Cloud-Native Hostel Management System: Architecture and Optimization

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Executive Summary

This project involved the development and deployment of a containerized web application designed to modernize student record management and room allocation systems. By migrating from a legacy monolithic architecture to AWS Fargate, the solution leverages serverless container orchestration to ensure high availability and automated scaling without the overhead of managing underlying infrastructure.
A critical component of this modernization was addressing the challenge of ephemeral storage inherent in containerized environments; this was achieved by integrating cloud-native persistence layers, ensuring that critical student data and allocation records remain durable and consistent across container lifecycles.

Introduction

The administration of university hostels is a data-intensive domain requiring the efficient handling of student records, room allocations, fee collection, and facility management. In the context of modern educational institutions, the demand for real-time access to these services has grown exponentially. Historically, hostel management has relied on **legacy monolithic applications** hosted on on-premise physical servers. While these traditional systems served their purpose initially, they lack the agility required for today's dynamic user base.
As institutions scale, the "monolithic" approach creates significant bottlenecks. A single server failure can render the entire system inaccessible, and maintenance often requires significant downtime, disrupting administrative workflows. Furthermore, the global shift towards **Cloud-Native computing** highlights the obsolescence of managing physical infrastructure manually.
This project introduces a **Cloud-Native Hostel Management System (HMS)** designed to address these legacy limitations. By migrating the application logic to **AWS Fargate (Serverless ECS)** and decoupling the data layer using **Amazon RDS**, this project aims to demonstrate how modern containerization and cloud orchestration can transform a static, fragile administrative tool into a highly available, secure, and auto-scaling platform.

Problem Statement

The primary problem this project addresses is the **inherent rigidity and fragility of on-premise monolithic architectures** in high-demand educational environments. Current legacy systems face several critical real-world challenges:

- **Inability to Scale (Traffic Spikes):** During the start of a semester, thousands of students attempt to log in simultaneously to book rooms. Traditional on-premise servers often crash under this load because they cannot auto-scale. They require manual hardware upgrades (vertical scaling) which is costly and slow.
- **Single Point of Failure (SPOF):** Legacy architectures often rely on a single physical server. If this hardware fails or experiences a power outage, the entire hostel management system goes offline, halting all administrative processes.
- **Ephemeral Storage Risks:** As organizations move to basic containerization (Docker) without cloud orchestration, they face the "Ephemeral Storage" problem. If a container crashes or restarts, any data (such as student profile pictures or logs) stored locally is permanently lost.
- **Security Vulnerabilities:** Many legacy systems expose their database ports directly to the local network or internet for ease of access, creating significant security loopholes. Additionally, reliance on static passwords without Multi-Factor Authentication (MFA) leaves sensitive student data vulnerable to unauthorized access.

- **Operational Overhead:** The manual effort required to patch OS security, manage server cooling, and handle hardware maintenance diverts IT resources away from feature development and improving the student experience.

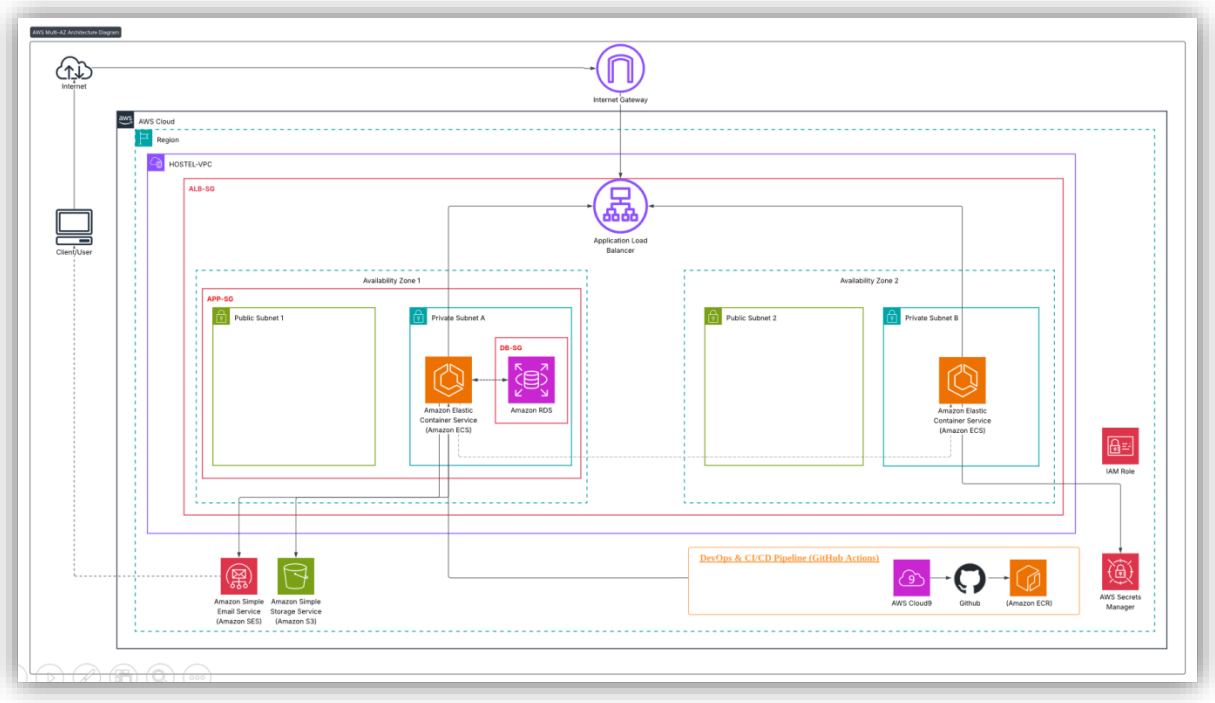
This project seeks to resolve these issues by re-architecting the system into a **Stateless, Serverless, and Multi-AZ (Availability Zone)** solution on AWS.

Aim and Objectives

This system leverages a serverless container strategy using AWS ECS Fargate, which eliminates manual infrastructure management while providing automated auto-scaling to meet fluctuating demand. The architecture is built for high availability and security, deploying resources across Multi-Availability Zones and isolating the database within private subnets to ensure it remains inaccessible from the public internet.

Media storage is externalized to Amazon S3 for durable object management, and application security is bolstered by a custom OTP logic integrated via SMTP to prevent unauthorized access. Additionally, the platform supports administrative efficiency through a bulk upload feature for processing large datasets via Excel.

Architecture Diagram



This AWS architecture represents a highly available, multi-tiered web application deployed across two Availability Zones (AZs) within a single Region. It utilizes a containerized approach for the application layer and a managed relational database for the data layer, all supported by a modern CI/CD pipeline.

Core Components & Purpose

- Frontend/Backend: Flask Application (Dockerized).
- Database: Amazon RDS (MySQL).
- Storage: Amazon S3 (Profile Images).
- Traffic: Application Load Balancer (ALB).
- Auth: Google SMTP.

Infrastructure & Networking

- VPC (Virtual Private Cloud): Provides a logically isolated section of the AWS Cloud where you can launch AWS resources in a defined virtual network.
- Public Subnets: Host the Application Load Balancer (ALB), which acts as the single point of contact for clients and distributes incoming application traffic across multiple targets.
- Private Subnets: Host the application containers and database instances, shielding them from direct internet access for enhanced security.
- Availability Zones (AZ1 & AZ2): Ensure high availability and fault tolerance; if one AZ fails, the application remains operational in the other.

Component	Resource Name	CIDR/Setting	Purpose
VPC	Hostel-VPC	10.0.0.0/16	Network Isolation
Public Subnet	subnet-public-1/2	10.0.0.0/20	Hosts Load Balancer
Private Subnet	subnet-private-1/2	10.0.128.0/20	Hosts App Containers
Availability Zones	us-east-1a, us-east-1b	Multi-AZ	High Availability

Application & Data Layer

- Amazon ECS (Elastic Container Service): Orchestrates and runs containerized applications (often using AWS Fargate for serverless management).
- Amazon RDS (Relational Database Service): A managed database service that, in this "Multi-AZ" setup, maintains a primary instance in one AZ and a standby in another for automatic failover.
- Amazon S3: Used for scalable object storage, typically for static assets or backups.
- AWS Secrets Manager: Securely stores and manages sensitive information like database credentials and API keys.

DevOps & Integration

- GitHub Actions: Automates the CI/CD workflow, triggering builds and deployments whenever code changes are pushed to the repository.
- Amazon ECR (Elastic Container Registry): A fully managed Docker container registry used to store and manage container images.
- AWS Cloud9: A cloud-based IDE used by developers to write, run, and debug code directly within the AWS environment.
- SMTP (Simple Mail Transfer Protocol): A standard email sending service used by the application to send notifications or transactional emails through an email server.

Technology Stack Summary

Layer	Technology
Language	Python 3.11 (Flask Framework)
Frontend	HTML5, CSS3 (Particles.js), Bootstrap 5
Container Engine	Docker
Orchestrator	AWS Fargate (Serverless ECS)
Database	Amazon RDS (MySQL 8.0)
Cloud Storage	Amazon S3
Email Service	Google SMTP
Infrastructure	VPC, Internet Gateway, ALB
CI/CD	GitHub Actions

DevOps & CI/CD Pipeline

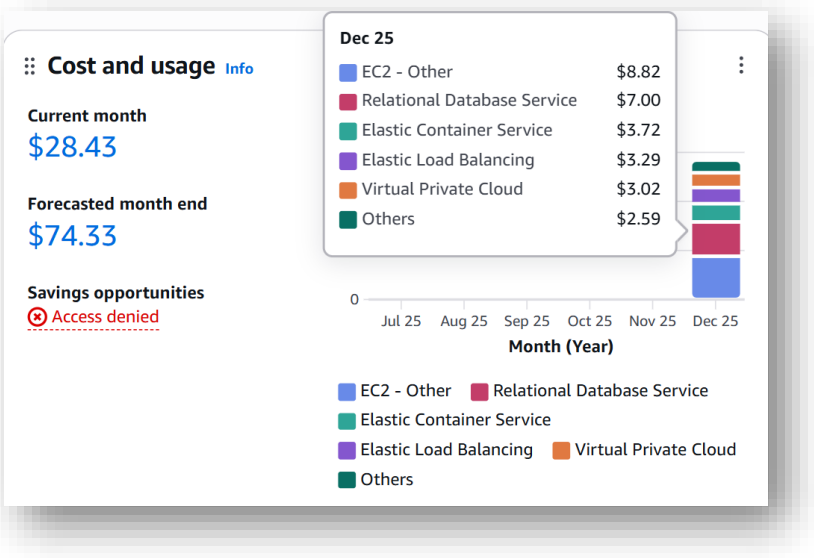
We moved away from manual deployments to a modern GitOps workflow.

- Source Control: GitHub (main branch).
- Pipeline Orchestrator: GitHub Actions.
- Container Registry: Amazon ECR.

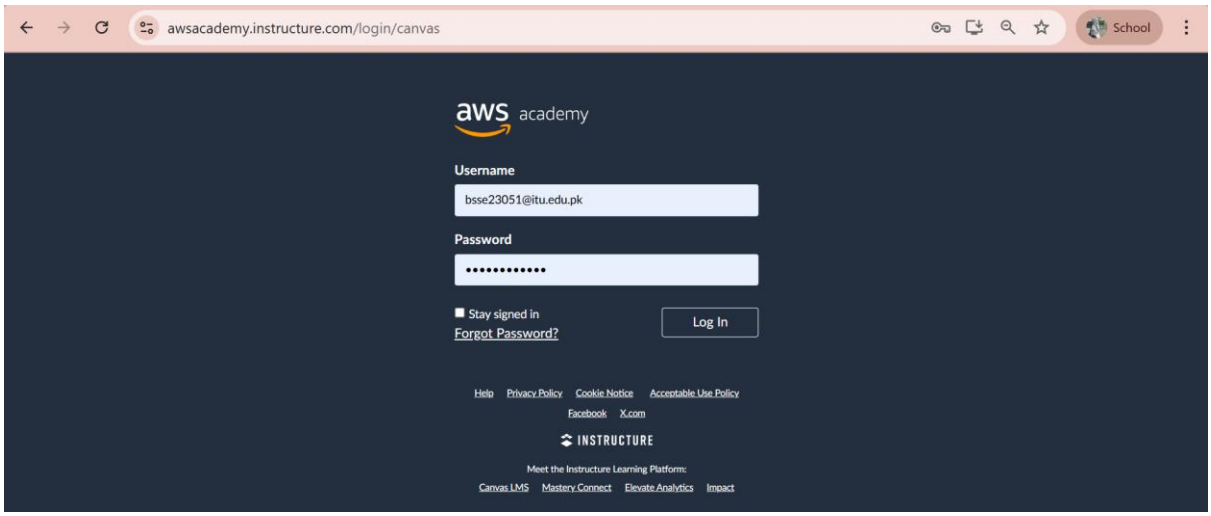
The Pipeline (deploy.yml) Workflow:

1. Trigger: Developer pushes code to GitHub.
2. Checkout: GitHub Runner pulls the latest code.
3. Auth: Runner authenticates with AWS using secure Secrets (AWS_ACCESS_KEY_ID, etc.).
4. Build: Docker image is built from the Dockerfile.
5. Push: Image is tagged and pushed to Amazon ECR.
6. Deploy: The runner commands AWS ECS to update the service. ECS drains old connections and spins up new Fargate tasks with the updated image.

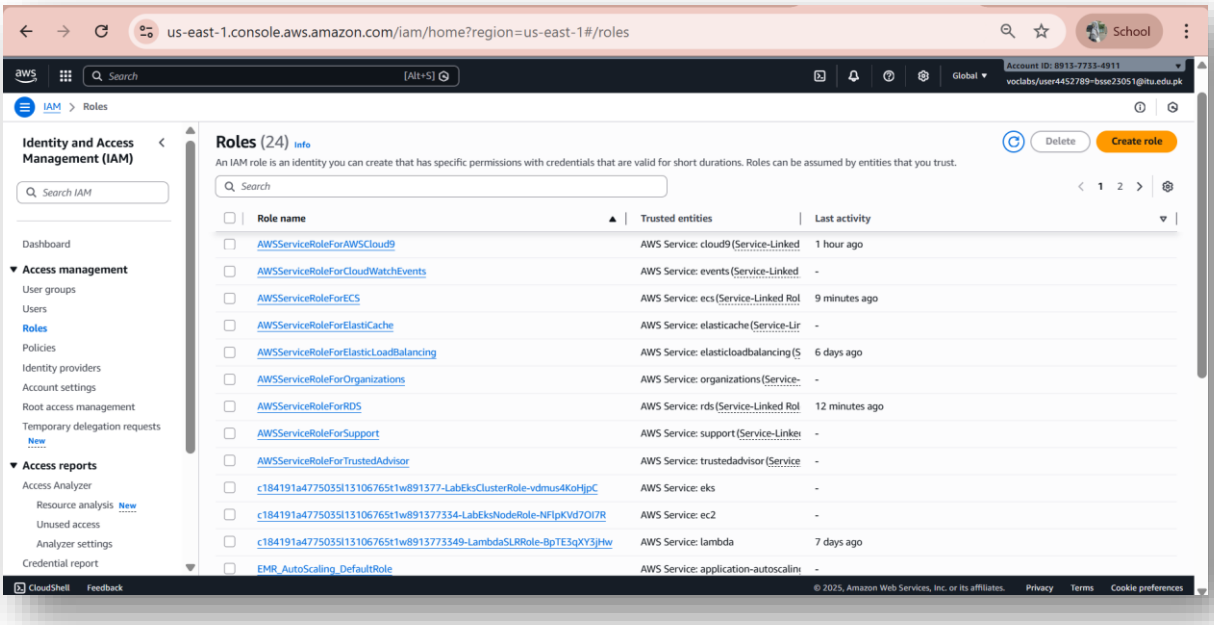
AWS Architecture Design, Implementation and Screenshots



AWS account setup

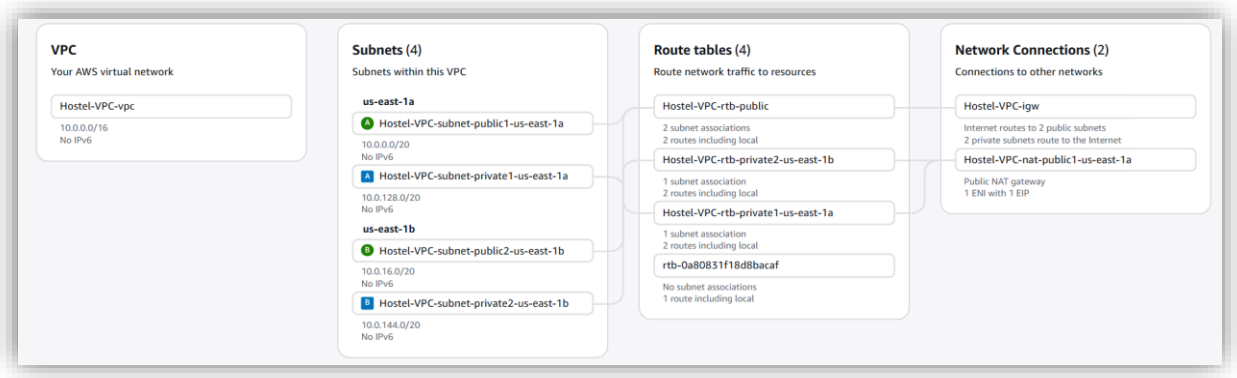


IAM roles and policies

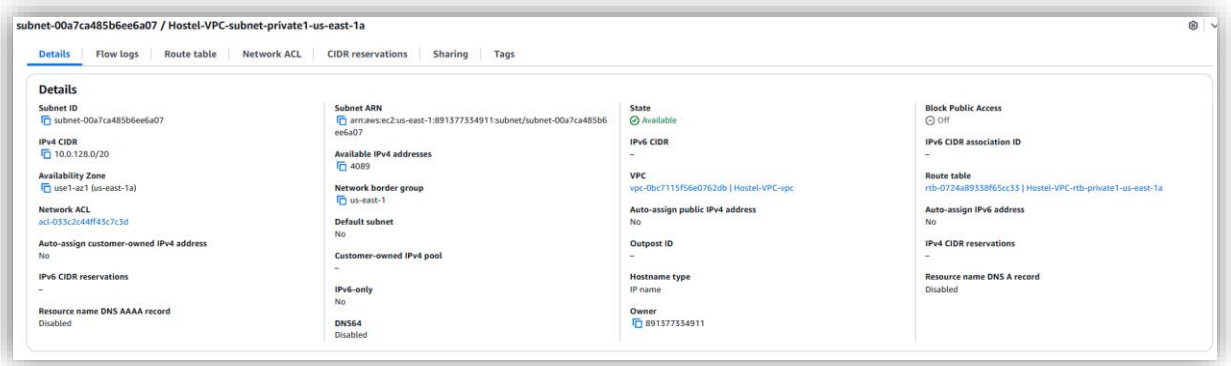


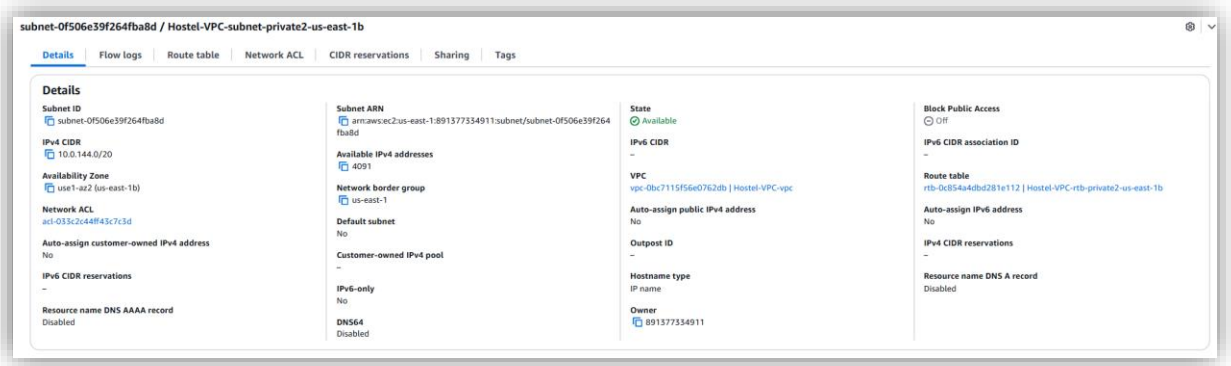
VPC/subnets/security groups

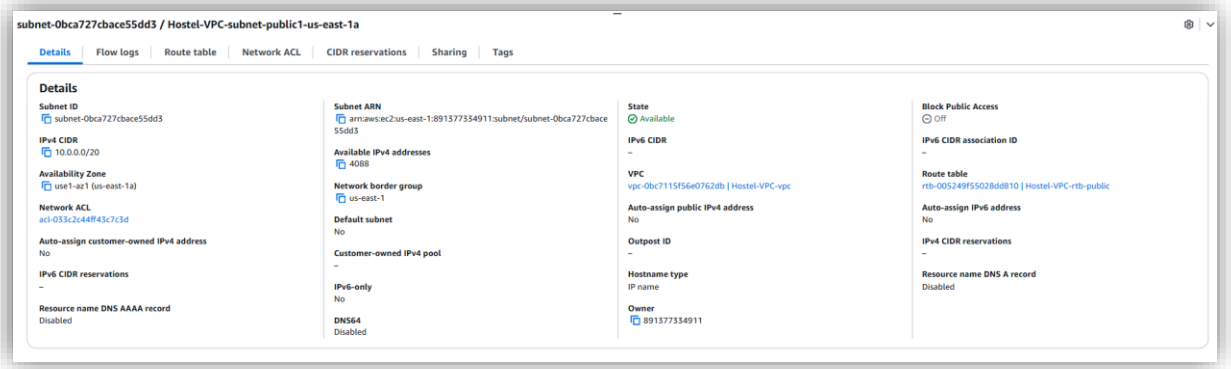
VPC

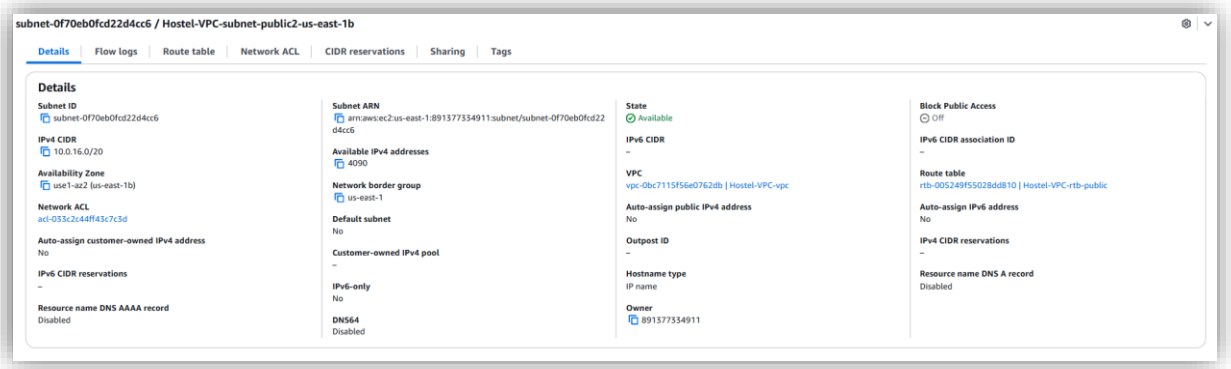


SUBNETS (PRIVATE AND PUBLIC)

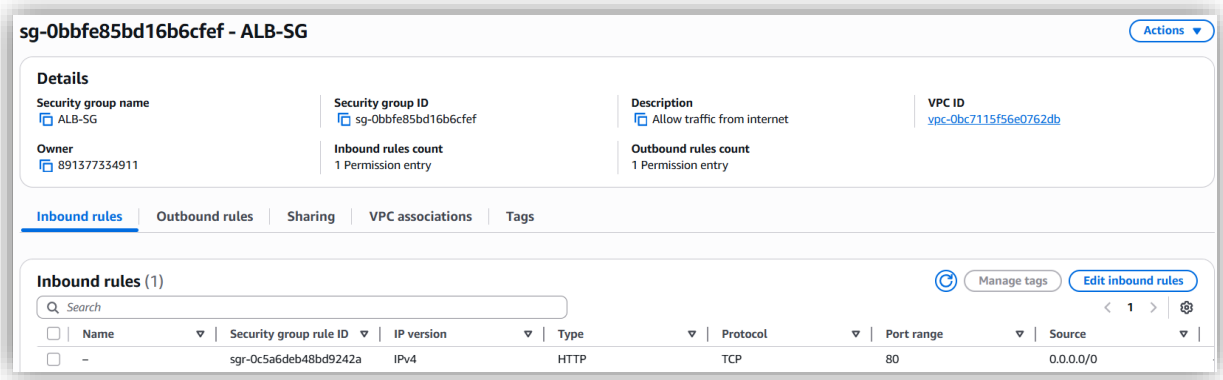








SECURITY GROUPS (ALB – APP – CLOUD9 – DB)



sg-0bbfe85bd16b6cfef - ALB-SG

Actions

Details

Security group name	Security group ID	Description	VPC ID
ALB-SG	sg-0bbfe85bd16b6cfef	Allow traffic from internet	vpc-0bc7115f56e0762db

Owner	Inbound rules count	Outbound rules count
891377334911	1 Permission entry	1 Permission entry

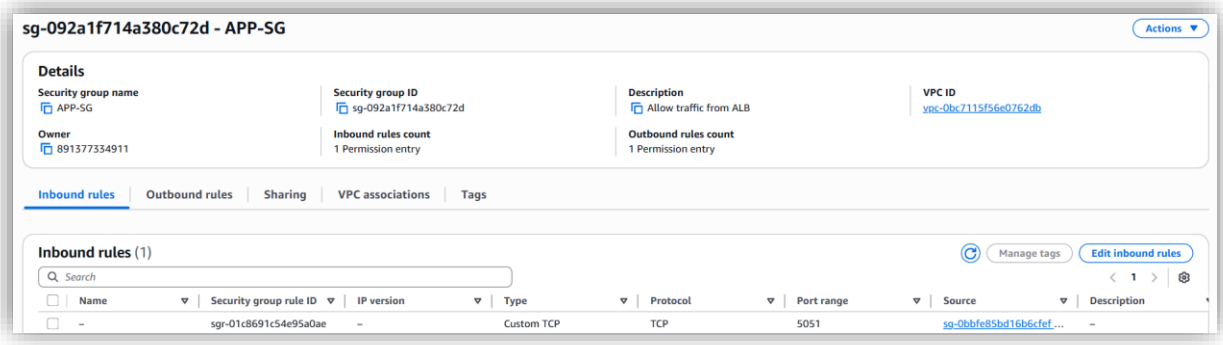
Inbound rules | Outbound rules | Sharing | VPC associations | Tags

Inbound rules (1)

Manage tags | Edit inbound rules

Search

Name	Security group rule ID	IP version	Type	Protocol	Port range	Source
–	sgr-0c5a6deb48bd9242a	IPv4	HTTP	TCP	80	0.0.0.0/0



sg-092a1f714a380c72d - APP-SG

Actions

Details

Security group name	Security group ID	Description	VPC ID
APP-SG	sg-092a1f714a380c72d	Allow traffic from ALB	vpc-0bc7115f56e0762db

Owner	Inbound rules count	Outbound rules count
891377334911	1 Permission entry	1 Permission entry

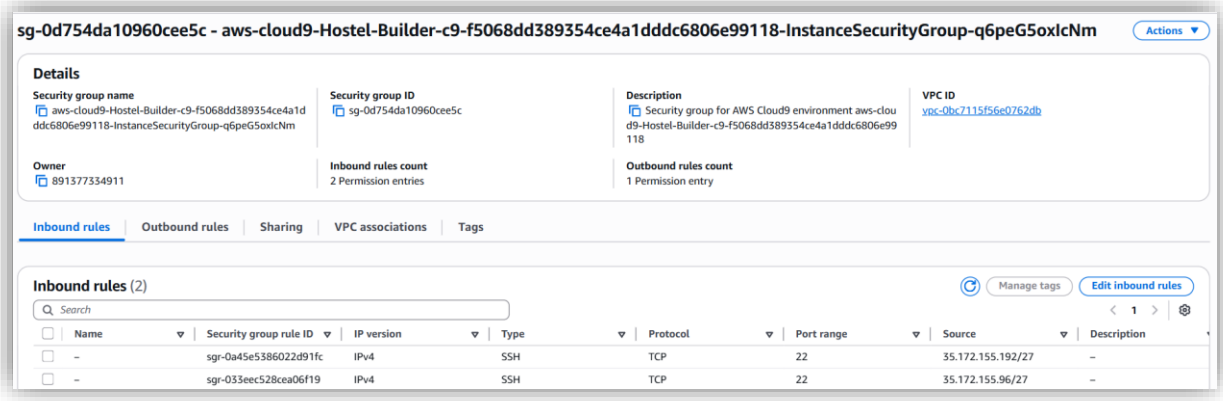
Inbound rules | Outbound rules | Sharing | VPC associations | Tags

Inbound rules (1)

Manage tags | Edit inbound rules

Search

Name	Security group rule ID	IP version	Type	Protocol	Port range	Source	Description
–	sgr-01c8691c54e95a0ae	–	Custom TCP	TCP	5051	sg-0bbfe85bd16b6cfef ...	–



sg-0d754da10960cee5c - aws-cloud9-Hostel-Builder-c9-f5068dd389354ce4a1dddc6806e99118-InstanceSecurityGroup-q6peG5oxlcNm

Actions

Details

Security group name	Security group ID	Description	VPC ID
aws-cloud9-Hostel-Builder-c9-f5068dd389354ce4a1dddc6806e99118-InstanceSecurityGroup-q6peG5oxlcNm	sg-0d754da10960cee5c	Security group for AWS Cloud9 environment aws-cloud9-Hostel-Builder-c9-f5068dd389354ce4a1dddc6806e99118	vpc-0bc7115f56e0762db

Owner	Inbound rules count	Outbound rules count
891377334911	2 Permission entries	1 Permission entry

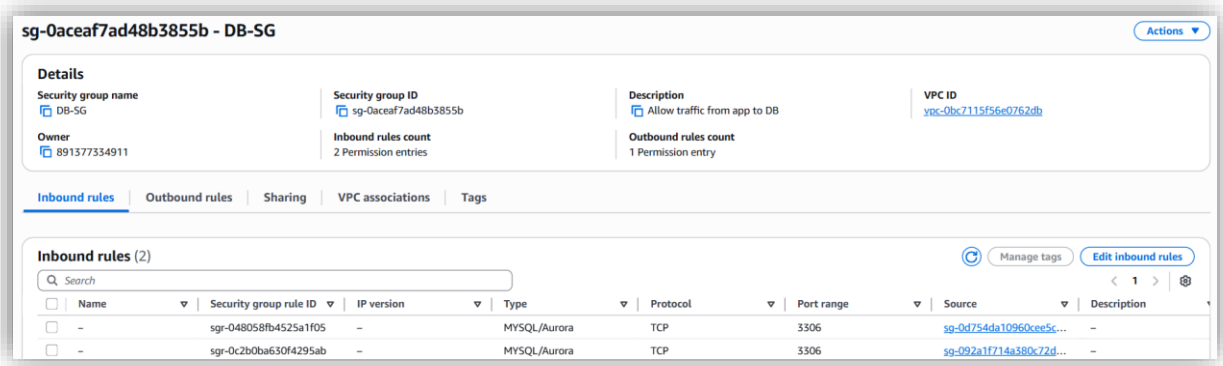
Inbound rules | Outbound rules | Sharing | VPC associations | Tags

Inbound rules (2)

Manage tags | Edit inbound rules

Search

Name	Security group rule ID	IP version	Type	Protocol	Port range	Source	Description
–	sgr-0a45e5386022d91fc	IPv4	SSH	TCP	22	35.172.155.192/27	–
–	sgr-033eec528cea06f19	IPv4	SSH	TCP	22	35.172.155.96/27	–



sg-0aceaf7ad48b3855b - DB-SG

Actions

Details

Security group name	Security group ID	Description	VPC ID
DB-SG	sg-0aceaf7ad48b3855b	Allow traffic from app to DB	vpc-0bc7115f56e0762db

Owner	Inbound rules count	Outbound rules count
891377334911	2 Permission entries	1 Permission entry

Inbound rules | Outbound rules | Sharing | VPC associations | Tags

Inbound rules (2)

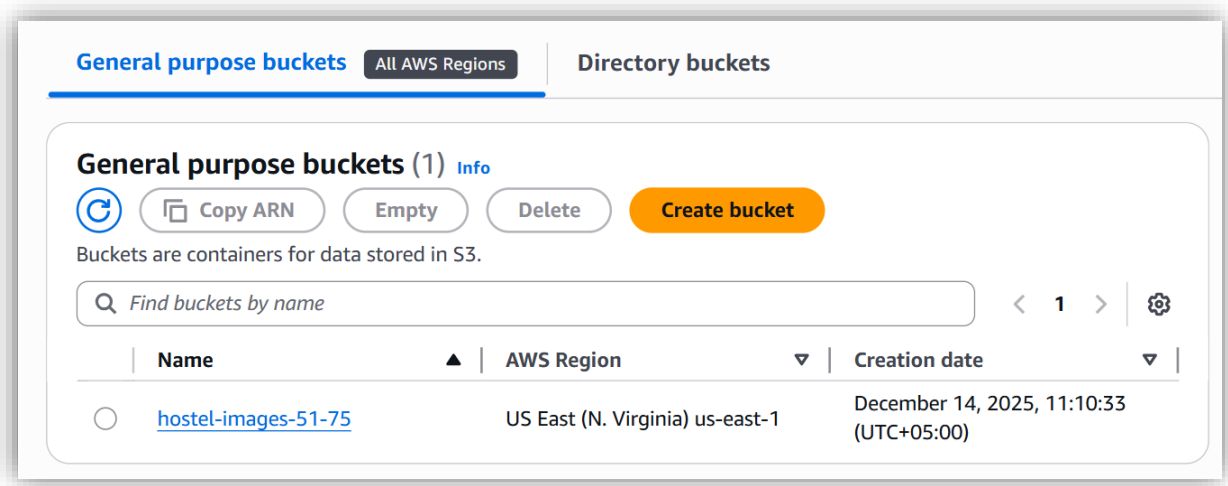
Manage tags | Edit inbound rules

Search

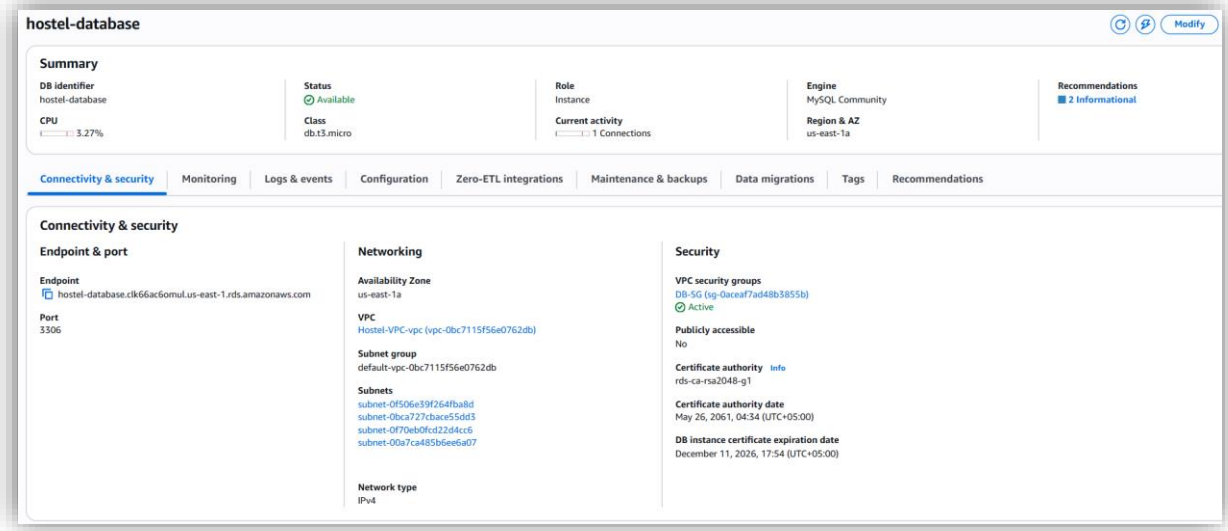
Name	Security group rule ID	IP version	Type	Protocol	Port range	Source	Description
–	sgr-048058fb4525a1f05	–	MYSQL/Aurora	TCP	3306	sg-0d754da10960cee5c...	–
–	sgr-0c2b0ba630f4295ab	–	MYSQL/Aurora	TCP	3306	sg-092a1f714a380c72d...	–

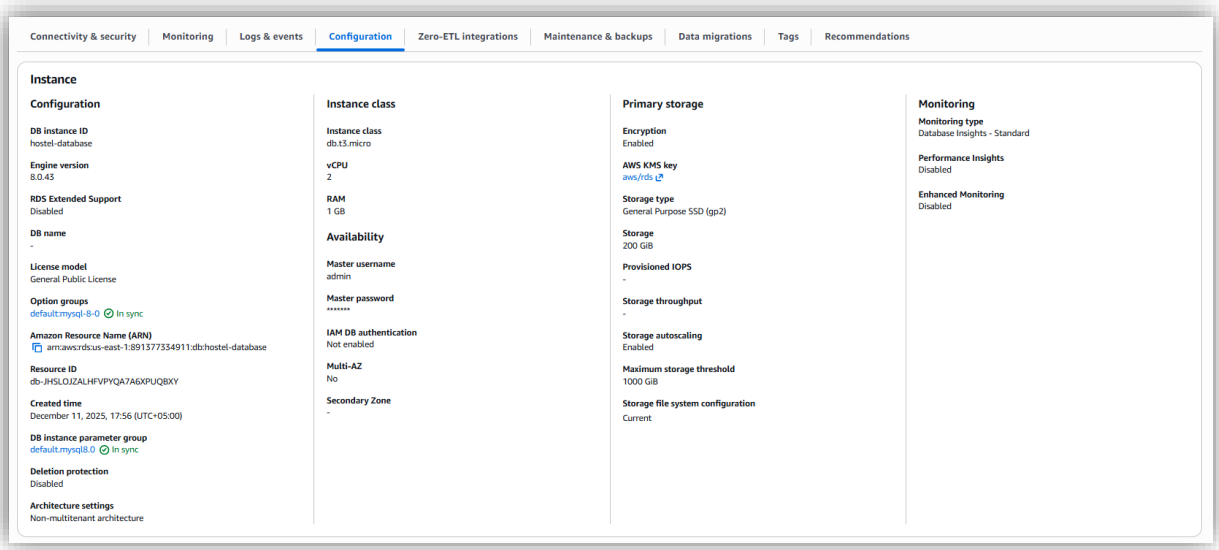
Used services

S3



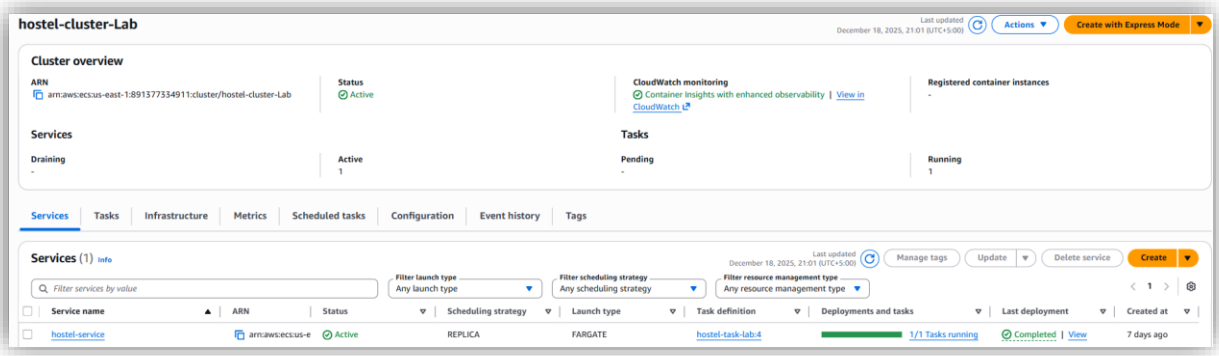
RDS

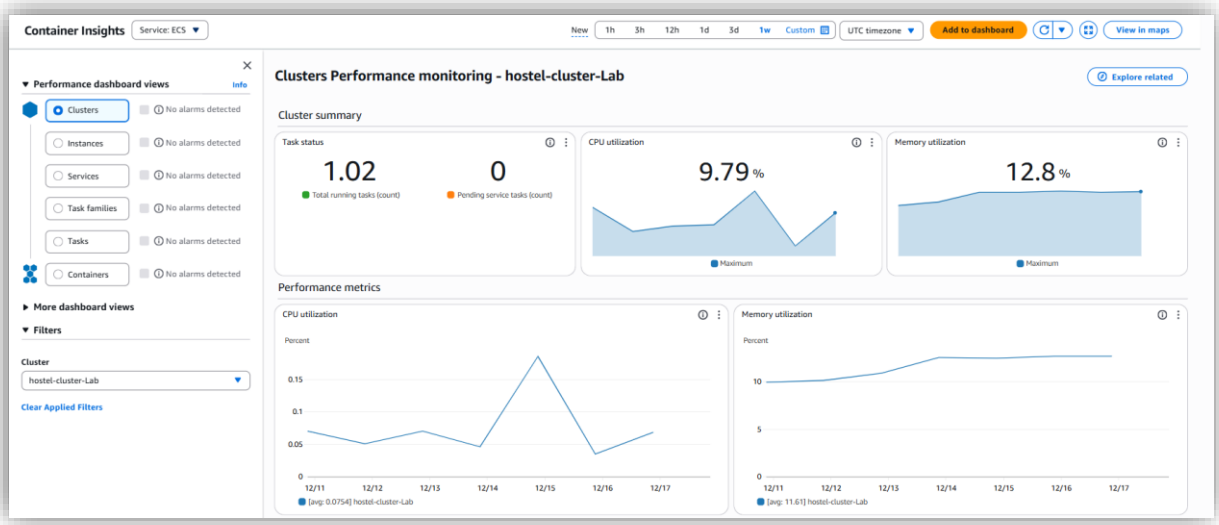


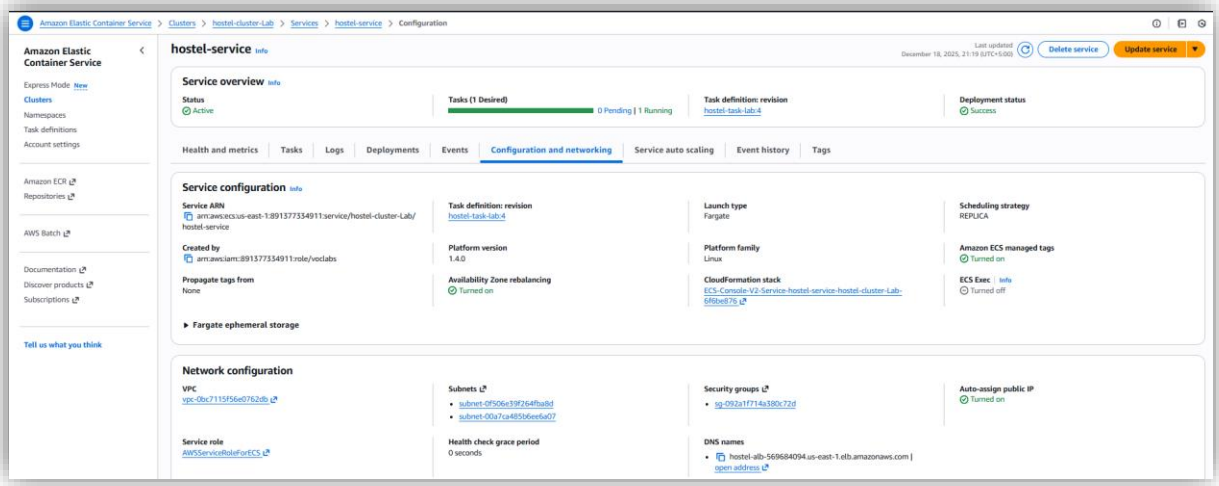


Deployment process

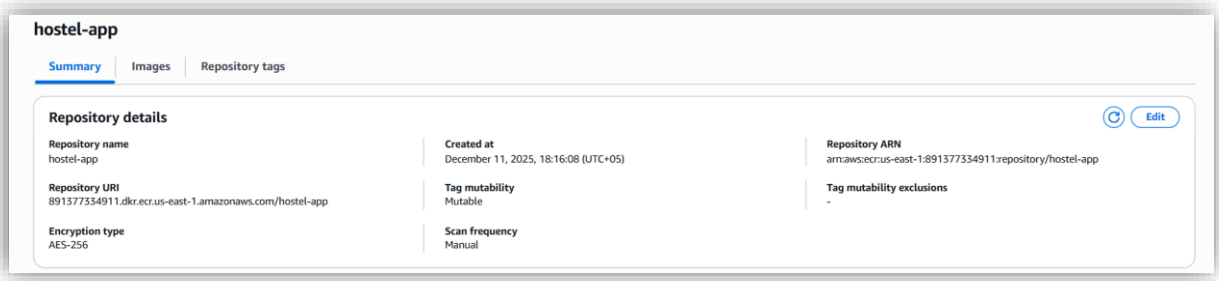
ECS-CLUSTER

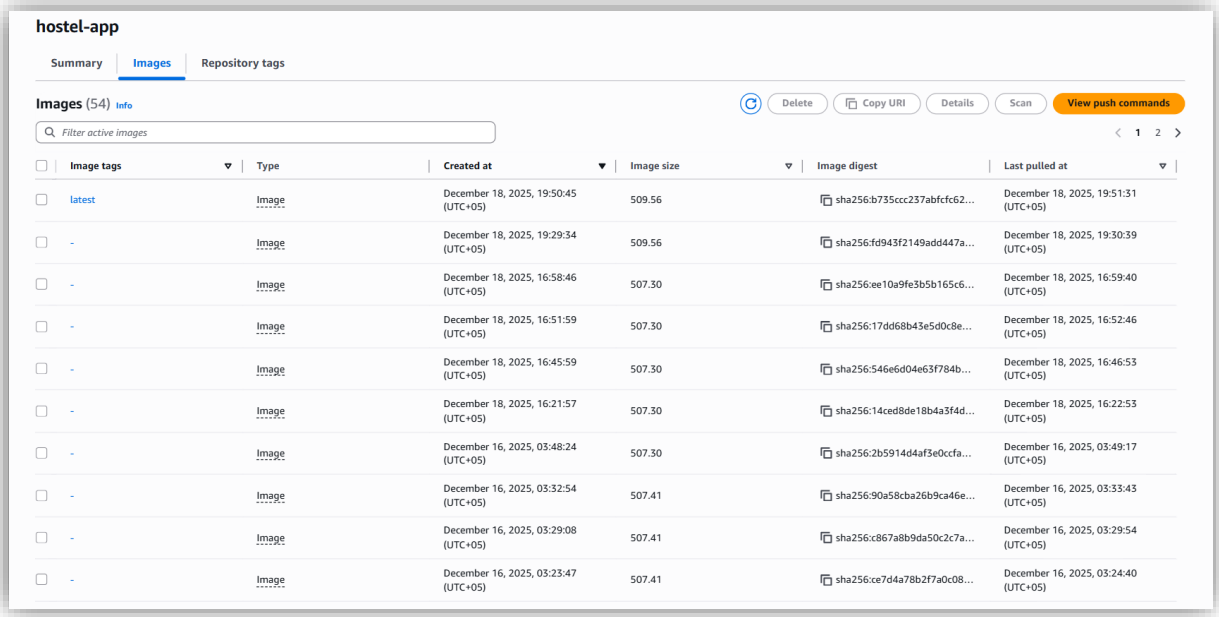




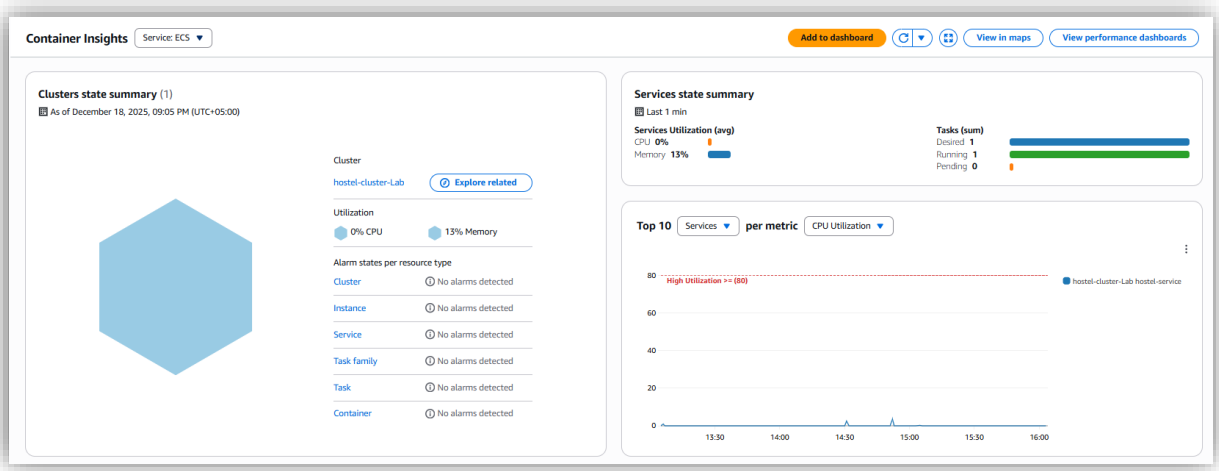


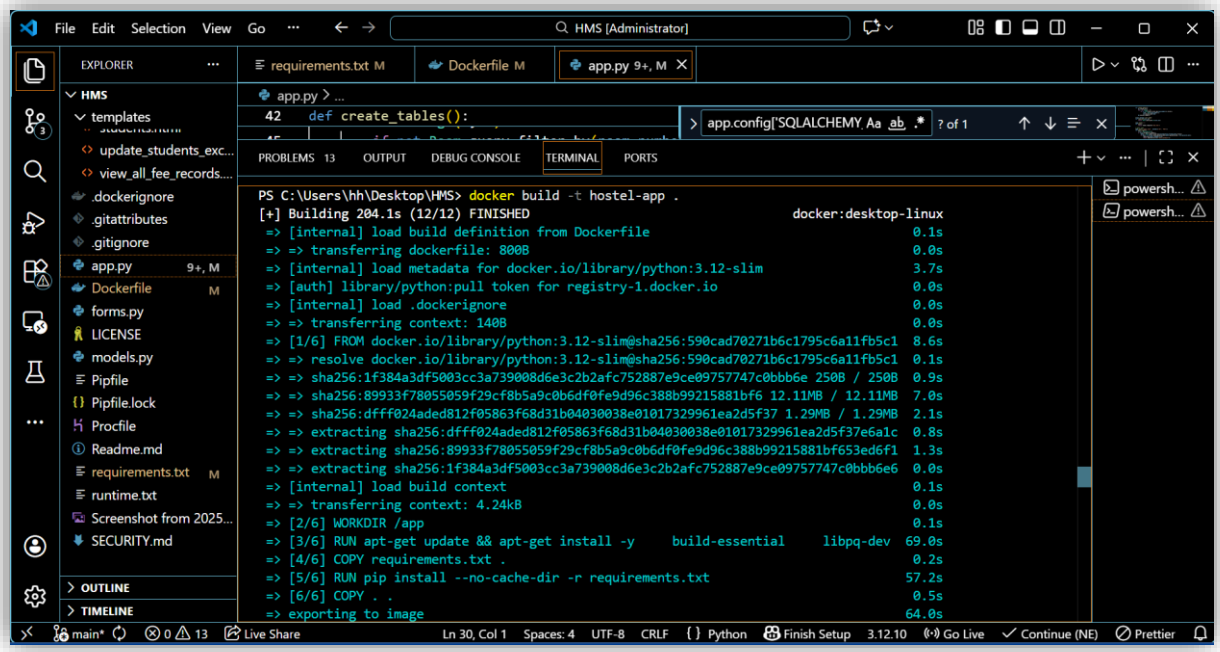
ECR- REPOSITORY

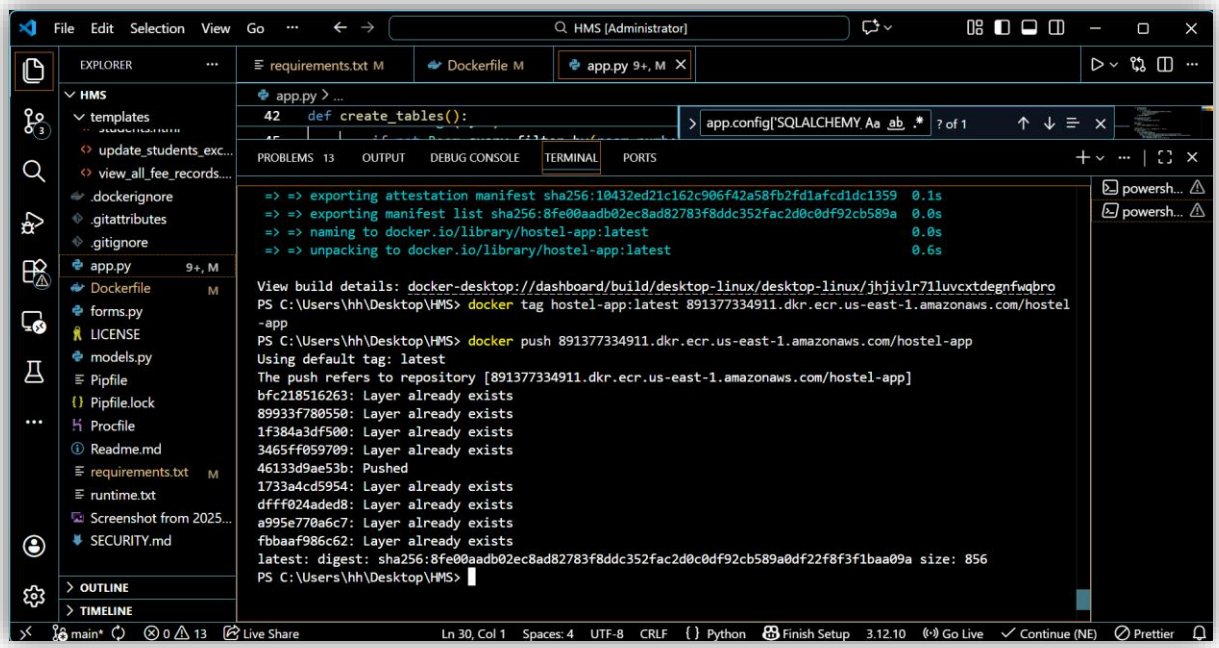




Testing workflow



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HMS [Administrator]
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Pipfile.lock
Procfile
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runtime.txt
Screenshot from 2025...
SECURITY.md
OUTLINE
TIMELINE
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42 def create_tables():
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PROBLEMS 13
OUTPUT
DEBUG CONSOLE
TERMINAL
PORTS
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=> => exporting manifest list sha256:8fe00aadb02ec8ad82783f8ddc352fac2d0c0df92cb589a 0.0s
=> => naming to docker.io/library/hostel-app:latest 0.0s
=> => unpacking to docker.io/library/hostel-app:latest 0.6s
View build details: docker-desktop://dashboard/build/desktop-linux/desktop-linux/jhjivlr71luvcxtdegnfwqbro
PS C:\Users\hh\Desktop\HMS> docker tag hostel-app:latest 891377334911.dkr.ecr.us-east-1.amazonaws.com/hostel-app
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Using default tag: latest
The push refers to repository [891377334911.dkr.ecr.us-east-1.amazonaws.com/hostel-app]
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89933f780550: Layer already exists
1f384a3df500: Layer already exists
3465ff059709: Layer already exists
46133d9ae53b: Pushed
1733a4cd5954: Layer already exists
dfff024aded8: Layer already exists
a995e770a6c7: Layer already exists
fbbaaf986c62: Layer already exists
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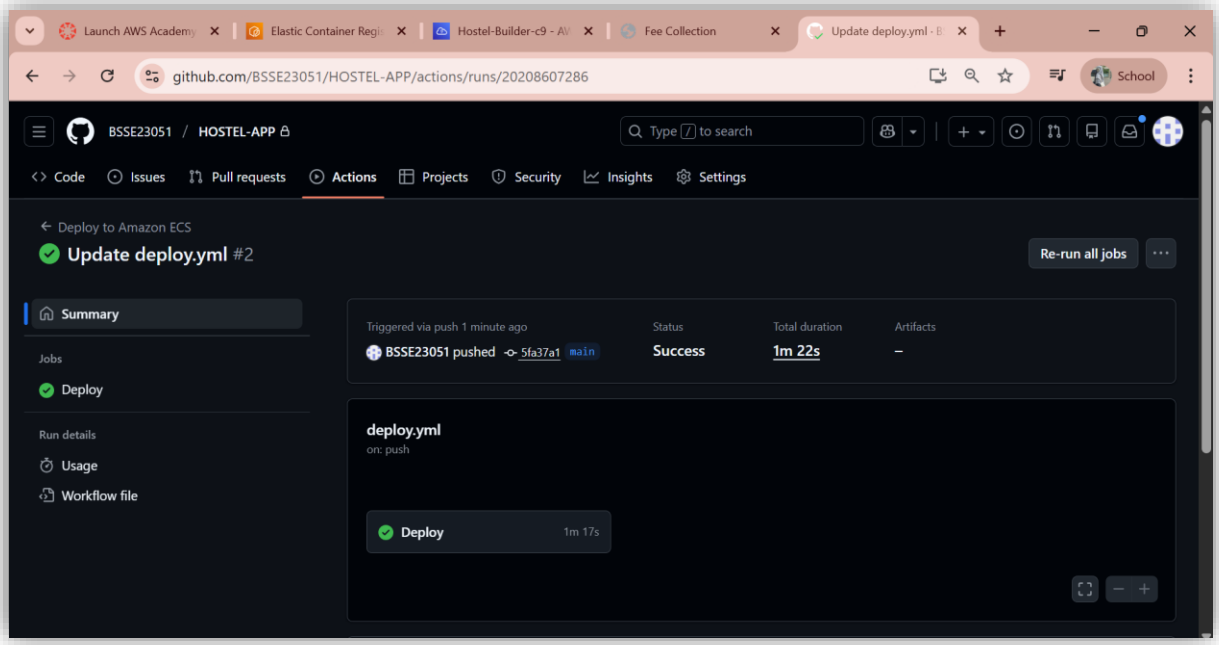
powersh...
powersh...
main*
Live Share
Ln 30, Col 1
Spaces: 4
UTF-8
CRLF
Python
Finish Setup
3.12.10
Go Live
Continue (NE)
Prettier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BSSE23051 / HOSTEL-APP
Code
Issues
Pull requests
Actions
Projects
Security
Insights
Settings
Deploy to Amazon ECS
Update deploy.yml #2
Re-run all jobs
Summary
Jobs
Deploy
Run details
Usage
Workflow file
Triggered via push 1 minute ago
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Success
Total duration
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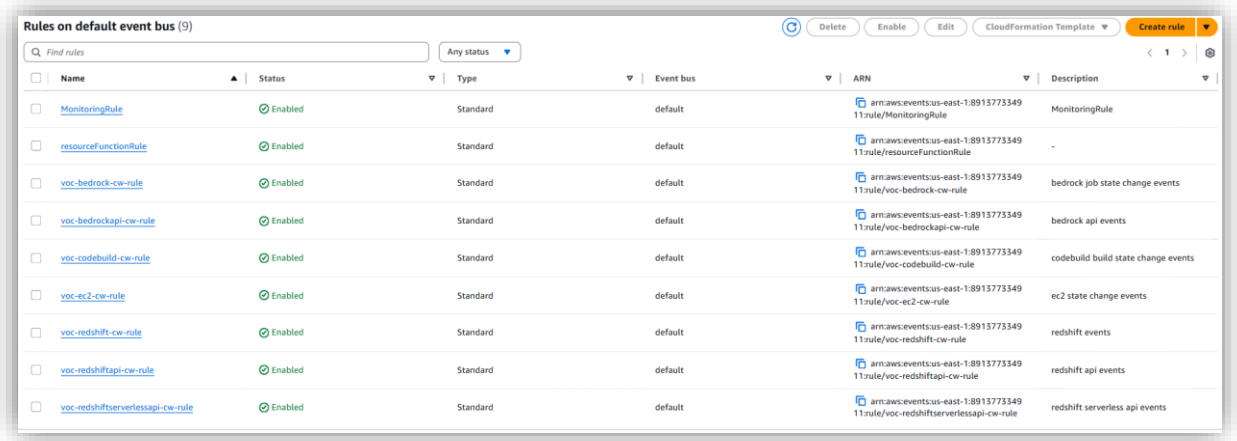
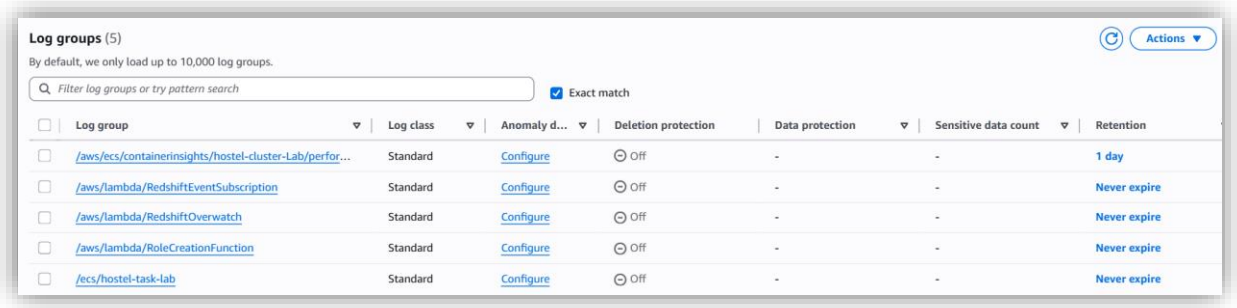
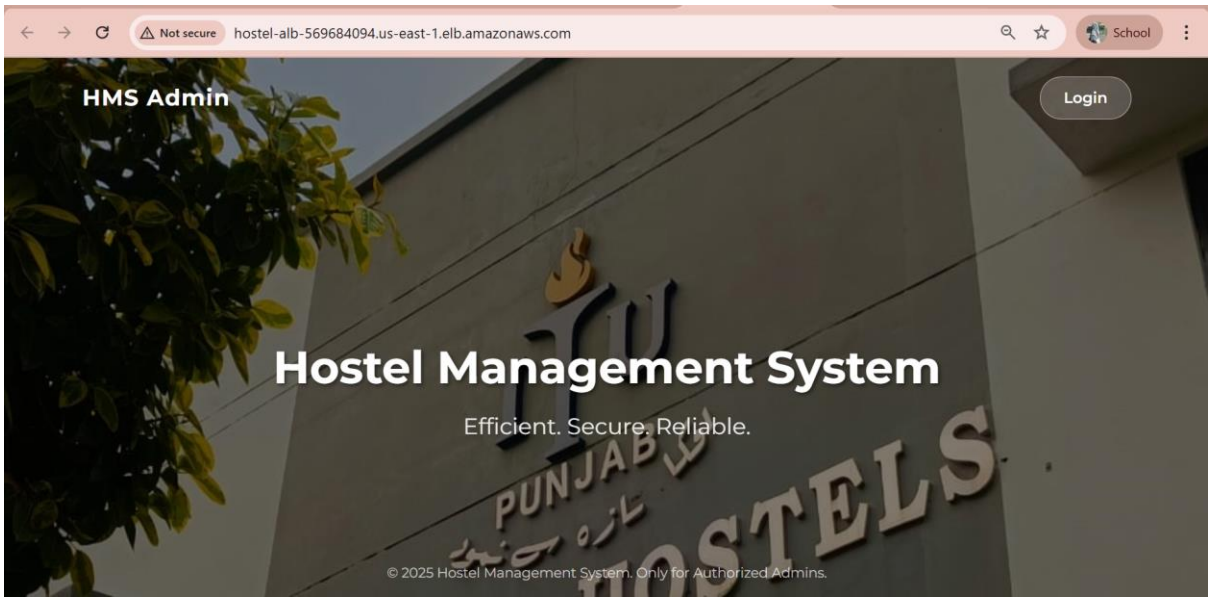
deploy.yml
on: push
Deploy
1m 17s

Monitoring / logging (CloudWatch)





Final output



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References:

Adzic, G., & Chatley, R. (2017). Serverless computing: Economic and architectural impact. *Proceedings of the 2017 11th Joint Meeting on Foundations of Software Engineering*, *11*(1), 884–889. https://doi.org/10.1145/3106237.3117767

Di Francesco, P., Malavolta, I., & Lago, P. (2019). Architecting microservices: A systematic mapping study. *Journal of Systems and Software*, *150*(1), 77–97. https://doi.org/10.1016/j.jss.2019.01.001

Merkel, D. (2014). Docker: Lightweight Linux containers for consistent development and deployment. *Linux Journal*, *2014*(239), 2–2. https://dl.acm.org/doi/10.5555/2600239.2600241

Shahin, M., Babar, M. A., & Zhu, L. (2017). Continuous integration, delivery and deployment: A systematic review on approaches, tools, challenges and practices. *IEEE Access*, *5*(1), 3909–3943. https://doi.org/10.1109/ACCESS.2017.2685629

Varghese, B., & Buyya, R. (2018). Next generation cloud computing: New trends and research directions. *Future Generation Computer Systems*, *79*(1), 849–861. https://doi.org/10.1016/j.future.2017.09.020