Cloud Computing Assignment Report

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Course: Cloud Computing (WS2024/25)

University of Vienna

1. Introduction

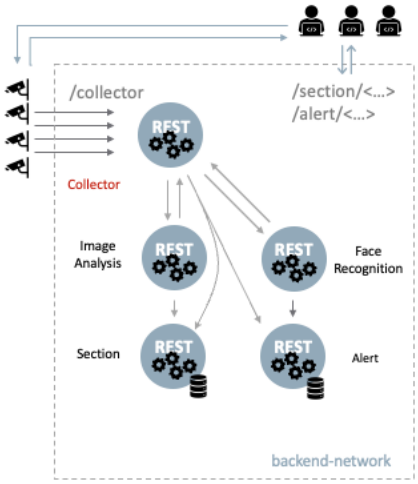
This assignment involved designing, implementing, deploying, scaling, and cost-estimating a microservice-based camera processing system using **Google Kubernetes Engine (GKE)**.

The architecture consists of six services:

1. **Camera** – Sends simulated frames.
2. **Collector** – *Implemented by me* (primary coding task).
3. **Image Analysis** – Detects persons from images.
4. **Face Recognition** – Detects known persons.
5. **Section** – Stores person-related events.
6. **Alert** – Stores alerts for known persons.

Goal of the system:
Camera → Collector → Image Analysis & Face Recognition → Section & Alert

I implemented the full Collector service using Flask, including logic to forward data to downstream services. All services were deployed into a Kubernetes namespace (assignment), with autoscaling configured via Horizontal Pod Autoscalers (HPAs), resource limits and requests defined, Ingress routing set up, and cost estimates calculated using the Google Cloud Pricing Calculator.



2. Implementation Details

2.1 Collector Service Implementation (my contribution)

Technologies used

- **Flask** (HTTP server)
- **requests** library (HTTP client for forwarding)
- **Kubernetes-ready Dockerfile**
- **Liveness/Readiness probes**
- **JSON forwarding to other services**

Collector responsibilities

- Receive frames from Camera
- Forward frame to Image Analysis
- Forward frame to Face Recognition
- Forward results to Section (persons detected)
- Forward known persons to Alert

Why synchronous communication?

My implementation uses **synchronous HTTP calls** (Flask + requests).
Pros:

- Easy to implement
- Ensures ordered processing
  Cons:
- Blocking requests → lower throughput
- Slower if Image Analysis takes time

Possible improvement:

Use **FastAPI + aiohttp** or a **message queue (Kafka/PubSub)** to allow asynchronous processing.

2.2 Communication Flow in Kubernetes

Inside the cluster, services communicate via **ClusterIP**:

- http://image-analysis:80/frame
- http://face-recognition:80/frame
- http://section:80/persons
- http://alert:80/alerts

Kubernetes DNS resolves service names automatically within the assignment namespace.

Flow:

1. Camera → Collector (/frame)
2. Collector → Image Analysis
3. Collector → Face Recognition
4. Collector → Section
5. Collector → Alert

2.3 Scalability & Bottlenecks

I deployed HPAs:

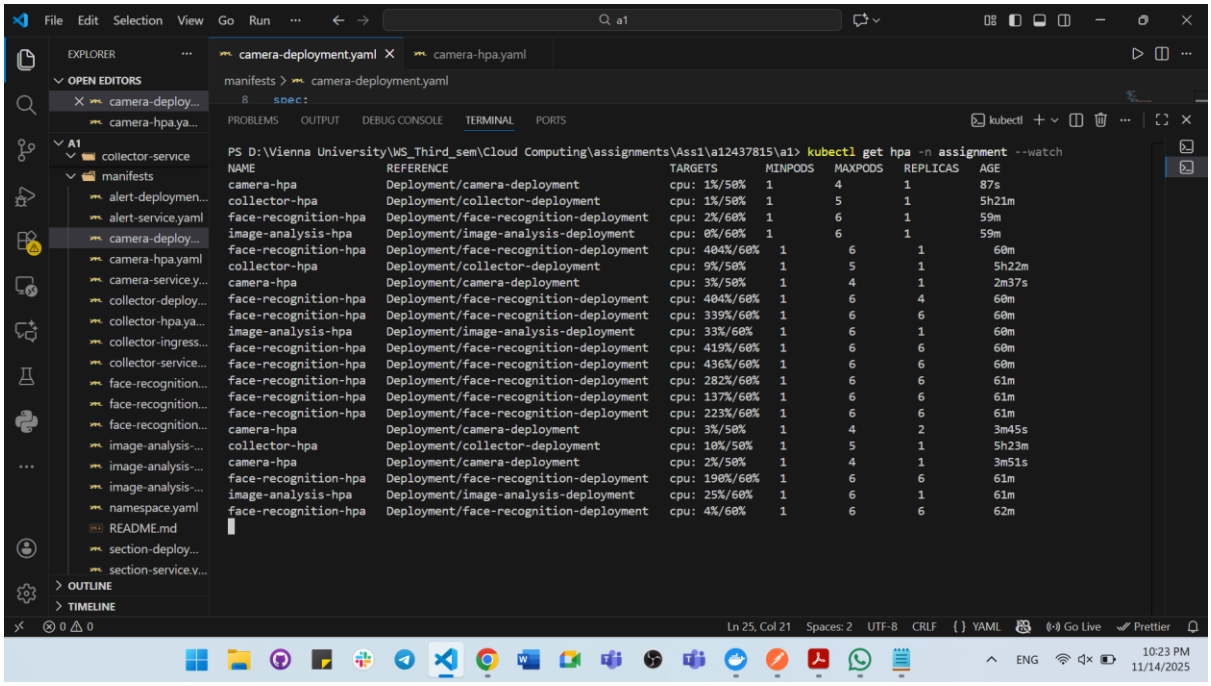
- Camera
- Collector
- Image Analysis
- Face Recognition

Findings

- **Image Analysis** = highest CPU & memory usage (up to 1 CPU, 1Gi RAM).
- **Collector** uses low CPU but increases when many cameras stream at once.
- **Camera** autoscaled correctly (1 → 4 replicas at ~50% CPU).
- **Face Recognition** scaled moderately but stayed stable.

Main bottleneck

Image Analysis due to heavy computation per frame, its resource usage grows nonlinearly with more cameras.



2.4 Kubernetes Objects

Deployments

Each service has its own Deployment with replica settings.

Services (ClusterIP)

Used for internal communication between services.

Ingress

Ingress routes configured as follows:

- /collector/* → collector-service
- /image-analysis/*
- /face-recognition/*
- /section/*
- /alert/*
- /camera/*

The nip.io domain was used to expose services externally, as required by the assignment.

Probes

Collector includes:

- /livenessProbe
- /readinessProbe

Resource Requests & Limits

All services include CPU & memory constraints (required by HPA).
Image Analysis uses highest resources:

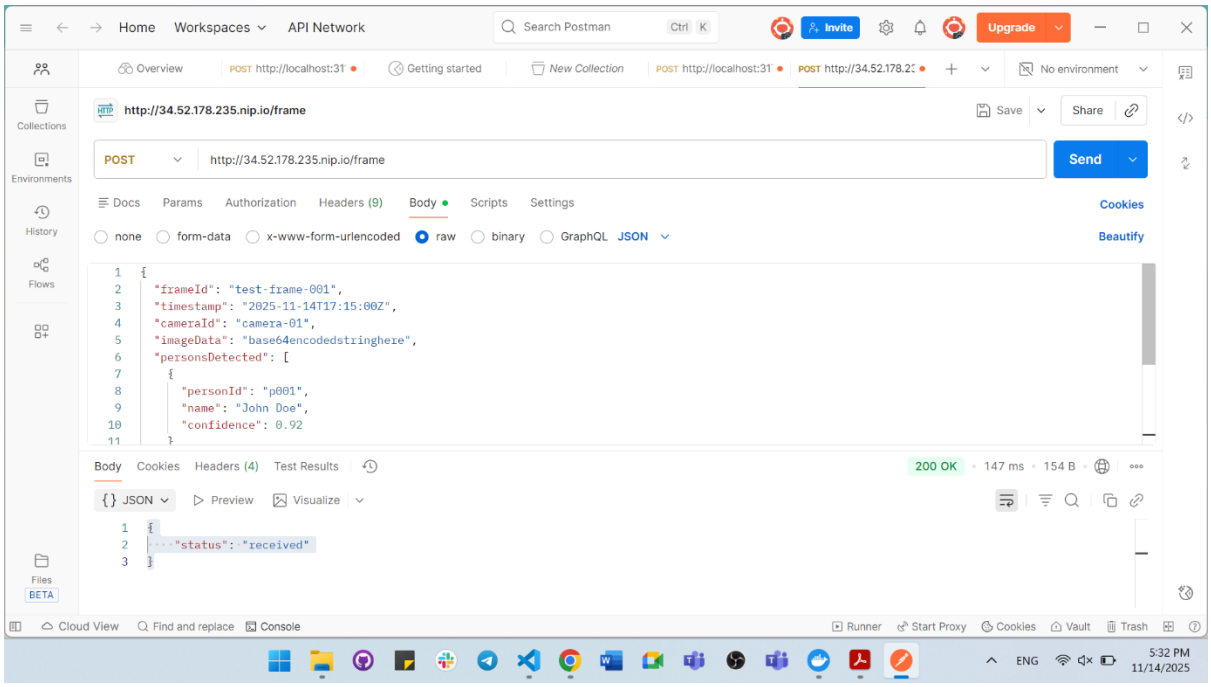
- 500m CPU request → 1 CPU limit
- 512Mi → 1Gi memory.

2.5 Ingress Setup

Ingress Controller: **NGINX**
Namespace: **assignment**
Domain: **34.52.178.235.nip.io**

Purpose:

- Provide external access
- Route traffic to appropriate downstream service
- Enable testing with Postman



3. Cost Analysis

3.1 GKE Standard (Estimated)

Node: **e2-standard-2 (2 vCPU, 8GB RAM)**
1 Node → **$136.50/month**
3 Nodes → **$263.51/month**

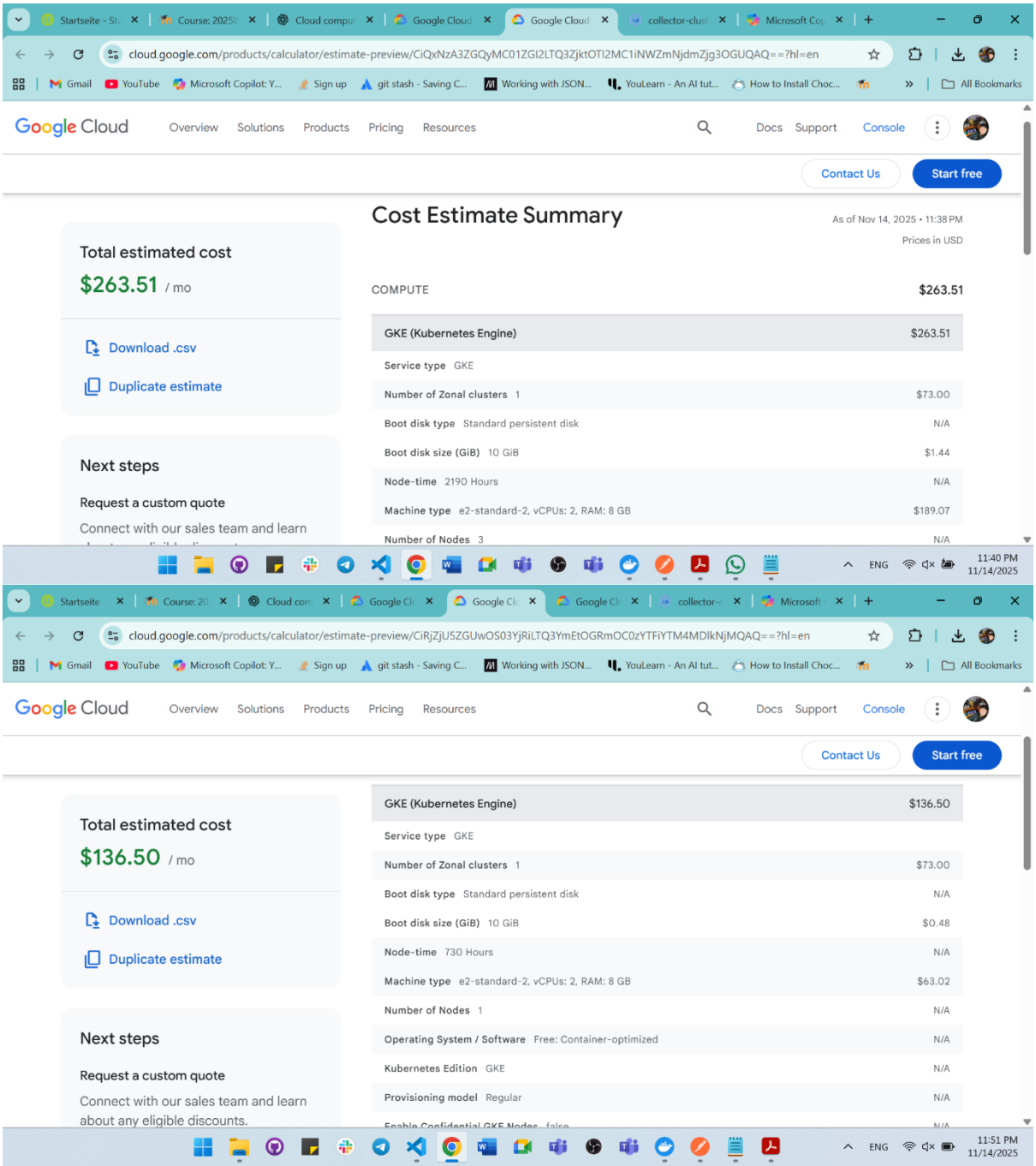
Pros:

- Full control

- Best for complex microservices

Cons:

- You pay for nodes 24/7 even if idle



3.2 GKE Autopilot (Based on the standard estimated)

The workload baseline: ~1.7 vCPU, 2Gi RAM
Autopilot cost: **≈ $150/month**

Pros:

- No node management
- Bills per Pod, not machine

Cons:

- Higher cost if large clusters

3.3 Cloud Run (Based on standard)

For REST services like Collector/Camera/Section/Alert:

100,000 requests / month → **≈ $20/month**

Pros:

- Cheapest for intermittent traffic
- Auto-scales instantly
- No nodes

Cons:

- Not suitable for stateful heavy ML tasks

3.4 Vision API (Based on standard)

Face detection + label detection
10,000 images / month → **≈ $13.50/month**

Pros:

- Cheapest AI option
- Best performance
- No servers needed

Cons:

- Requires redesign of system

3.5 Cost Comparison Table

Option	Monthly Cost	Annual Cost	Notes
GKE Standard	$136–263	$1,638–3,162	Manual node mgmt
GKE Autopilot	$150	$1,800	Easiest to manage
Cloud Run	$20	$240	Serverless
Vision API	$13.50	$162	Serverless ML

4. Resource Usage

Baseline usage

- ~1.7 vCPU total
- ~2.0 GiB total memory

Peak with scaling

- 3–4 vCPU
- 3 GiB memory

5. Problems Encountered & Solutions

1. Camera HPA showed <unknown>

Cause: missing CPU/memory requests.
Fix: Added requests.

2. Duplicate HPAs

Cause: duplicate application of manifests
Fix: Deleted extra resources → reapplied manifests.

3. Pending pods on Image Analysis

Cause: CPU/memory requests too high.
Fix: Reduced limits OR increased node count.

4. Ingress debugging required

Cause: Regex rewrite rules.
Fix: Added use-regex + rewrite target.

5. Cost estimation confusion

Fix: Clarified difference between node-based billing (Standard) and pod-based billing (Autopilot)

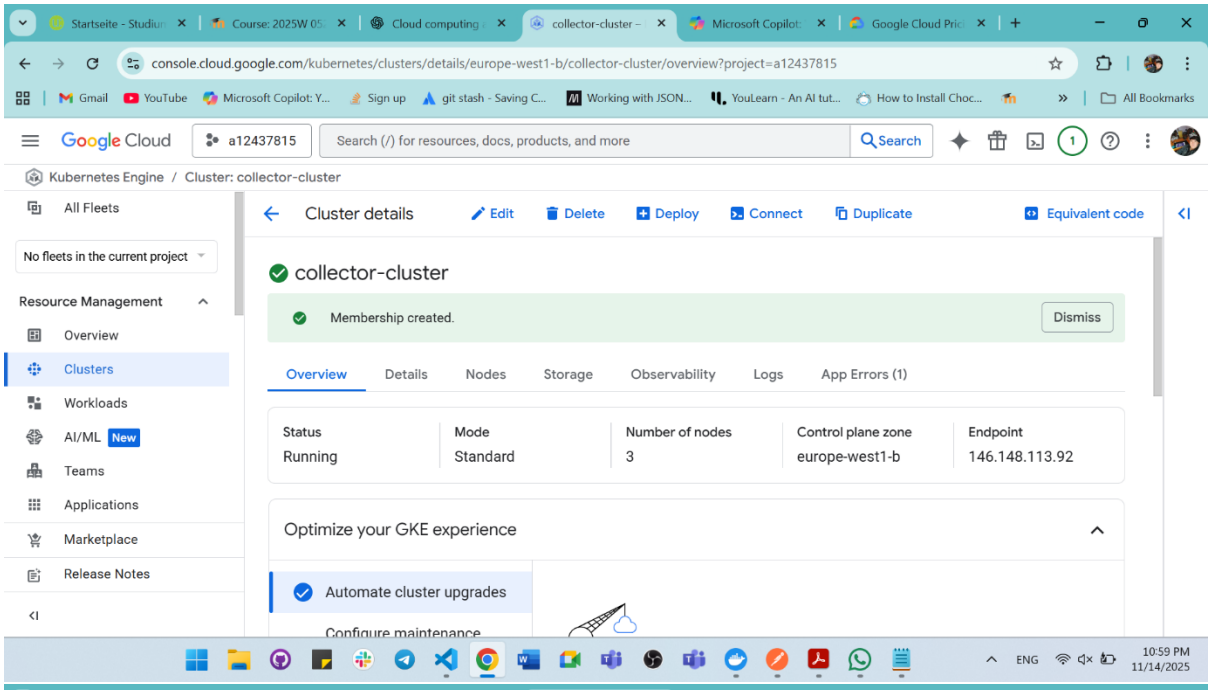
Note: I implemented and tested GKE Standard; the other estimates were based on its resource statistics.

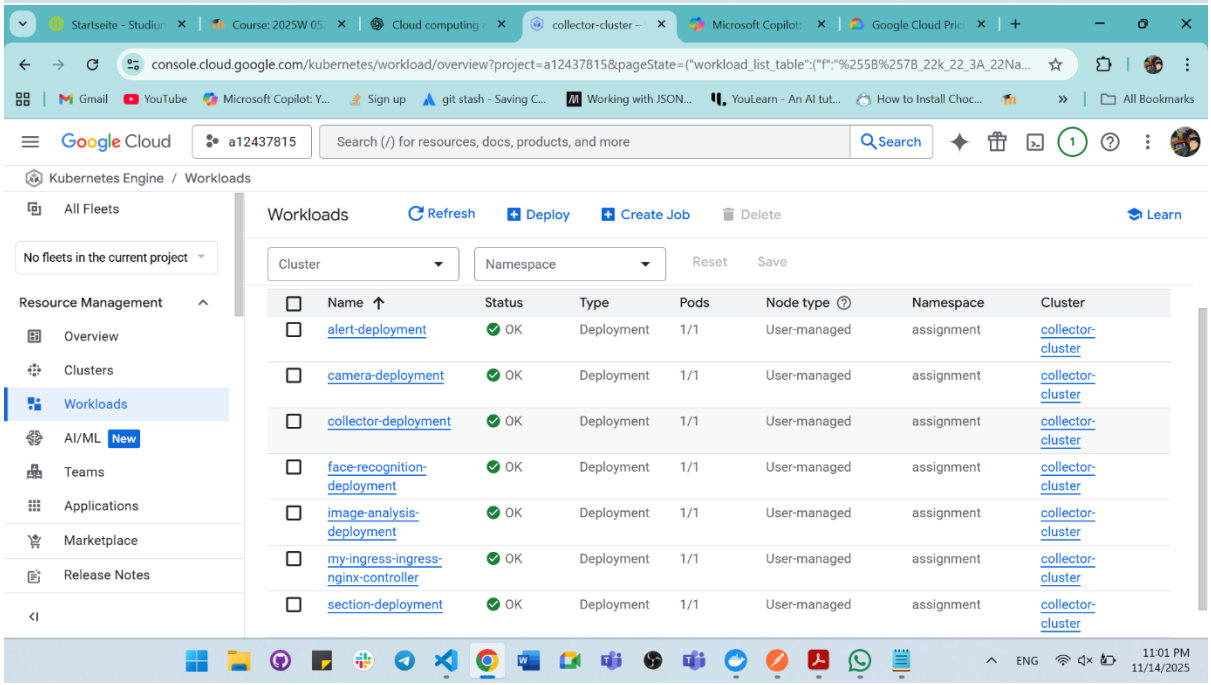
6. Conclusion

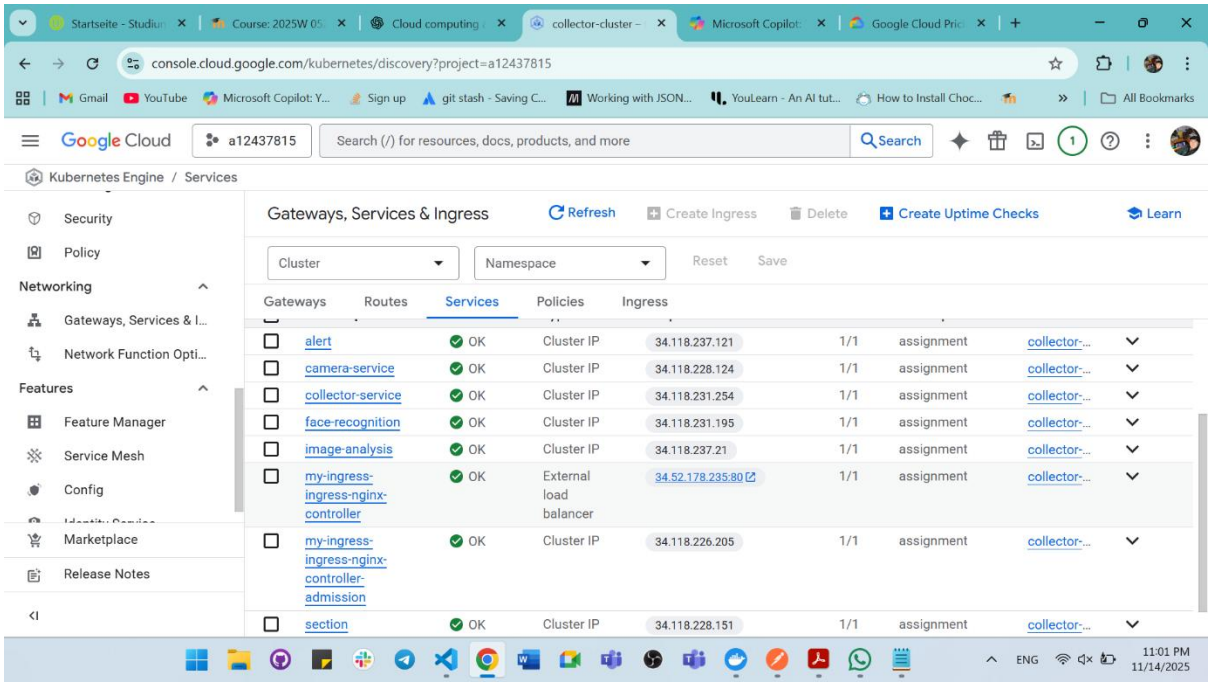
This report documents the design, deployment, scaling, and cost analysis of a microservice-based camera processing system on GKE. The Collector service was implemented in Flask and integrated with five other services. Kubernetes features such as HPAs, resource constraints, and Ingress were configured. Cost estimates were calculated for GKE Standard, Autopilot, Cloud Run, and Vision API. The system was successfully deployed and scaled, with Image Analysis identified as the main bottleneck. Recommendations include exploring asynchronous communication and serverless alternatives for future optimization.

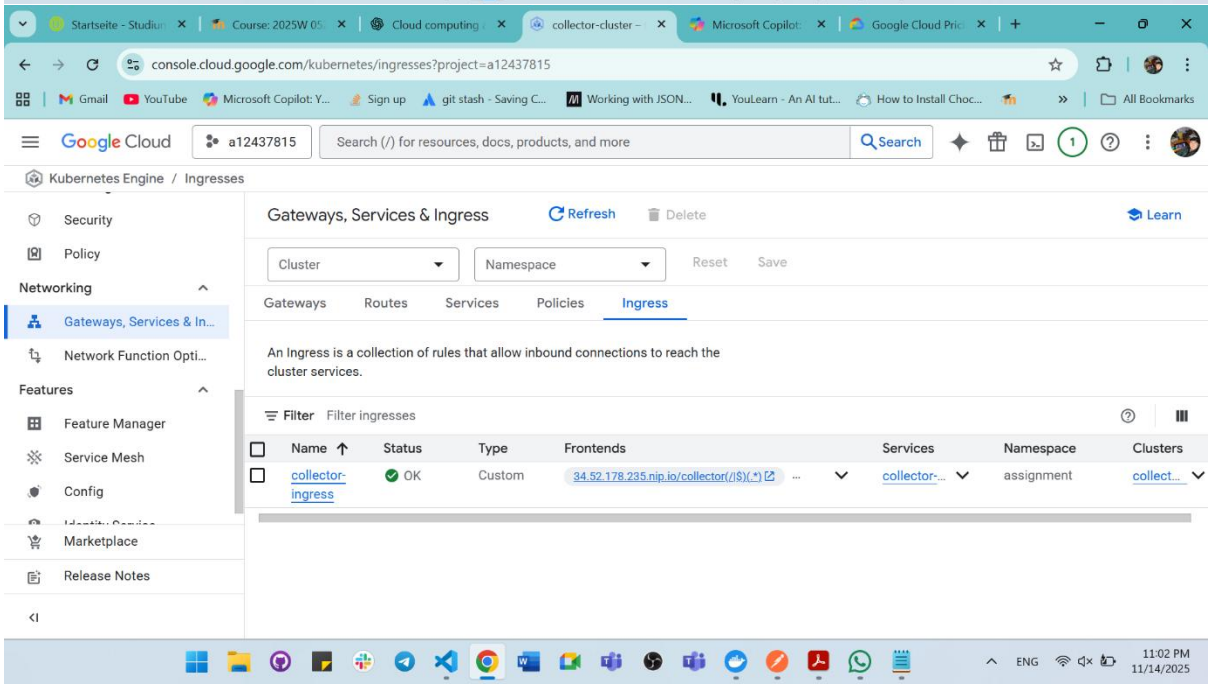
7. Screenshots

This are the screenshots assignment required.






console.cloud.google.com/kubernetes/discovery?project=a12437815
Google Cloud
a12437815
Search (/) for resources, docs, products, and more
Search
Kubernetes Engine / Services
Gateways, Services & Ingress
Refresh
Create Ingress
Delete
Create Uptime Checks
Learn
Cluster
Namespace
Reset
Save
Gateways
Routes
Services
Policies
Ingress
Security
Policy
Networking
Gateways, Services & I...
Network Function Opti...
Features
Feature Manager
Service Mesh
Config
Marketplace
Release Notes
alert OK Cluster IP 34.118.237.121 1/1 assignment collector-...
camera-service OK Cluster IP 34.118.228.124 1/1 assignment collector-...
collector-service OK Cluster IP 34.118.231.254 1/1 assignment collector-...
face-recognition OK Cluster IP 34.118.231.195 1/1 assignment collector-...
image-analysis OK Cluster IP 34.118.237.21 1/1 assignment collector-...
my-ingress-ingress-nginx-controller OK External load balancer 34.52.178.235:80 1/1 assignment collector-...
my-ingress-ingress-nginx-controller-admission OK Cluster IP 34.118.226.205 1/1 assignment collector-...
section OK Cluster IP 34.118.228.151 1/1 assignment collector-...
ENG
11:01 PM
11/14/2025


console.cloud.google.com/kubernetes/ingresses?project=a12437815
Google Cloud
a12437815
Search (/) for resources, docs, products, and more
Search
Kubernetes Engine / Ingresses
Gateways, Services & Ingress
Refresh
Delete
Learn
Cluster
Namespace
Reset
Save
Gateways
Routes
Services
Policies
Ingress
Security
Policy
Networking
Gateways, Services & In...
Network Function Opti...
Features
Feature Manager
Service Mesh
Config
Marketplace
Release Notes
An Ingress is a collection of rules that allow inbound connections to reach the cluster services.
Filter
Filter ingresses
Name
Status
Type
Frontends
Services
Namespace
Clusters
collector-ingress OK Custom 34.52.178.235.nip.io/collector(/|$)(.*) collector-... assignment collect...
ENG
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