Pulling
: 15bb3e15f562 Pull complete          13.0s
: 96c2ab237a1b Pull complete          8.5s
: 8aa3ac85066b Pull complete          9.4s
: ac7e5241fc99 Pull complete          9.8s
: f6a88631064f Pull complete          10.1s
: 15bb3e15f5f50 Extracting   [=====] 13.11MB/14.06MB      12.7s
: ae65dc337dc8 Download complete          12.7s
: a4d4c43adaf5f2 Download complete          12.7s
: c6cab33e8ff1 Download complete          12.7s
: 2e1cf2c43f16 Download complete          12.7s
: 2e5ee322aaf48 Download complete          12.7s
```

Figure A.13: Docker Compose

The screenshot shows the AWS Launch Wizard interface for creating a new Amazon Linux 2 instance. The 'Network settings' section is active, displaying a network named 'vpc-006b19b59ed484041' and a subnet with no preference. It includes options for auto-assigning a public IP and enabling security groups. Under 'Security groups (Firewall)', it says 'We'll create a new security group called "launch-wizard-1" with the following rules:' followed by a list of three checked rules: 'Allow SSH traffic from Anywhere', 'Allow HTTPs traffic from the internet', and 'Allow HTTP traffic from the internet'. The 'Summary' section shows one instance, the AMI (Amazon Linux 2 Kernel 5.10 AMI), the virtual server type (t2.micro), and the firewall (New security group). The 'Configure storage' section shows a root volume of 8 GiB gp2. At the bottom right are 'Cancel' and 'Launch instance' buttons.

aws Services Search for services, features, blogs, docs, and more [Option+Shift]

☰ N. Virginia v vclabs/user1803655=Christopher.Perry2@mail.bcu.ac.uk @ 4241...

▼ Network settings

Network
vpc-006b19b59ed484041

Subnet
No preference (Default subnet in any availability zone)

Auto-assign public IP
Enable

Security groups (Firewall) [Info](#)

We'll create a new security group called 'launch-wizard-1' with the following rules:

Allow SSH traffic from Anywhere
Helps you connect to your instance 0.0.0.0/0 ▾

Allow HTTPs traffic from the internet
To set up an endpoint, for example when creating a web server

Allow HTTP traffic from the internet
To set up an endpoint, for example when creating a web server

▼ Summary

Number of instances [Info](#)
1

Software Image (AMI)
Amazon Linux 2 Kernel 5.10 AMI...read more
ami-0022f774911c1d690

Virtual server type (instance type)
t2.micro

Firewall (security group)
New security group

Storage (volumes)
1 volume(s) - 8 GiB

Cancel Launch instance

▼ Configure storage [Info](#) Advanced

1x 8 GiB gp2 Root volume

Feedback Looking for language selection? Find it in the new [Unified Settings](#)

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Figure A.14: Edit Instance - Network Settings

```
[ec2-user@ip-172-31-27-208 ~]$ sudo yum update
Loaded plugins: extras_suggestions, langpacks, priorities, update-motd
amzn2-core
[ec2-user@ip-172-31-27-208 ~]$ sudo yum install docker docker-compose
Loaded plugins: extras_suggestions, langpacks, priorities, update-motd
No package docker-compose available.
Resolving Dependencies
--> Running transaction check
--> Package docker x86_64 0:20.10.13-2.amzn2 will be installed
--> Processing Dependency: runc >= 1.0.0 for package: docker-20.10.13-2.amzn2.x86_64
--> Processing Dependency: libcgroup >= 0.40.rcl5-15 for package: docker-20.10.13-2.amzn2.x86_64
--> Processing Dependency: containerd >= 1.3.2 for package: docker-20.10.13-2.amzn2.x86_64
--> Processing Dependency: pigz for package: docker-20.10.13-2.amzn2.x86_64
--> Running transaction check
--> Package containerd.x86_64 0:1.4.13-2.amzn2.0.1 will be installed
--> Package libcgroup.x86_64 0:0.41-21.amzn2 will be installed
--> Package pigz.x86_64 0:2.3.4-1.amzn2.0.1 will be installed
--> Package runc.x86_64 0:1.0.3-2.amzn2 will be installed
--> Finished Dependency Resolution

Dependencies Resolved

=====


| Package                                                                                               | Arch   | Version            | Repository        | Size  |
|-------------------------------------------------------------------------------------------------------|--------|--------------------|-------------------|-------|
| <hr/>                                                                                                 |        |                    |                   |       |
| Installing:                                                                                           |        |                    |                   |       |
| docker                                                                                                | x86_64 | 20.10.13-2.amzn2   | amzn2extra-docker | 40 M  |
| Installing for dependencies:                                                                          |        |                    |                   |       |
| containerd                                                                                            | x86_64 | 1.4.13-2.amzn2.0.1 | amzn2extra-docker | 23 M  |
| libcgroup                                                                                             | x86_64 | 0.41-21.amzn2      | amzn2-core        | 66 k  |
| pigz                                                                                                  | x86_64 | 2.3.4-1.amzn2.0.1  | amzn2-core        | 81 k  |
| runc                                                                                                  | x86_64 | 1.0.3-2.amzn2      | amzn2extra-docker | 3.0 M |
| <hr/>                                                                                                 |        |                    |                   |       |
| Transaction Summary                                                                                   |        |                    |                   |       |
| <hr/>                                                                                                 |        |                    |                   |       |
| Install 1 Package (<4 Dependent packages)                                                             |        |                    |                   |       |
| Total download size: 67 M                                                                             |        |                    |                   |       |
| Installed size: 280 M                                                                                 |        |                    |                   |       |
| Is this ok [y/N]:                                                                                     |        |                    |                   |       |
| snuffle   ↵   □ ~   % ssh + fish + bash + zsh + fish + fish + fish + fish + fish + fish   □ spacedust |        |                    |                   |       |
| 54% ━━━━━━   5.2 GB ━━━━━━   0 18% ━━   ⏳ 5-04, 1:31 PM                                               |        |                    |                   |       |


```

Figure A.15: Installing Docker using Package Manager

```
Resolving Dependencies
--> Running transaction check
--> Package docker.x86_64 0:20.10.13-2.amzn2 will be installed
--> Processing Dependency: runc >= 1.0.0 for package: docker-20.10.13-2.amzn2.x86_64
--> Processing Dependency: libcgroup >= 0.40.rcl5-15 for package: docker-20.10.13-2.amzn2.x86_64
--> Processing Dependency: containerd >= 1.3.2 for package: docker-20.10.13-2.amzn2.x86_64
--> Processing Dependency: pigz for package: docker-20.10.13-2.amzn2.x86_64
--> Running transaction check
--> Package containerd.x86_64 0:1.4.13-2.amzn2.0.1 will be installed
--> Package libcgroup.x86_64 0:0.41-21.amzn2 will be installed
--> Package pigz.x86_64 0:2.3.4-1.amzn2.0.1 will be installed
--> Package runc.x86_64 0:1.0.3-2.amzn2 will be installed
--> Finished Dependency Resolution

Dependencies Resolved

=====


| Package                                                                                               | Arch   | Version            | Repository        | Size                     |
|-------------------------------------------------------------------------------------------------------|--------|--------------------|-------------------|--------------------------|
| <hr/>                                                                                                 |        |                    |                   |                          |
| Installing:                                                                                           |        |                    |                   |                          |
| docker                                                                                                | x86_64 | 20.10.13-2.amzn2   | amzn2extra-docker | 40 M                     |
| Installing for dependencies:                                                                          |        |                    |                   |                          |
| containerd                                                                                            | x86_64 | 1.4.13-2.amzn2.0.1 | amzn2extra-docker | 23 M                     |
| libcgroup                                                                                             | x86_64 | 0.41-21.amzn2      | amzn2-core        | 66 k                     |
| pigz                                                                                                  | x86_64 | 2.3.4-1.amzn2.0.1  | amzn2-core        | 81 k                     |
| runc                                                                                                  | x86_64 | 1.0.3-2.amzn2      | amzn2extra-docker | 3.0 M                    |
| <hr/>                                                                                                 |        |                    |                   |                          |
| Transaction Summary                                                                                   |        |                    |                   |                          |
| <hr/>                                                                                                 |        |                    |                   |                          |
| Install 1 Package (<4 Dependent packages)                                                             |        |                    |                   |                          |
| Total download size: 67 M                                                                             |        |                    |                   |                          |
| Installed size: 280 M                                                                                 |        |                    |                   |                          |
| Is this ok [D/y/N]: y                                                                                 |        |                    |                   |                          |
| Downloading packages:                                                                                 |        |                    |                   |                          |
| (1/5): libcgroup-0.41-21.amzn2.x86_64.rpm                                                             |        |                    |                   | 1 66 kB 00:00:00         |
| (2/5): pigz-2.3.4-1.amzn2.0.1.x86_64.rpm                                                              |        |                    |                   | 1 81 kB 00:00:00         |
| (3/5): containerd-1.4.13-2.amzn2.0.1.x86_64.rpm                                                       |        |                    |                   | 1 23 MB 00:00:00         |
| (4/5): docker-20.10.13-2.amzn2.x86_64.rpm                                                             |        |                    |                   | 1 40 MB 00:00:00         |
| (5/5): runc-1.0.3-2.amzn2.x86_64.rpm                                                                  |        |                    |                   | 1 3.0 MB 00:00:00        |
| <hr/>                                                                                                 |        |                    |                   |                          |
| Total                                                                                                 |        |                    |                   | 66 MB/s   67 MB 00:00:01 |
| Running transaction check                                                                             |        |                    |                   |                          |
| Running transaction test                                                                              |        |                    |                   |                          |
| Transaction test succeeded                                                                            |        |                    |                   |                          |
| Running transaction                                                                                   |        |                    |                   |                          |
| Installing : runc-1.0.3-2.amzn2.x86_64                                                                |        |                    |                   | 1/5                      |
| Installing : containerd-1.4.13-2.amzn2.0.1.x86_64                                                     |        |                    |                   | 2/5                      |
| Installing : libcgroup-0.41-21.amzn2.x86_64                                                           |        |                    |                   | 3/5                      |
| Installing : pigz-2.3.4-1.amzn2.0.1.x86_64                                                            |        |                    |                   | 4/5                      |
| Installing : docker-20.10.13-2.amzn2.x86_64 [##### <td></td> <td></td> <td></td> <td>] 5/5</td>       |        |                    |                   | ] 5/5                    |
| snuffle   ↵   □ ~   % ssh + fish + bash + zsh + fish + fish + fish + fish + fish + fish   □ spacedust |        |                    |                   |                          |
| 74% ━━━━   5.3 GB ━━━━   0 18% ━━   ⏳ 5-04, 1:31 PM                                                   |        |                    |                   |                          |


```

Figure A.16: Installing Docker using Package Manager (In Progress)

```

git-core.x86_64          2.32.0-1.amzn2.0.1
git-core-doc.noarch        2.32.0-1.amzn2.0.1
perl-Error.noarch         1:0.17020-2.amzn2
perl-Git.noarch           2.32.0-1.amzn2.0.1
perl-TermReadKey.x86_64   2.30-20.amzn2.0.2

Transaction Summary
Install 1 Package (+6 Dependent packages)

Total download size: 7.8 M
Installed size: 38 M
Is this ok [y/N]: y
Downloading packages:
(1/7): emacs-filesystem-27.2-4.amzn2.0.1.noarch.rpm | 67 kB 00:00:00
(2/7): git-2.32.0-1.amzn2.0.1.x86_64.rpm | 126 kB 00:00:00
(3/7): git-core-doc-2.32.0-1.amzn2.0.1.noarch.rpm | 2.7 MB 00:00:00
(4/7): perl-Error-0.17020-2.amzn2.noarch.rpm | 32 kB 00:00:00
(5/7): perl-Git-2.32.0-1.amzn2.0.1.noarch.rpm | 43 kB 00:00:00
(6/7): git-core-2.32.0-1.amzn2.0.1.x86_64.rpm | 4.8 MB 00:00:00
(7/7): perl-TermReadKey-2.30-20.amzn2.0.2.x86_64.rpm | 31 kB 00:00:00
29 MB/s | 7.8 MB 00:00:00

Total
Running transaction check
Running transaction test
Transaction test succeeded
Running transaction
  Installing : git-core-2.32.0-1.amzn2.0.1.x86_64
  Installing : git-core-doc-2.32.0-1.amzn2.0.1.noarch
  Installing : 1:perl-Error-0.17020-2.amzn2.noarch
  Installing : 1:emacs-filesystem-27.2-4.amzn2.0.1.noarch
  Installing : perl-TermReadKey-2.30-20.amzn2.0.2.x86_64
  Installing : git-2.32.0-1.amzn2.0.1.noarch
  Verifying : git-core-2.32.0-1.amzn2.0.1.noarch
  Verifying : perl-Git-2.32.0-1.amzn2.0.1.noarch
  Verifying : 1:emacs-filesystem-27.2-4.amzn2.0.1.noarch
  Verifying : git-2.32.0-1.amzn2.0.1.x86_64
  Verifying : git-core-2.32.0-1.amzn2.0.1.x86_64
  Verifying : 1:perl-Error-0.17020-2.amzn2.noarch

Installed:
  git.x86_64 0:2.32.0-1.amzn2.0.1

Dependency Installed:
  emacs-filesystem.noarch 1:27.2-4.amzn2.0.1  git-core.x86_64 0:2.32.0-1.amzn2.0.1  git-core-doc.noarch 0:2.32.0-1.amzn2.0.1  perl-Error.noarch 1:0.17020-2.amzn2  perl-Git.noarch 0:2.32.0-1.amzn2.0.1
  perl-TermReadKey.x86_64 0:2.30-20.amzn2.0.2

Complete!
[ec2-user@ip-172-31-27-208 ~]$ 

snugle | ↵ □ ~ | ssh + fish + bash + zsh + fish + fish + fish + fish + fish + spacedust | 59% ━━━━━━ 5.4 GB ━━━━━━ 19% ━━━━ 5-04, 1:33 PM
```

Figure A.17: Installing Git

```

ec2-user@ip-172-31... #1
          Load  Upload Total Spent Left Speed
~ (-fish) #2 0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0
100 25.2M 100 25.2M 0    0 39.1M 0    0    0    0    0    0
[ec2-user@ip-172-31-27-208 digital-link]$ uname -a
Linux ip-172-31-27-208.ec2.internal 5.10.109-104.500.amzn2.x86_64 #1 SMP Wed Apr 13 20:31:43 UTC 2022 x86_64 x86_64 x86_64 GNU/Linux
[ec2-user@ip-172-31-27-208 digital-link]$ cat /etc/*-release
NAME="Amazon Linux"
VERSION="2"
ID="amzn"
ID_LIKE="centos rhel fedora"
VERSION_ID="2"
PRETTY_NAME="Amazon Linux 2"
ANSI_COLOR="0;33"
CPE_NAME="cpe:2.3:o:amazon:amazon_linux:2"
HOME_URL="https://amazonlinux.com/"
Amazon Linux 2 (Xenon)
[ec2-user@ip-172-31-27-208 digital-link]$ sudo chmod +x /usr/local/bin/docker-compose
[ec2-user@ip-172-31-27-208 digital-link]$ docker-compose --version
Docker Compose version v2.5.0
[ec2-user@ip-172-31-27-208 digital-link]$ systemctl status docker
● docker.service - Docker Application Container Engine
  Loaded: loaded (/usr/lib/systemd/system/docker.service; disabled; vendor preset: disabled)
  Active: inactive (dead)
    Docs: https://docs.docker.com
[ec2-user@ip-172-31-27-208 digital-link]$ sudo systemctl start docker
[ec2-user@ip-172-31-27-208 digital-link]$ systemctl status docker
● docker.service - Docker Application Container Engine
  Loaded: loaded (/usr/lib/systemd/system/docker.service; disabled; vendor preset: disabled)
  Active: active (running) since Wed 2022-05-04 12:40:06 UTC; 1s ago
    Docs: https://docs.docker.com
  Process: 3788 ExecStartPre=/usr/libexec/docker/docker-setup-runtimes.sh (code=exited, status=0/SUCCESS)
  Process: 3791 ExecStartPre=/bin/mkdir -p /run/docker (code=exited, status=0/SUCCESS)
Main PID: 3791 (docker)
  Tasks: 7
    Memory: 26.9M
  CGroup: /system.slice/docker.service
          └─3791 /usr/bin/dockerd -H fd:// --containerd=/run/containerd/containerd.sock --default-ulimit nofile=32768:65536

May 04 12:40:06 ip-172-31-27-208.ec2.internal dockerd[3791]: time="2022-05-04T12:40:06+00:00" level=info msg="ClientConn switching balancer to \"pick_first\""
May 04 12:40:06 ip-172-31-27-208.ec2.internal dockerd[3791]: time="2022-05-04T12:40:06+00:00" level=warning msg="Your kernel does not support cgroup blkio weight"
May 04 12:40:06 ip-172-31-27-208.ec2.internal dockerd[3791]: time="2022-05-04T12:40:06+00:00" level=warning msg="Your kernel does not support cgroup blkio weight_device"
May 04 12:40:06 ip-172-31-27-208.ec2.internal dockerd[3791]: time="2022-05-04T12:40:06+00:00" level=info msg="Loading containers: start"
May 04 12:40:06 ip-172-31-27-208.ec2.internal dockerd[3791]: time="2022-05-04T12:40:06+00:00" level=info msg="Default bridge (docker0) is assigned with an IP address... address"
May 04 12:40:06 ip-172-31-27-208.ec2.internal dockerd[3791]: time="2022-05-04T12:40:06+00:00" level=info msg="Loading containers: done."
May 04 12:40:06 ip-172-31-27-208.ec2.internal dockerd[3791]: time="2022-05-04T12:40:06+00:00" level=info msg="Docker daemon" commit="906f57f graphdriver(s)=overlay..=20.10.13"
May 04 12:40:06 ip-172-31-27-208.ec2.internal dockerd[3791]: time="2022-05-04T12:40:06+00:00" level=info msg="Daemon has completed initialization"
May 04 12:40:06 ip-172-31-27-208.ec2.internal systemd[1]: Started Docker Application Container Engine.
May 04 12:40:06 ip-172-31-27-208.ec2.internal dockerd[3791]: time="2022-05-04T12:40:06+00:00" level=info msg="API listen on /run/docker.sock"
Hint: Some lines were ellipsized, use -l to show in full.
[ec2-user@ip-172-31-27-208 digital-link]$ 

snugle | ↵ □ ~ | ssh + fish + bash + zsh + fish + fish + fish + fish + spacedust | 67% ━━━━━━ 5.4 GB ━━━━━━ 26% ━━━━ 5-04, 1:40 PM
```

Figure A.18: Starting Docker systemd Service

The screenshot shows the AWS EC2 Instances page. On the left, there's a sidebar with various navigation options like EC2 Dashboard, EC2 Global View, Events, Tags, Limits, Instances (selected), Instance Types, Launch Templates, Spot Requests, Savings Plans, Reserved Instances, Dedicated Hosts, Scheduled Instances, Capacity Reservations, Images, AMIs, and AMI Catalog. The main content area has a title 'Instances (2) Info' with a search bar and a table. The table lists two instances: 'Group4_EC2' (terminated, t2.micro, us-east-1d) and 'Group4_EC2' (running, t2.micro, us-east-1d). At the bottom, there's a 'Select an instance' section and a footer with copyright information.

Figure A.19: Instances

The screenshot shows the 'Launching instance' step in the AWS EC2 instance launch process. It includes a progress bar at 80%, a 'Launch initiation' status, and a 'Details' link. A message at the top says 'You've been opted into the new launch experience. Find out more about this experience or send us feedback. You can still return to the previous version by opting-out.' There's also an 'Opt-out to the old experience' button.

Figure A.20: Launching Instance

```

ec2-user@ip-172-31-27-208:~/digital-ink
logout
Connection to 3.91.192.250 closed.
> ssh -i ~/Desktop/Group4_KeyPair.pem ec2-user@3.91.192.250
Last login: Wed May  4 13:21:09 2022 from 193.60.143.12
  _\|_ / Amazon Linux 2 AMI
  _\|_|_|
https://aws.amazon.com/amazon-linux-2/
[ec2-user@ip-172-31-27-208 ~]$ cd digital-ink
[ec2-user@ip-172-31-27-208 digital-ink]$ cd ..
[ec2-user@ip-172-31-27-208 ~]$ sudo mv digital-ink digital-ink.old
[ec2-user@ip-172-31-27-208 ~]$ git clone https://github.com/ChrisP99/digital-ink.git
Cloning into 'digital-ink'...
remote: Enumerating objects: 9909, done.
remote: Counting objects: 100% (9909/9909), done.
remote: Compressing objects: 100% (6382/6382), done.
remote: Total 9909 (delta 3080), reused 9863 (delta 3034), pack-reused 0
Receiving objects: 100% (9909/9909), 17.59 MiB | 14.30 MiB/s, done.
Resolving deltas: 100% (3080/3080), done.
Updating files: 100% (8963/8963), done.
[ec2-user@ip-172-31-27-208 ~]$ cd digital-ink
[ec2-user@ip-172-31-27-208 digital-ink]$ sudo /usr/local/bin/docker-compose up -d
[*] Running 3/3
  • Container digital-ink-db-1  Running
  • Container phpmyadmin  Running
  • Container digital-ink-app-1 Started
[ec2-user@ip-172-31-27-208 digital-ink]$ sudo /usr/local/bin/docker-compose down
[*] Running 4/4
  • Container phpmyadmin  Removed
  • Container digital-ink-app-1 Removed
  • Container digital-ink-db-1 Removed
  • Network digital-ink_default Removed
[ec2-user@ip-172-31-27-208 digital-ink]$ sudo /usr/local/bin/docker-compose up -d
[*] Running 4/4
  • Network digital-ink_default Created
  • Container digital-ink-db-1 Started
  • Container phpmyadmin  Started
  • Container digital-ink-app-1 Started
[ec2-user@ip-172-31-27-208 digital-ink]$ sudo /usr/local/bin/docker-compose exec app bash
root@c565ab9c37ff:/srv/app# php artisan migrate
Nothing to migrate.
root@c565ab9c37ff:/srv/app# 

```

Figure A.21: Log In with Key Pair

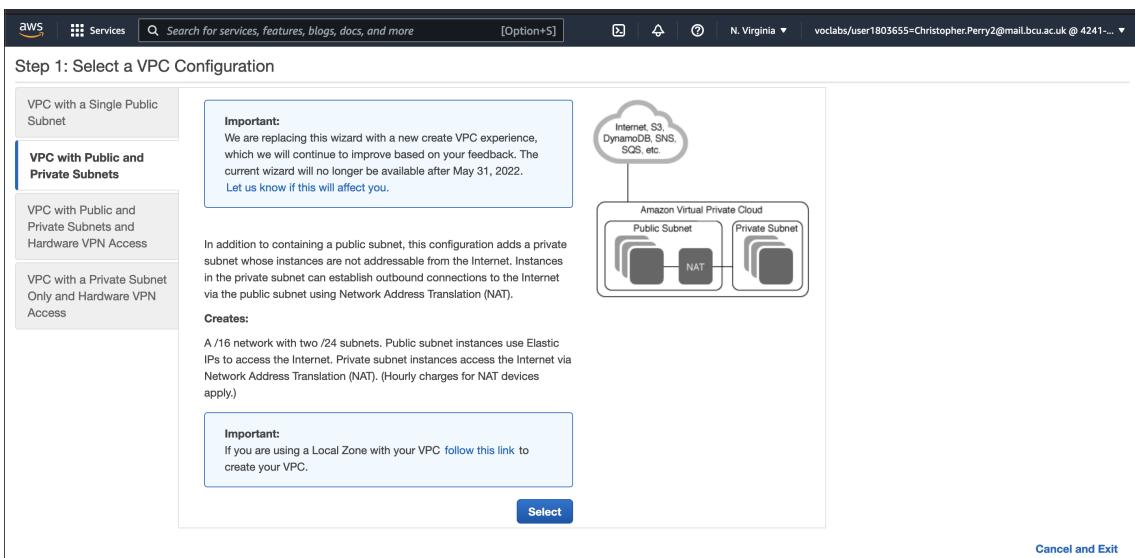


Figure A.22: Selecting a VPC Configuration

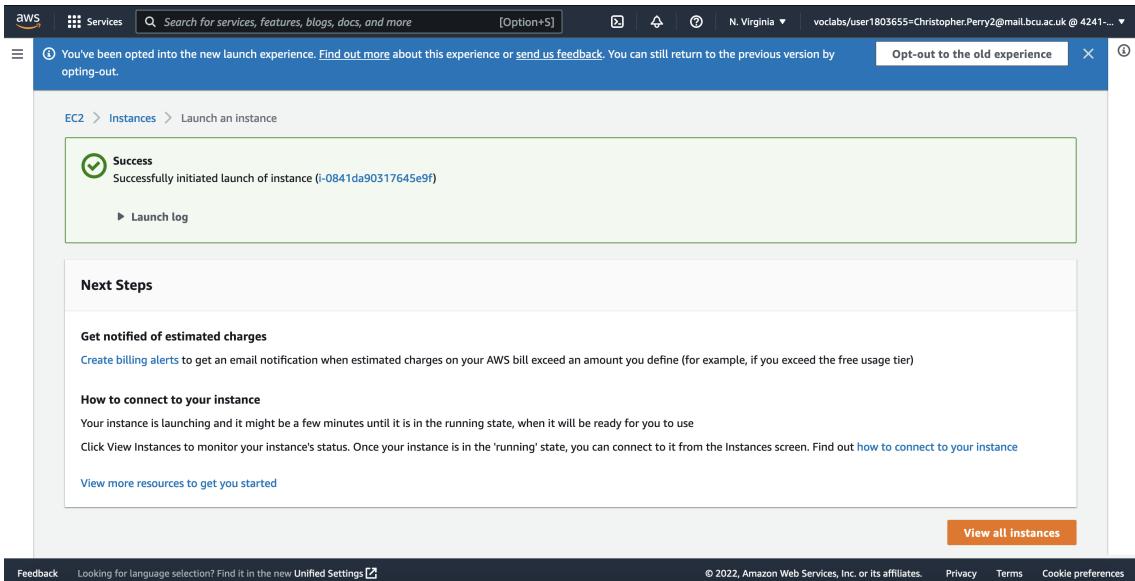


Figure A.23: Successfully Initiated Instance

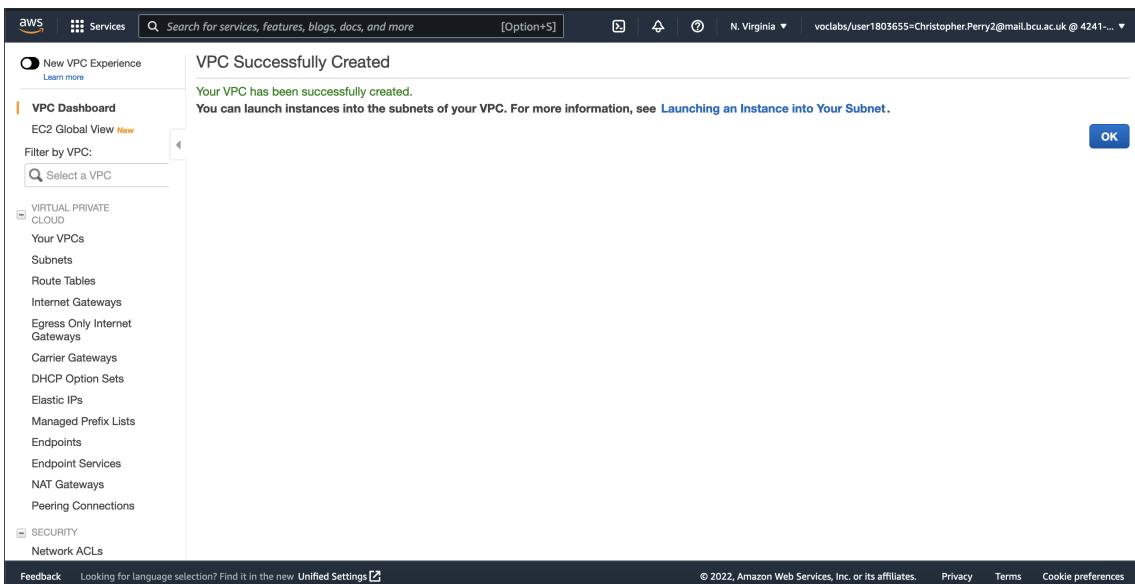


Figure A.24: VPC Successfully Created

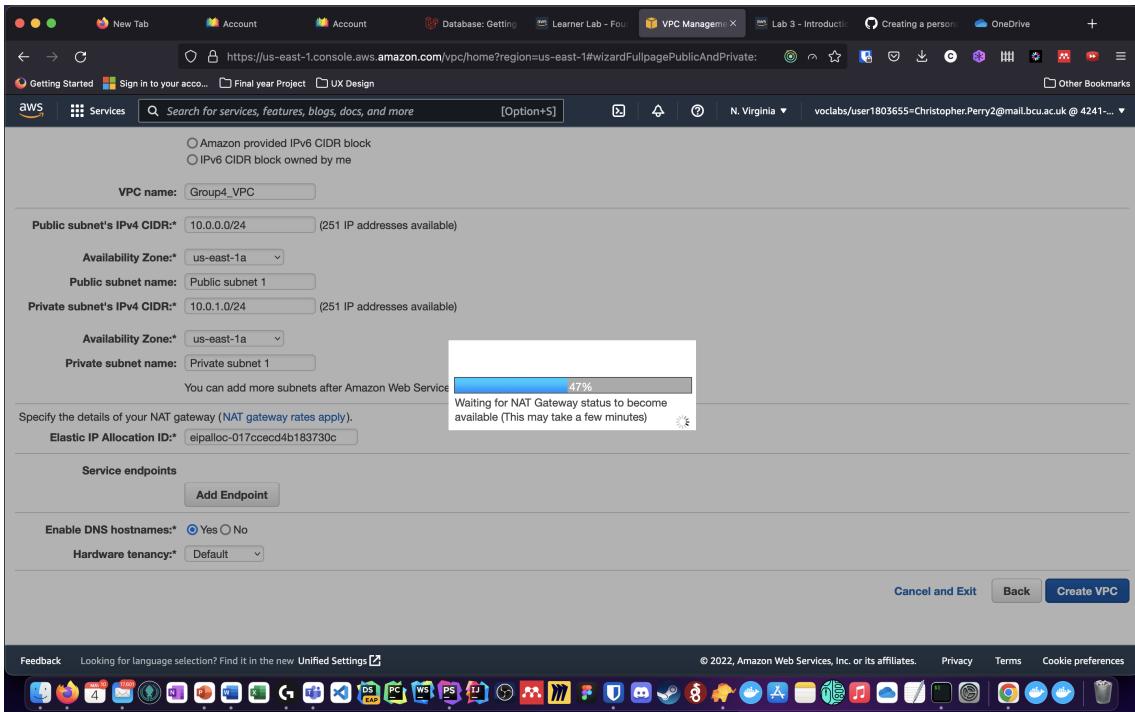


Figure A.25: VPC with Public and Private Subnets, Loading

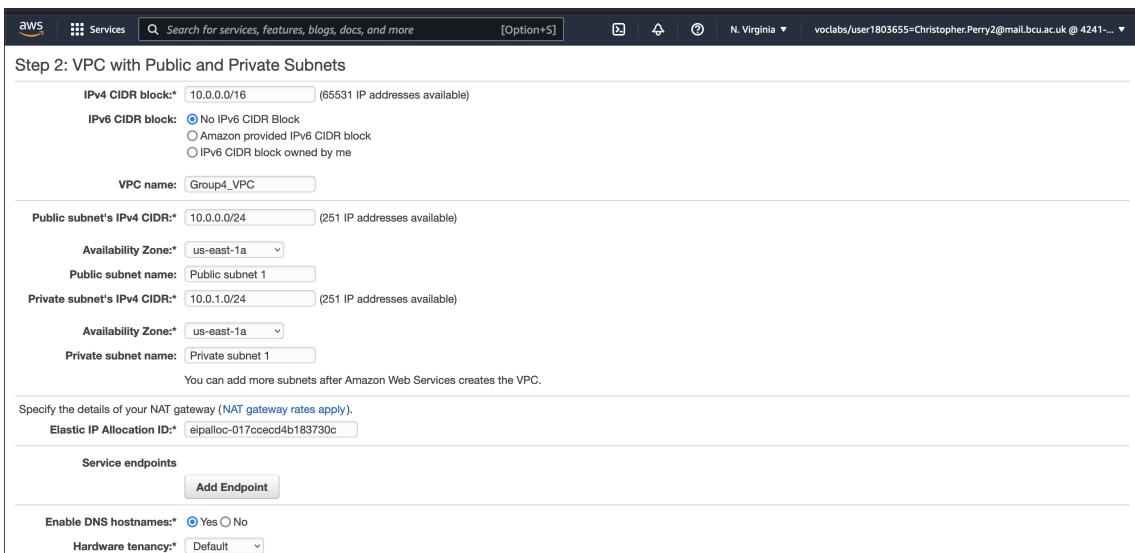


Figure A.26: VPC with Public and Private Subnets

Your VPCs (2) Info

| Name | VPC ID | State | IPv4 CIDR | IPv6 CIDR |
|------------|-----------------------|-----------|---------------|-----------|
| - | vpc-006b19b59ed484041 | Available | 172.31.0.0/16 | - |
| Group4_VPC | vpc-0b0472507c8bf18c9 | Available | 10.0.0.0/16 | - |

vpc-07657585bc0e3b3b5

Details CIDs | Flow logs | Tags

| | | | |
|---------------------------------|--------------------|---------------------------|---------------------------|
| VPC ID vpc-07657585bc0e3b3b5 | State Available | DNS hostnames Disabled | DNS resolution Enabled |
|---------------------------------|--------------------|---------------------------|---------------------------|

Feedback Looking for language selection? Find it in the new Unified Settings [?](#)

Figure A.27: Your VPCs