techsavvyrc.com

Domain Setup

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1 Overview

This documentation outlines the process for setting up a multi-node ELK stack (Elasticsearch, Logstash, Kibana) using Docker, with additional containers for Zookeeper, Kafka, and a Python-based banking application. The banking app generates synthetic bank transaction data, which is sent to a Kafka topic and then ingested into Elasticsearch via Logstash. The ingested data is then visualized using Kibana dashboards.

This setup is intended to simulate a real-time streaming pipeline where a producer (banking app) pushes data to Kafka, and Logstash acts as a consumer that processes and sends the data to Elasticsearch. Kibana is used to analyze and visualize the data through customized dashboards.

2 Setup Guide for Docker Containers Using GitHub Repository

2.1 Prerequisites

Before starting the setup, ensure the following are installed on your system:

- **Docker:** Install Docker from the official Docker website.
- **Docker Compose:** Install Docker Compose from the official Docker Compose installation guide.
- **Git:** If using git clone to retrieve repository files, ensure Git is installed. Download from Git SCM.

For users unfamiliar with Docker, basic knowledge of Linux commands and Docker is recommended.

2.2 Repository Structure

The repository TechSavvyRC/elk_docker contains the necessary files to configure and run the ELK stack, Kafka, and the Python banking app in Docker containers. Below is the structure of the repository:

Git Repository Link: https://github.com/TechSavvyRC/elk_docker.git

```
TechSavvyRC/elk_docker
│
├── docker-compose.yml            # Main orchestration file
├── .env                          # Global environment variables
│
├── banking/                      # Python banking app directory
│     ├── .env                    # Banking app environment file
│     ├── banking_app.template.py # Python script template for generating bank app
│     ├── Dockerfile              # Dockerfile for the banking app container
│     ├── entrypoint.sh           # Script for configuring & running the banking app
│     └── requirements.txt        # Python dependencies for the banking app
│
└── logstash/                     # Logstash configuration directory
      ├── .env                    # Logstash environment file
      ├── Dockerfile              # Dockerfile for the Logstash container
      ├── entrypoint.sh           # Script for configuring and running Logstash
      └── logstash.template.conf  # Logstash configuration template
```

2.3 Retrieve Repository Files

- **Manual Download**

1. Navigate to the repository's GitHub page: https://github.com/TechSavvyRC/elk_docker.
2. Click the **Code** button.
3. Select **Download ZIP** and save the file.
4. Extract the ZIP file on your local machine using your preferred tool (e.g., unzip or graphical interface).

➢ Using Git Command-Line

1. Open a terminal.
2. Run the following command to clone the repository:
   ```
   git clone https://github.com/TechSavvyRC/elk_docker.git
   ```
3. Navigate into the cloned directory:
   ```
   cd elk_docker
   ```

➢ Using wget

1. Open a terminal.
2. Run the following wget command to download the repository's ZIP file:
   ```
   wget https://github.com/TechSavvyRC/elk_docker/archive/refs/heads/main.zip
   ```
3. Extract the ZIP file:
   ```
   unzip main.zip
   cd elk_docker-main
   ```

➢ Using GitHub Desktop

1. Download and install GitHub Desktop.
2. Click **File > Clone Repository**.
3. Paste the repository URL: https://github.com/TechSavvyRC/elk_docker.git.
4. Choose a local path and click **Clone**.

2.4 Setup Instructions

Step 1: Review .env Files

- The **.env** files contain environment variables for each service (Elasticsearch, Kafka, Logstash, and the banking app). Ensure the **.env** files are correctly configured.

1. **Global .env file (root directory):** Contains general settings such as Elasticsearch ports, memory limits, and Kafka topics.
2. **Logstash .env file (under logstash/):** Contains Logstash-specific configurations for Elasticsearch and Kafka.
3. **Banking app .env file (under banking/):** Contains Kafka connection details and the topics where the app will publish transactions.

Step 2: Modify Environment Variables (Optional)

If needed, customize the values in the **.env** files according to your requirements, such as changing ports, memory allocation, or Kafka topics.

For example, to change the Elasticsearch port:

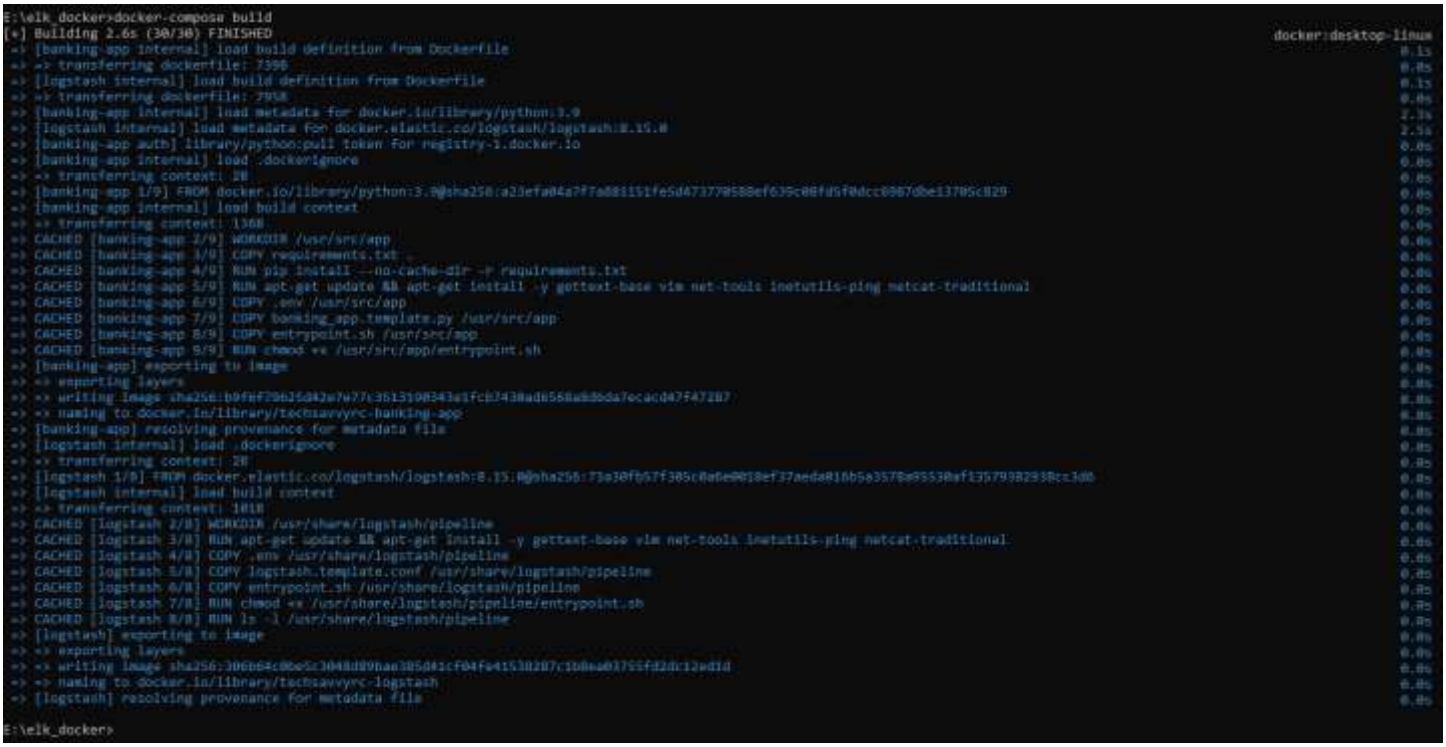
```
ES_PORT=9200  # Default port for Elasticsearch
```

Step 3: Build the Docker Containers

The repository includes **Dockerfiles** for each service, and **docker-compose.yml** orchestrates these services. Ensure Docker is running, then build the services:

From the root directory of the repository, run:

```
docker-compose build
```



2.5 Configuration

docker-compose.yml: The main configuration file defines the services, volumes, networks, and dependencies. It will start the following services:

- Elasticsearch (Coordination and Master Nodes)
- Logstash
- Kibana
- Kafka
- Zookeeper
- Python Banking Application

Environment Variables:

- All services are configured using values from **.env** files.
- The variables ensure that Logstash consumes from the correct Kafka topics, Elasticsearch is properly secured, and the banking app connects to Kafka.

2.6 Running Docker Containers

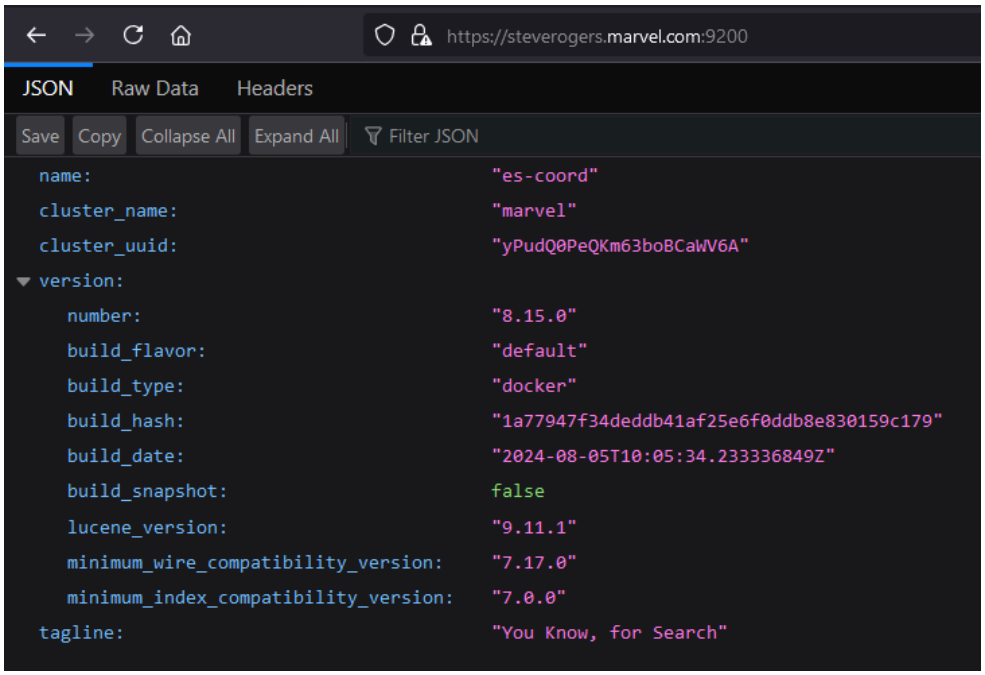
After building the Docker containers, follow these steps to start the services:

1. Start the entire stack:
   ```
   docker-compose up -d
   ```

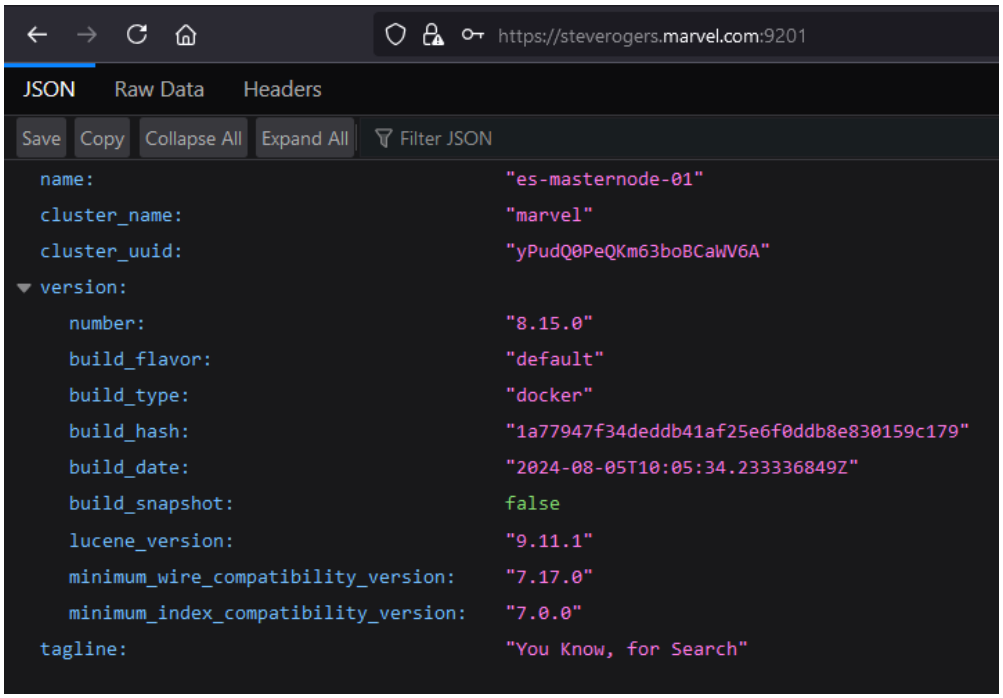
```
E:\delete\elk_docker>docker-compose up -d
[+] Running 45/45
 ✔ zookeeper Pulled                                                    2855.5s
   ✔ 98acab318002 Pull complete                                        2846.7s
   ✔ 878348106a95 Pull complete                                        2846.8s
 ✔ kafka Pulled                                                         571.2s
   ✔ 56f27190e824 Pull complete                                           7.7s
   ✔ 8e70b9b9b078 Pull complete                                         560.9s
   ✔ 732c9ebb730c Pull complete                                         560.9s
   ✔ ed746366f1b8 Pull complete                                         561.0s
   ✔ 10894799ccd9 Pull complete                                         561.0s
   ✔ 8d377259558c Pull complete                                         561.3s
   ✔ e7688095d1e6 Pull complete                                         561.3s
   ✔ 8eab815b3593 Pull complete                                         561.4s
   ✔ 00ded6dd259e Pull complete                                         561.4s
   ✔ 296f622c8150 Pull complete                                         561.4s
   ✔ 4ee3050cff6b Pull complete                                         561.4s
   ✔ 519f42193ec8 Pull complete                                         562.4s
   ✔ 5df3538dc51e Pull complete                                         562.5s
 ✔ es-masternode-01 Pulled                                               62.3s
   ✔ bef9b66d64c1 Already exists                                          0.0s
   ✔ 1fd631a7f77b Already exists                                          1.8s
   ✔ be0505076ce2 Already exists                                          1.8s
   ✔ 4ca545ee6d5d Pull complete                                         232.9s
   ✔ dc9db6ea5ff2 Pull complete                                          54.7s
   ✔ dd7fea410473 Pull complete                                          54.8s
   ✔ 7aaf9e867095 Pull complete                                          54.8s
   ✔ 8c9e11efa7e5 Pull complete                                          54.9s
   ✔ 8d0f979b52e8 Pull complete                                          54.9s
   ✔ 8cadc84c16df Pull complete                                          54.9s
 ✔ es-masternode-03 Pulled                                               62.3s
 ✔ es-masternode-02 Pulled                                               62.3s
 ✔ kibana-02 Pulled                                                     240.4s
 ✔ es-coord Pulled                                                       62.3s
 ✔ kibana-01 Pulled                                                     240.4s
   ✔ f6b84247827c Pull complete                                         145.3s
   ✔ b1a5a823635f Pull complete                                         231.1s
   ✔ 7ff3c1349574 Pull complete                                         231.1s
   ✔ acaf211e68f0 Pull complete                                         231.3s
   ✔ e6482380a03e Pull complete                                         231.4s
   ✔ 5d37849b8bfb Pull complete                                         231.4s
   ✔ 38a4f0ace1b9 Pull complete                                         231.5s
   ✔ 93469ea36cfe Pull complete                                         231.5s
   ✔ 40d69daa44b4 Pull complete                                         231.5s
   ✔ 9bcdcf41232d Pull complete                                         231.6s
   ✔ 50c27f863681 Pull complete                                         231.6s
 ✔ setup Pulled                                                          62.3s
[+] Running 20/20
 ✔ Network techsavvyrc_elastic_network  Created                           0.1s
 ✔ Network techsavvyrc_kafka_network    Created                           0.0s
 ✔ Volume "techsavvyrc_esdata-coord"    Created                           0.0s
 ✔ Volume "techsavvyrc_es-data-03"      Created                           0.0s
 ✔ Volume "techsavvyrc_kibana-data-02"  Created                           0.0s
 ✔ Volume "techsavvyrc_kibana-data-01"  Created                           0.0s
 ✔ Volume "techsavvyrc_certs"           Created                           0.0s
 ✔ Volume "techsavvyrc_es-data-01"      Created                           0.0s
 ✔ Volume "techsavvyrc_es-data-02"      Created                           0.0s
 ✔ Container techsavvyrc-setup-1        Healthy                           7.5s
 ✔ Container marvel-zookeeper           Healthy                           6.5s
 ✔ Container marvel-es-coord            Healthy                          68.1s
 ✔ Container marvel-kafka               Healthy                          17.1s
 ✔ Container marvel-es-masternode-02    Started                          68.8s
 ✔ Container marvel-kibana-01           Started                          68.7s
 ✔ Container marvel-es-masternode-03    Started                          68.5s
 ✔ Container marvel-es-masternode-01    Started                          68.8s
 ✔ Container marvel-kibana-02           Started                          69.1s
 ✔ Container marvel-logstash            Started                          69.2s
 ✔ Container marvel-banking-app         Started                          17.3s

E:\delete\elk_docker>
```

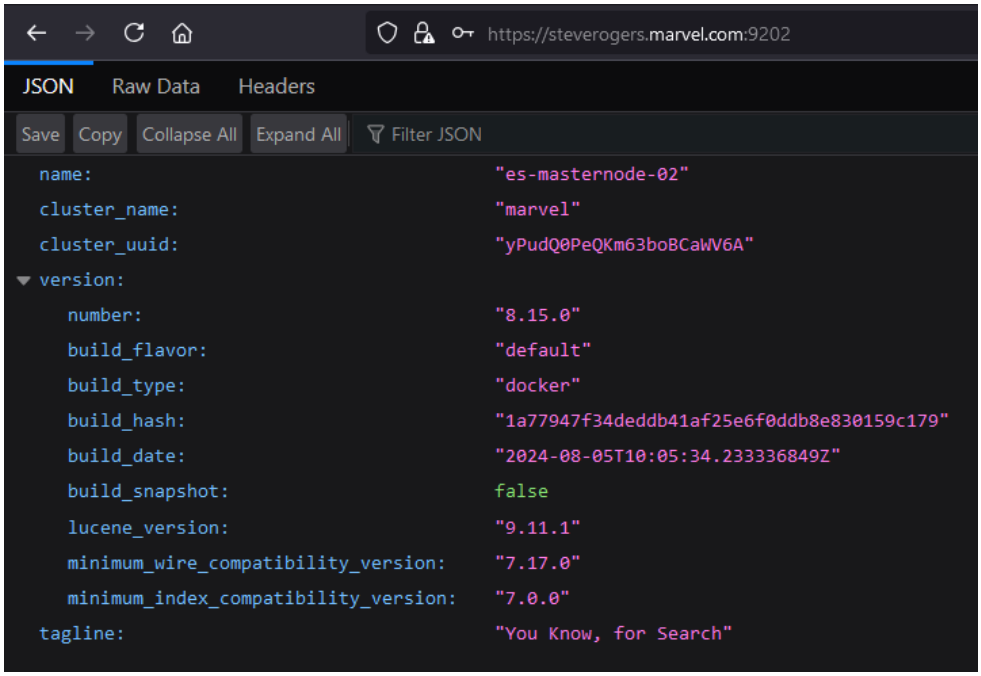
2. Monitor the logs for any issues:
   `docker-compose logs -f`
3. To verify the services from Docker host machine:
   - **es-coord:**



   - **es-masternode-01:**

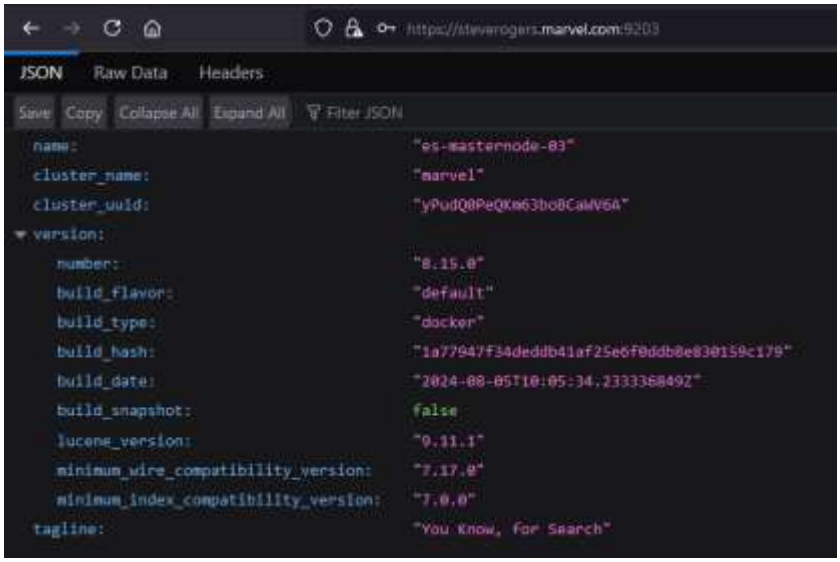


- **es-masternode-02:**



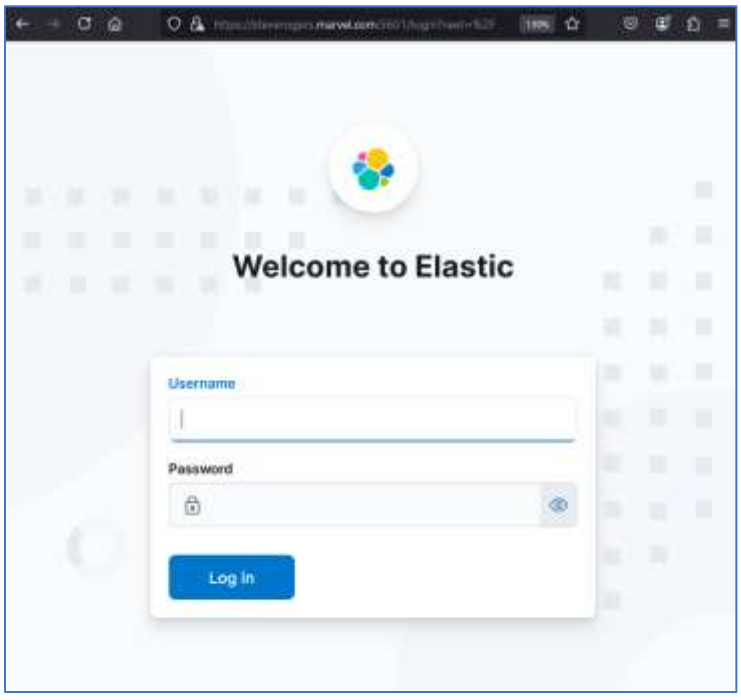
- **es-masternode-03:**

```
steve@SteveRogers:~$ curl -u "elastic:elastic" "https:///steverogers.marvel.com:9203" -k
{
  "name" : "es-masternode-03",
  "cluster_name" : "marvel",
  "cluster_uuid" : "yPudQ0PeQKm63boBCaWV6A",
  "version" : {
    "number" : "8.15.0",
    "build_flavor" : "default",
    "build_type" : "docker",
    "build_hash" : "1a77947f34deddb41af25e6f0ddb8e830159c179",
    "build_date" : "2024-08-05T10:05:34.233368492Z",
    "build_snapshot" : false,
    "lucene_version" : "9.11.1",
    "minimum_wire_compatibility_version" : "7.17.0",
    "minimum_index_compatibility_version" : "7.0.0"
  },
  "tagline" : "You Know, for Search"
}
steve@SteveRogers:~$
```



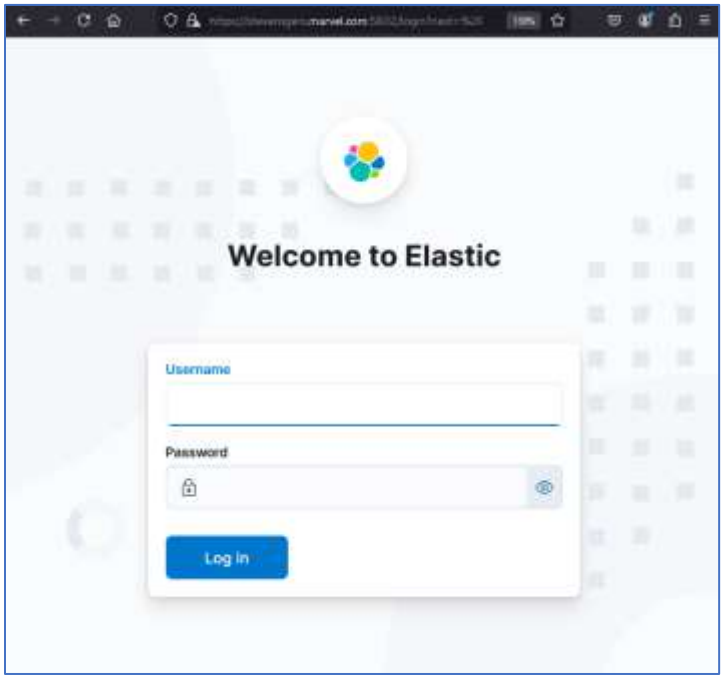
- **kibana-01:**

```
steve@SteveRogers:~$ curl -u "elastic:elastic" "https:///steverogers.marvel.com:5601" -k -w "HTTP Code: %{http_code}\n"
HTTP Code: 302
steve@SteveRogers:~$
```



- **kibana-02:**

```
steve@SteveRogers:~$ curl -u "elastic:elastic" "https:///steverogers.marvel.com:5602" -k -w "HTTP Code: %{http_code}\n"
HTTP Code: 302
steve@SteveRogers:~$
```



2.7 Troubleshooting and Common Issues

- **Issue 1:** Incorrect Line Endings (If on Windows)

  When using Windows, the files may have Windows-style line endings (CRLF), which are incompatible with Linux-based Docker containers that expect Unix-style line endings (LF). This can cause the file to fail to execute properly, resulting in errors like no such file or directory.

  Solution:

  Convert the file to use Unix-style line endings (LF):

  1. **Using Git Configuration:**

     Run the following command to ensure Git converts line endings to LF when checking out files:

     ```
     git config --global core.autocrlf input
     ```

  2. **Using dos2unix Tool:**

     If you have the dos2unix utility installed, convert the line endings by running:

     ```
     dos2unix logstash/entrypoint.sh
     ```

  After converting the line endings, rebuild the Docker image using:

  ```
  docker build --no-cache -f Dockerfile .
  ```

- **Issue 2:** Docker Build Fails

  Solution: Check for errors in the **Dockerfile**, such as missing dependencies. Ensure Docker is properly installed and the internet connection is stable for downloading required packages.

- **Issue 3:** Kafka Connection Issues

  Solution: Ensure Kafka is running on the correct port (default 9092) and that it is accessible from other containers. Use **netcat** or **ping** from within the containers to check connectivity:

  ```
  docker exec -it <container_id> ping kafka
  ```

- **Issue 4:** Logstash Not Processing Data

  Solution: Check Logstash logs:

  ```
  docker-compose logs logstash
  ```

  Ensure the Kafka topics are correctly set in the .env file and that the **logstash.template.conf** file references them.

- **Issue 5:** Memory Limits Exceeded

  Solution: Increase memory allocation for Elasticsearch, Logstash, or Kibana in the .env file:

  ```
  ES_MEM_LIMIT=4294967296  # 4 GB for Elasticsearch
  ```

3 DOCKER COMMANDS

3.1 Docker System Management Commands

1. docker version

Description: This command shows the installed version of Docker, including both the client and server versions. It is useful for verifying the Docker installation and ensuring compatibility with specific features.

```
docker version
```

2. docker info

Description: Provides detailed information about the Docker environment, including the number of containers, images, networks, storage drivers, and other system details. This is useful for diagnosing system issues or understanding the current Docker setup.

```
docker info
```

3. docker system prune

Description: Cleans up unused containers, networks, images, and volumes. This command helps reclaim disk space by removing resources that are no longer in use.

```
docker system prune
```

3.2 Docker Container Management Commands

1. docker ps

Description: Lists all running containers, displaying details such as container IDs, names, and the image they are running. It is helpful for monitoring active containers.

```
docker ps
```

2. docker ps -a

Description: Lists all containers, including stopped ones. This command helps in tracking containers that have been created but are not currently running.

```
docker ps -a
```

3. **docker start <container-name-or-id>**

   Description: Starts a stopped container. Use this command when you want to resume a container without creating a new one.

   ```
   docker start <container-name-or-id>
   ```

4. **docker stop <container-name-or-id>**

   Description: Stops a running container gracefully. It allows the container to terminate its processes cleanly before shutting down.

   ```
   docker stop <container-name-or-id>
   ```

5. **docker restart <container-name-or-id>**

   Description: Restarts a running or stopped container. This command is useful for applying new configurations or refreshing a container without removing it.

   ```
   docker restart <container-name-or-id>
   ```

6. **docker rm <container-name-or-id>**

   Description: Removes a stopped container permanently. It clears the container's associated resources but doesn't affect the image used to create it.

   ```
   docker rm <container-name-or-id>
   ```

7. **docker run -d --name <container-name> <image-name>**

   Description: Runs a new container from the specified image in detached mode (-d), which means the container runs in the background. The --name flag assigns a custom name to the container for easier identification.

   ```
   docker run -d --name my_container my_image
   ```

3.3 Docker Image Management Commands

1. **docker images**

   Description: Lists all Docker images available on the local machine. It provides details like the repository name, tag, and size of each image.

   ```
   docker images
   ```

2. **docker rmi <image-name-or-id>**

   Description: Removes an image from the local Docker registry. This command helps in cleaning up unused or outdated images.

   ```
   docker rmi <image-name-or-id>
   ```

3. **docker build -t <image-name> <path-to-dockerfile>**

   Description: Builds a Docker image from a **Dockerfile** and tags it with a custom name (-t). The *<path-to-dockerfile>* specifies where the **Dockerfile** and related files are located.

   ```
   docker build -t my_image .
   ```

4. **docker pull <image-name>**

Description: Downloads (pulls) an image from a Docker registry, such as Docker Hub. This command ensures that the latest or specified version of an image is available locally.

```
docker pull my_image
```

5. **docker push <image-name>**

Description: Uploads (pushes) a locally built image to a Docker registry. This is commonly used for sharing images or deploying applications to production environments.

```
docker push my_image
```

3.4 Docker Network Management Commands

1. **docker network ls**

Description: Lists all Docker networks on the host. It shows network names, IDs, and the types of networks (bridge, overlay, etc.) available.

```
docker network ls
```

2. **docker network inspect <network-name>**

Description: Provides detailed information about a specific Docker network, including connected containers and network settings.

```
docker network inspect my_network
```

3. **docker network create <network-name>**

Description: Creates a new custom Docker network. This is useful for isolating containers within a specific network.

```
docker network create my_network
```

4. **docker network rm <network-name>**

Description: Removes a Docker network that is no longer in use. This command is useful for cleaning up unused networks.

```
docker network rm my_network
```

5. **docker network prune**

Description: Removes all unused networks. This is useful for cleaning up networks that no longer have active containers attached.

```
docker network prune
```

6. **docker run --network host <image>**

Description: Runs a container on the host network, giving the container direct access to the host's network interface. This is useful when the container needs to communicate with other services running on the host.

```
docker run --network host my_image
```

7. **docker run --network none <image>**

Description: Runs a container with no network access. This is useful for security purposes when the container doesn't need any external connectivity.

```
docker run --network none my_image
```

3.5 Docker Log Management Commands

1. **docker logs <container-name-or-id>**

   Description: Displays logs generated by a container. It is useful for debugging and monitoring container activity.

   ```
   docker logs my_container
   ```

2. **docker logs -f <container-name-or-id>**

   Description: Follows the log output in real-time. This is particularly useful for monitoring long-running processes.

   ```
   docker logs -f my_container
   ```

3. **docker logs --since <timestamp> <container-name-or-id>**

   Description: Shows logs generated by the container since the specified timestamp. This helps focus on recent logs, especially after a specific event.

   ```
   docker logs --since 2023-09-01T00:00:00Z my_container
   ```

4. **docker logs --until <timestamp> <container-name-or-id>**

   Description: Shows logs generated up to a specified timestamp. This is useful for investigating logs within a specific time range.

   ```
   docker logs --until 2023-09-01T00:00:00Z my_container
   ```

5. **docker logs --tail <number-of-lines> <container-name-or-id>**

   Description: Displays the last ***N*** lines of logs from the container. This is useful for quickly reviewing the latest activity.

   ```
   docker logs --tail 50 my_container
   ```

6. **docker logs -t <container-name-or-id>**

   Description: Shows logs with timestamps, which is useful for tracking when specific events occurred.

   ```
   docker logs -t my_container
   ```

7. **docker logs --details <container-name-or-id>**

   Description: Displays extra details about the log messages, such as environment variables and labels, if available.

   ```
   docker logs --details my_container
   ```

8. **docker logs -f -t --tail 100 <container-name-or-id>**

   Description: Combines multiple log options: follows real-time logs, includes timestamps, and shows the last 100 log lines.

   ```
   docker logs -f -t --tail 100 my_container
   ```

3.6 Docker Volume Management Commands

1. **docker volume ls**

   Description: Lists all Docker volumes on the host. It shows volume names and helps identify which volumes are in use.

   ```
   docker volume ls
   ```

2. **docker volume create <volume-name>**

   Description: Creates a new Docker volume. Volumes are used for persisting data across container restarts.

   ```
   docker volume create my_volume
   ```

3. **docker volume inspect <volume-name>**

   Description: Displays detailed information about a specific volume, including its mount point and usage.

   ```
   docker volume inspect my_volume
   ```

4. **docker volume rm <volume-name>**

   Description: Removes a Docker volume that is no longer needed. This command is useful for cleaning up unused volumes.

   ```
   docker volume rm my_volume
   ```

3.7 Docker Exec (Running Commands in Containers)

1. **docker exec <container-name-or-id> <command>**

   Description: Executes a command inside a running container. It is commonly used to run commands like checking the status of services within the container.

   ```
   docker exec my_container ls -l
   ```

2. **docker exec -it <container-name-or-id> /bin/bash**

   Description: Opens an interactive shell session inside a running container. This is useful for inspecting and troubleshooting the container from within.

   ```
   docker exec -it my_container /bin/bash
   ```

3. **docker exec -d <container-name-or-id> <command>**

   Description: Runs a command inside a container in detached mode, meaning the command runs in the background.

   ```
   docker exec -d my_container my_command
   ```

4. **docker exec -e VAR_NAME=value <container-name-or-id> <command>**

   Description: Executes a command inside a container with a specified environment variable. This is useful for temporarily passing environment variables into a running container.

   ```
   docker exec -e MY_VAR=123 my_container my_command
   ```

5. **docker exec -u <user> <container-name-or-id> <command>**

   Description: Executes a command inside a container as a specific user. This is useful when dealing with permission-sensitive operations.

   ```
   docker exec -u root my_container my_command
   ```

6. **docker exec -w /path/to/dir <container-name-or-id> <command>**

   Description: Runs a command inside a container with a specified working directory. This ensures the command is executed from the correct location within the container.

   ```
   docker exec -w /app my_container ls
   ```

3.8 Docker Compose Commands

1. **docker-compose up**

   Description: Starts the services defined in the ***docker-compose.yml*** file. It builds and runs the containers as specified in the Compose configuration.

   ```
   docker-compose up
   ```

2. **docker-compose up -d**

   Description: Starts the services in detached mode, meaning the containers run in the background.

   ```
   docker-compose up -d
   ```

3. **docker-compose down**

   Description: Stops and removes all services, networks, and volumes defined in the ***docker-compose.yml*** file.

   ```
   docker-compose down
   ```

4. **docker-compose build**

   Description: Builds the services as specified in the ***docker-compose.yml*** file. This is useful when changes have been made to the service configuration or Dockerfiles.

   ```
   docker-compose build
   ```

5. **docker-compose logs**

   Description: Displays logs from all services managed by Docker Compose.

   ```
   docker-compose logs
   ```

6. **docker-compose logs -f**

   Description: Follows the log output in real-time for all services.

   ```
   docker-compose logs -f
   ```

7. **docker-compose run <service-name> <command>**

   Description: Runs a one-off command on a specific service defined in the Compose file. This is useful for running ad-hoc tasks in isolated containers.

   ```
   docker-compose run my_service my_command
   ```

8. **docker-compose pause**

   Description: Pauses running services managed by Docker Compose.

   ```
   docker-compose pause
   ```

9. **docker-compose unpause**

   Description: Resumes paused services.

   ```
   docker-compose unpause
   ```

10. **docker-compose restart**

    Description: Restarts all services managed by Docker Compose.

    ```
    docker-compose restart
    ```

11. docker-compose rm

Description: Removes stopped services.

```
docker-compose rm
```

12. docker-compose config

Description: Validates the ***docker-compose.yml*** file and displays the effective configuration. This is useful for checking the integrity of the Compose setup.

```
docker-compose config
```

13. docker-compose ps

Description: Lists all services managed by Docker Compose, showing their current status.

```
docker-compose ps
```

14. docker-compose pull

Description: Pulls the latest images for all services defined in the ***docker-compose.yml*** file.

```
docker-compose pull
```

15. docker-compose down --volumes

Description: Stops and removes all services, networks, and volumes.

```
docker-compose down --volumes
```

3.9 File Copying Between Host and Containers

1. docker cp <container-id>:/path/to/file /path/on/host

Description: Copies a file from the container to the host. This is useful for extracting logs, configuration files, or other data from a container.

```
docker cp my_container:/app/file.txt /host/path/
```

2. docker cp /path/on/host <container-id>:/path/to/file

Description: Copies a file from the host to the container. This is useful for injecting configuration files or data into a running container.

```
docker cp /host/path/file.txt my_container:/app/
```

3. docker cp -a <container-id>:/path/to/file /path/on/host

Description: Copies files from the container to the host while preserving file attributes like timestamps and permissions.

```
docker cp -a my_container:/app/file.txt /host/path/
```

4. docker cp -L <container-id>:/path/to/file /path/on/host

Description: Copies a file from the container to the host while resolving symbolic links.

```
docker cp -L my_container:/app/link_file /host/path/
```

3.10 Kafka Management with Docker

1. **docker exec -it kafka /opt/kafka/bin/kafka-topics.sh --create --topic my-topic --bootstrap-server localhost:9092 --partitions 1 --replication-factor 1**

   Description: Creates a new Kafka topic inside a Kafka container. The number of partitions and replication factor can be customized as needed.

   ```
   docker exec -it kafka /opt/kafka/bin/kafka-topics.sh --create --topic my-topic --bootstrap-server localhost:9092 --partitions 1 --replication-factor 1
   ```

2. **docker exec -it kafka /opt/kafka/bin/kafka-topics.sh --list --bootstrap-server localhost:9092**

   Description: Lists all available Kafka topics on the specified Kafka broker.

   ```
   docker exec -it kafka /opt/kafka/bin/kafka-topics.sh --list --bootstrap-server localhost:9092
   ```

3. **docker exec -it kafka /opt/kafka/bin/kafka-console-producer.sh --topic my-topic --bootstrap-server localhost:9092**

   Description: Starts a Kafka producer console to send messages to a specified topic.

   ```
   docker exec -it kafka /opt/kafka/bin/kafka-console-producer.sh --topic my-topic --bootstrap-server localhost:9092
   ```

4. **docker exec -it kafka /opt/kafka/bin/kafka-console-consumer.sh --topic my-topic --from-beginning --bootstrap-server localhost:9092**

   Description: Starts a Kafka consumer console to consume messages from a topic. The *--from-beginning* flag ensures that all messages, even old ones, are consumed.

   ```
   docker exec -it kafka /opt/kafka/bin/kafka-console-consumer.sh --topic my-topic --from-beginning --bootstrap-server localhost:9092
   ```

4 Docker Containers

Containers are the building blocks of this architecture. Each service (Elasticsearch, Logstash, Kafka, etc.) runs inside its own Docker container. These containers are lightweight, isolated environments that allow the services to run independently on the same host machine. The key Docker containers in this architecture are:

Elasticsearch Cluster:

- Coordination Node (1 container)
- Master Nodes (3 containers)

Kibana Instances:

- Two Kibana containers for dashboard and data visualization.

Logstash:

- One container that connects Kafka (producer) to Elasticsearch (consumer).

Kafka Stack:

- Zookeeper (1 container): Manages Kafka brokers.
- Kafka (1 container): Receives and stores data from the banking app.

Python Banking Application:

- One container that generates fake bank transactions and sends them to Kafka.

5 Network Configuration

Docker allows the creation of bridge networks to isolate and control communication between containers. Two bridge networks are defined in this architecture:

elastic_network:

This network connects all the ELK containers (Elasticsearch, Logstash, Kibana). Its purpose is to ensure isolated communication for the ELK stack and allows the following:

- Kibana instances connect to the Elasticsearch coordination node.
- Logstash connects to Elasticsearch to send processed data.

kafka_network:

This network connects the Kafka stack (Kafka and Zookeeper) and the Python banking application. The purpose is to enable communication between:

- Kafka and Zookeeper for managing Kafka brokers.
- The Python banking application and Kafka for publishing data to the Kafka topic.

Logstash is connected to both networks (*elastic_network* and *kafka_network*) to act as a bridge, facilitating data transfer between Kafka and Elasticsearch.

6 Host Machine

The host machine is the physical or virtual machine where Docker is installed. This machine orchestrates all the Docker containers and provides the necessary resources (CPU, memory, disk space) for the containers to operate.

- **Docker Engine:** The Docker engine runs on the host machine, allowing containers to run independently with isolated resources.
- **Networks on the Host:** The Docker bridge networks (*elastic_network*, *kafka_network*) exist only within the Docker environment but use the host machine's network interfaces for external communication.

7 Architecture Breakdown

7.1 Elasticsearch Nodes

The Elasticsearch cluster comprises different containers, each playing a crucial role in managing, indexing, and storing data.

Coordination Node (1):

- Acts as a gateway for communication between Kibana, Logstash, and Elasticsearch master nodes.
- Routes and distributes requests from Kibana and Logstash to the appropriate master nodes.
- Manages traffic and client requests, but does not store data.

- Ensures efficient coordination of data distribution across the master nodes.

Master Nodes (3):

- Responsible for cluster state management, data indexing, and search operations.
- Distribute and replicate data to ensure high availability and redundancy within the cluster.
- Manage indexing and searching tasks, ensuring consistent performance across the cluster.

7.2 Kibana Instances

- Provides a user interface for visualizing and interacting with data stored in Elasticsearch.
- Both Kibana containers connect to the coordination node for data retrieval.
- Enable users to create dashboards, visualizations, and queries based on indexed data in Elasticsearch.
- Serve as the front-end for Elasticsearch, offering real-time data insights.

7.3 Logstash

Logstash is the key component for data ingestion in the pipeline, bridging Kafka and Elasticsearch.

- Consumes data from the Kafka topic (***banking_transactions***) generated by the Python banking app.
- Processes and forwards the data to Elasticsearch for indexing.
- Acts as a bridge between two Docker networks (**elastic_network** and **kafka_network**), enabling seamless data transfer between Kafka and Elasticsearch.
- Configured via a **logstash.conf** file, where Kafka is the input source and Elasticsearch is the output destination.
    - **Input:** Reads transaction data from Kafka.
    - **Output:** Processes and sends the data to Elasticsearch for storage and indexing.

7.4 Zookeeper and Kafka

Zookeeper and Kafka form the backbone of the message queue system, which manages the real-time data flow.

Zookeeper:

- Coordinates Kafka brokers, ensuring the proper functioning of the Kafka cluster.
- Manages cluster configuration, maintaining a consistent view of the brokers and ensuring they operate correctly.

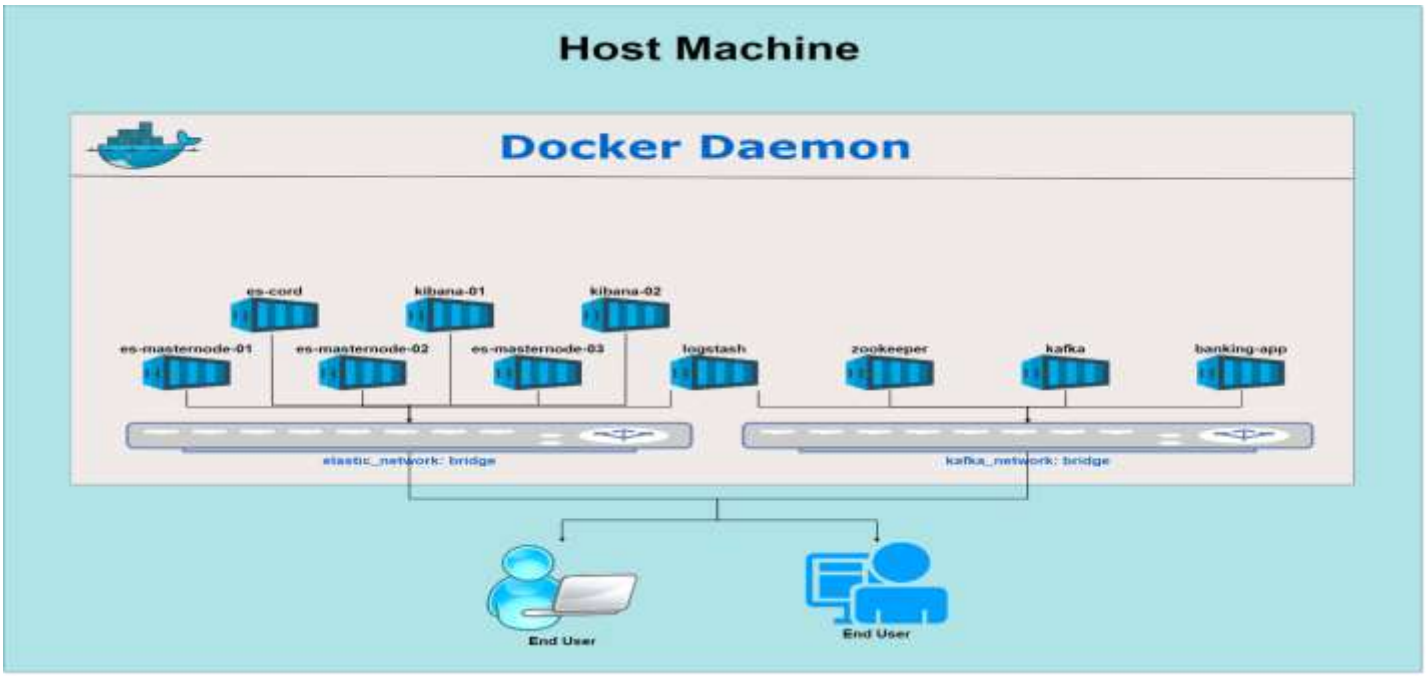
Kafka:

- Acts as the message broker, receiving transaction data from the banking app and making it available to consumers like Logstash.
- Data is published to a Kafka topic (**banking_transactions**), where it is stored until consumed by Logstash.
- Brokers in Kafka manage and handle message distribution, ensuring that data from the banking app is available for downstream processing.

7.5 Python Banking Application

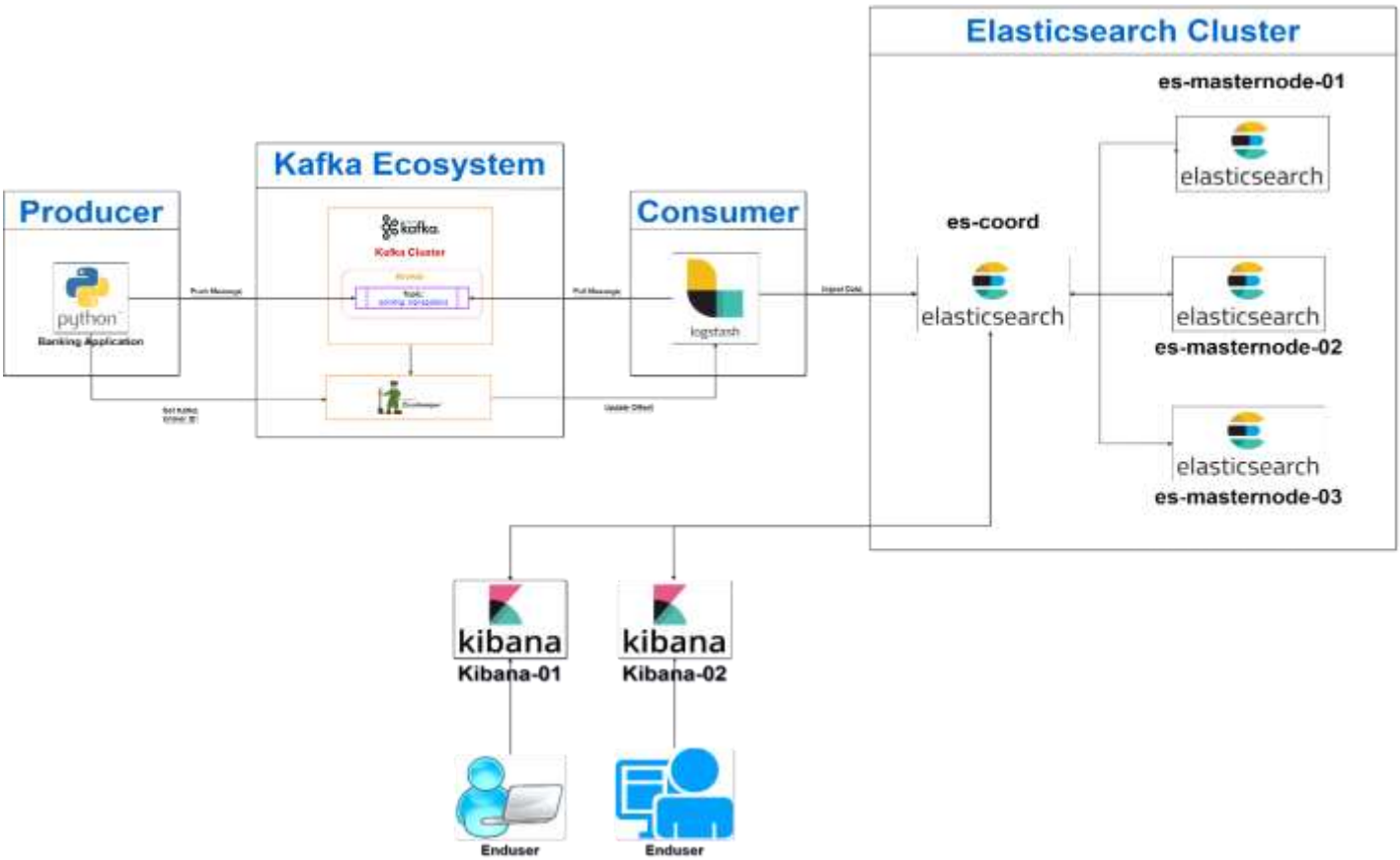
The Python-based banking app simulates a data producer that generates synthetic bank transactions and sends them to Kafka.

- Generates fake transaction data, including fields like transaction_id, amount, and timestamp.
- Publishes the data to the Kafka topic (***banking_transactions***), serving as the producer in the data pipeline.
- Connected to the *kafka_network*, allowing direct communication with the Kafka brokers for data transfer.
- Acts as the source of transaction data in the pipeline, simulating real-time financial transactions for testing purposes.



8 Data Flow

The architecture comprises various containers (Python banking app, Kafka, Logstash, Elasticsearch, and Kibana), each playing a specific role in the data pipeline. Here's a step-by-step breakdown of the data flow between these containers, highlighting how data is generated, ingested, processed, stored, and visualized.



8.1 Data Generation

Python Banking Application:

- The Python banking app generates random synthetic transaction data. This data simulates real-world bank transactions and includes key details such as:
  - **transaction_id:** A unique identifier for each transaction.
  - **amount:** A randomly generated amount for each transaction.
  - **transaction_timestamp:** The time the transaction occurred.
- The generated data is published to Kafka over the *kafka_network*. This network is shared between Kafka, Zookeeper, and the Python banking app, enabling communication between these components.
- **Publishing to Kafka:** The transaction data is sent to a Kafka topic named *banking_transactions*. Kafka topics are essentially channels where producers (like the banking app) send data and consumers (like Logstash) subscribe to receive it.

8.2 Data Ingestion

Kafka:

- Kafka brokers, managed by Zookeeper, receive the transaction data from the banking app. The data is stored in the Kafka topic **banking_transactions**.
- Kafka ensures the message (transaction data) is persisted until a consumer (Logstash) subscribes to the topic and processes the data.
- Kafka acts as a buffer to store data until Logstash is ready to consume it, ensuring a reliable and fault-tolerant message queue.

Logstash:

- Logstash is connected to both the ***kafka_network*** (to consume data from Kafka) and the ***elastic_network*** (to forward data to Elasticsearch).
- Logstash is configured to subscribe to the ***banking_transactions*** topic in Kafka. Once connected, it continuously listens for new transaction data produced by the banking app.
- As new data arrives in Kafka, Logstash consumes the data in near real-time, moving it to the next stage of the pipeline for further processing.

8.3 Data Processing

Logstash Processing:

- After consuming the transaction data from Kafka, Logstash processes the data according to its configuration file (*logstash.conf*). This step might include:
  - **Data transformation:** Logstash can transform or modify the data (e.g., converting field names, adjusting formats).
  - F**iltering:** Specific filters can be applied to clean, parse, or structure the data. For example, Logstash could apply grok patterns to extract specific fields from raw data or standardize data formats.
- The processing ensures that the data is in a format suitable for indexing in Elasticsearch. This structured format will make searching, analyzing, and visualizing the data more efficient.

Forwarding to Elasticsearch:

- Once the data is processed, Logstash forwards the processed data to Elasticsearch for storage. This is done through the **elastic_network**, which connects Logstash to the Elasticsearch containers.
- **Logstash Output Configuration:** Logstash's output configuration specifies the destination (Elasticsearch coordination node) where the processed data should be sent for indexing.

8.4 Data Storage

Elasticsearch Coordination Node:

- The coordination node in Elasticsearch is responsible for receiving the data from Logstash. It acts as an intermediary between Logstash and the Elasticsearch master nodes.
- Upon receiving the data, the coordination node distributes the indexing requests to the appropriate master nodes in the Elasticsearch cluster.

Master Nodes:

- The master nodes handle the indexing and storage of the transaction data. Elasticsearch breaks down the data into indices (structured records) to enable fast search and retrieval.
- The data is replicated and distributed across multiple master nodes, ensuring high availability and fault tolerance. This means even if one node goes down, the data remains accessible from another node.
- **Cluster Management:** The master nodes ensure that the cluster remains healthy, balancing the load across all nodes for optimal performance.

8.5 Data Visualization

Kibana:

- Kibana connects to the Elasticsearch coordination node to access the stored transaction data. The coordination node provides Kibana with the necessary information to query the Elasticsearch cluster.
- **Retrieving Data:** Kibana retrieves data from Elasticsearch through queries, allowing users to search and filter the transaction records based on different criteria (e.g., transaction amount, time, or transaction ID).

Dashboards and Visualizations:

- Users can use Kibana to build dashboards, graphs, charts, and visualizations based on the stored transaction data. These visualizations provide insights into patterns and trends in the financial data.
- Kibana's interface supports creating real-time visualizations, enabling users to see live updates as new data is ingested into Elasticsearch.
- **User Interaction:** Through Kibana, users can explore the transaction data, create custom queries, and display real-time data in the form of visual dashboards, offering insights into financial transactions.

8.6 Data Flow Summary

1) **Data Generation:** The Python banking app generates fake transaction data and publishes it to the Kafka topic (**banking_transactions**) over the *kafka_network*.
2) **Data Ingestion:** Kafka stores the data in the topic until Logstash subscribes to and consumes it from the Kafka message queue.
3) **Data Processing:** Logstash processes the consumed data, applying transformations or filters, and forwards the cleaned data to Elasticsearch for indexing through the *elastic_network*.

4) **Data Storage:** Elasticsearch stores the processed transaction data across its master nodes, ensuring data replication and high availability.

5) **Data Visualization:** Kibana connects to Elasticsearch, allowing users to query and visualize the stored transaction data through custom dashboards and visual reports.

This data flow outlines a real-time streaming data pipeline that efficiently generates, processes, stores, and visualizes data using Docker containers and networked services.

9 Directory Structure and File Overview

The project directory (***/project-directory***) is structured to organize all the necessary files and configurations required for deploying and managing the multi-container ELK stack with Kafka and a Python-based banking app. Each subdirectory contains relevant files for individual services, such as Docker configuration files, environment variables, and service-specific scripts. Each file within the structure plays a crucial role in configuring, deploying, and managing the containers in this setup. Further details of each file are explained below.

```
/project-directory
│
├─ docker-compose.yml
├─ .env
│
├─ banking
│     ├─ .env
│     ├─ banking_app.template.py
│     ├─ Dockerfile
│     ├─ entrypoint.sh
│     └─ requirements.txt
│
└── logstash
      ├─ .env
      ├─ Dockerfile
      ├─ entrypoint.sh
      └─ logstash.template.conf
```

9.1 docker-compose.yml

This ***docker-compose.yml*** file defines the multi-container setup for the ELK stack (Elasticsearch, Logstash, Kibana) integrated with Kafka, Zookeeper, and a Python-based banking application. The configuration specifies how the services interact with each other, defines network topologies, and ensures that volumes are used for persistent storage. Below is a detailed explanation of each section:

Volumes

These volumes store persistent data for various services, ensuring that data is retained even when containers are restarted.

- **certs:** Stores SSL/TLS certificates used by Elasticsearch and Kibana to secure communication.
- **esdata-coord:** Stores data for the Elasticsearch coordination node.
- **es-data-01, es-data-02, es-data-03:** Store data for the respective Elasticsearch master nodes.
- **kibana-data-01, kibana-data-02:** Store Kibana configuration data.

These volumes ensure data is not lost between container restarts and support the persistence of Elasticsearch indices, Kibana settings, and certificates.

```
volumes:
    certs:
        driver: local
    esdata-coord:
        driver: local
    es-data-01:
        driver: local
    es-data-02:
        driver: local
    es-data-03:
        driver: local
    kibana-data-01:
        driver: local
    kibana-data-02:
        driver: local
```

Networks

Two custom bridge networks are created to isolate the ELK stack and Kafka services.

- **elastic_network:** Connects the ELK stack (Elasticsearch, Logstash, Kibana) containers.
- **kafka_network:** Connects Kafka, Zookeeper, and the Python banking app.

The use of separate networks ensures proper service isolation while allowing containers to communicate across networks (e.g., Logstash needs to access both Kafka and Elasticsearch).

```
networks:
    elastic_network:
        driver: bridge
    kafka_network:
        driver: bridge
```

Services

Setup Service

- **Purpose:** Initializes the environment by generating SSL certificates for Elasticsearch and Kibana, handling security configurations.
- **Image:** *docker.elastic.co/elasticsearch/elasticsearch:${STACK_VERSION}* — The official Elasticsearch image with a dynamic version.
- **Command:** Runs a Bash script that:
  - Verifies required environment variables like **ES_PASSWORD** and **KIBANA_PASSWORD**.
  - Generates a certificate authority (CA) and individual SSL certificates for Elasticsearch, Kibana, and other services.
  - Sets the Kibana system password.
- **Volumes:** Uses certs volume to store generated certificates.
- **Networks:** Connected to ***elastic_network***.
- **Healthcheck:** Verifies that the required certificates exist before marking the service as healthy.

```
services:
    setup:
        image: docker.elastic.co/elasticsearch/elasticsearch:${STACK_VERSION}
        networks:
            - elastic_network
        volumes:
            - certs:/usr/share/elasticsearch/config/certs
        user: "0"
        command: >
            bash -c '
              if [ x${ES_PASSWORD} == x ]; then
                echo "Set the ES_PASSWORD environment variable in the .env file";
                exit 1;
              elif [ x${KIBANA_PASSWORD} == x ]; then
                echo "Set the KIBANA_PASSWORD environment variable in the .env file";
                exit 1;
              fi;
              if [ ! -f config/certs/ca.zip ]; then
                echo "Creating CA";
                bin/elasticsearch-certutil ca --silent --pem -out config/certs/ca.zip;
                unzip config/certs/ca.zip -d config/certs;
              fi;
              if [ ! -f config/certs/certs.zip ]; then
                echo "Creating certs";
                echo -ne \
                "instances:\n"\
                "  - name: es-coord\n"\
                "    dns:\n"\
                "      - es-coord\n"\
                "      - localhost\n"\
                "    ip:\n"\
                "      - 127.0.0.1\n"\
                "  - name: es-masternode-01\n"\
                "    dns:\n"\
                "      - es-masternode-01\n"\
                "      - localhost\n"\
                "    ip:\n"\
                "      - 127.0.0.1\n"\
                "  - name: es-masternode-02\n"\
                "    dns:\n"\
                "      - es-masternode-02\n"\
                "      - localhost\n"\
                "    ip:\n"\
                "      - 127.0.0.1\n"\
                "  - name: es-masternode-03\n"\
                "    dns:\n"\
                "      - es-masternode-03\n"\
                "      - localhost\n"\
                "    ip:\n"\
                "      - 127.0.0.1\n"\
                "  - name: kibana-01\n"\
                "    dns:\n"\
                "      - kibana-01\n"\
                "      - localhost\n"\
                "    ip:\n"\
                "      - 127.0.0.1\n"\
                "  - name: kibana-02\n"\
                "    dns:\n"\
                "      - kibana-02\n"\
                "      - localhost\n"\
                "    ip:\n"\
                "      - 127.0.0.1\n"\
```

```
                "  - name: logstash\n"\
                "    dns:\n"\
                "      - logstash\n"\
                "      - localhost\n"\
                "    ip:\n"\
                "      - 127.0.0.1\n"\
                "  - name: nginx\n"\
                "    dns:\n"\
                "      - nginx\n"\
                "      - nginx\n"\
                "    ip:\n"\
                "      - 127.0.0.1\n"\
                > config/certs/instances.yml;
                bin/elasticsearch-certutil cert --silent --pem -out
config/certs/certs.zip --in config/certs/instances.yml --ca-cert
config/certs/ca/ca.crt --ca-key config/certs/ca/ca.key;
                unzip config/certs/certs.zip -d config/certs;
              fi;
              # Ensure Kibana certificates are moved to the correct directory
              if [ ! -d config/certs/kibana ]; then
                mkdir -p config/certs/kibana;
              fi;
              mv config/certs/kibana-01/* config/certs/kibana/;
              mv config/certs/kibana-02/* config/certs/kibana/;
              echo "Setting file permissions"
              chown -R root:root config/certs;
              find . -type d -exec chmod 750 \{\} \;;
              find . -type f -exec chmod 640 \{\} \;;
              echo "Waiting for Elasticsearch availability";
              until curl -s --cacert config/certs/ca/ca.crt https://es-coord:9200 |
grep -q "missing authentication credentials"; do sleep 30; done;
              echo "Setting kibana_system password";
              until curl -s -X POST --cacert config/certs/ca/ca.crt -u
"${ES_USER}:${ES_PASSWORD}" -H "Content-Type: application/json" https://es-
coord:9200/_security/user/kibana_system/_password -d
"{\"password\":\"${KIBANA_PASSWORD}\"}" | grep -q "^{}"; do sleep 10; done;
              echo "All done!";
            '
        healthcheck:
            test: ["CMD-SHELL", "[ -f config/certs/es-coord/es-coord.crt ]"]
            interval: 1s
            timeout: 5s
            retries: 120
```

Elasticsearch Coordination Node (es-coord)

- **Purpose:** Routes client requests from Kibana and Logstash to the appropriate Elasticsearch master nodes. Does not store data itself.
- **Image:** Elasticsearch image defined by **${STACK_VERSION}**.
- **Hostname:** *sheild-es-coord* — Unique hostname for internal networking.
- **Ports:** Exposes Elasticsearch on *${ES_PORT}* (typically **9200**) for API interactions.
- **Volumes:** Stores SSL certificates in certs and uses *esdata-coord* for data.
- **Environment Variables:**
  - **node.name:** Identifies the node.
  - **cluster.name:** Defines the cluster name.
  - **discovery.seed_hosts:** Specifies other master nodes for cluster discovery.

    - **xpack.security:** Enables SSL and sets up certificates for secure communication.
- **Mem_limit:** Restricts memory usage based on **${ES_MEM_LIMIT}** (to prevent excessive resource usage).
- **Healthcheck:** Verifies that the service is available by testing the certificate-based secure connection.

```
    es-coord:
        image: docker.elastic.co/elasticsearch/elasticsearch:${STACK_VERSION}
        hostname: sheild-es-coord
        container_name: marvel-es-coord
        depends_on:
            setup:
                condition: service_healthy
        volumes:
            - certs:/usr/share/elasticsearch/config/certs
            - esdata-coord:/usr/share/elasticsearch/data
        ports:
            - ${ES_PORT}:${ES_PORT}
        networks:
            - elastic_network
        environment:
            - node.name=es-coord
            - node.roles=!!seq ""
            - cluster.name=${CLUSTER_NAME}
            - cluster.initial_master_nodes=es-masternode-01,es-masternode-02,es-
masternode-03
            - discovery.seed_hosts=es-masternode-01,es-masternode-02,es-masternode-03
            - ELASTIC_PASSWORD=${ES_PASSWORD}
            - bootstrap.memory_lock=true
            - xpack.security.enabled=true
            - xpack.security.http.ssl.enabled=true
            - xpack.security.http.ssl.key=certs/es-coord/es-coord.key
            - xpack.security.http.ssl.certificate=certs/es-coord/es-coord.crt
            - xpack.security.http.ssl.certificate_authorities=certs/ca/ca.crt
            - xpack.security.transport.ssl.enabled=true
            - xpack.security.transport.ssl.key=certs/es-coord/es-coord.key
            - xpack.security.transport.ssl.certificate=certs/es-coord/es-coord.crt
            - xpack.security.transport.ssl.certificate_authorities=certs/ca/ca.crt
            - xpack.security.transport.ssl.verification_mode=certificate
            - xpack.license.self_generated.type=${LICENSE}
            - ES_JAVA_OPTS=-Xms512m -Xmx512m
        mem_limit: ${ES_MEM_LIMIT}
        ulimits:
            memlock:
                soft: -1
                hard: -1
        healthcheck:
            test:
                [
                   "CMD-SHELL",
                   "curl -s --cacert config/certs/ca/ca.crt https://es-
coord:${ES_PORT} | grep -q 'missing authentication credentials'"
                ]
            interval: 10s
            timeout: 10s
            retries: 120
```

Elasticsearch Master Nodes (es-masternode-01, es-masternode-02, es-masternode-03)

- **Purpose:** Store and manage the Elasticsearch data across the cluster. Each node is responsible for indexing and searching.

- **Image:** Uses the same Elasticsearch image as the coordination node.
- **Ports:** Exposes each node on different ports (***9201, 9202, 9203***).
- **Volumes:** Each node has a separate data volume (***es-data-01, es-data-02, es-data-03***) and shares the certs volume for SSL certificates.
- **Environment Variables:**
  - Similar to the coordination node, but with **node.roles=master,data** indicating this node handles both master and data roles.
  - Sets memory usage and configures SSL.
- **Healthcheck:** Verifies that the node is healthy by checking for a successful SSL connection on its respective port.

```
    es-masternode-01:
        image: docker.elastic.co/elasticsearch/elasticsearch:${STACK_VERSION}
        hostname: sheild-es-masternode-01
        container_name: marvel-es-masternode-01
        depends_on:
            es-coord:
                condition: service_healthy
        volumes:
            - certs:/usr/share/elasticsearch/config/certs
            - es-data-01:/usr/share/elasticsearch/data
        networks:
            - elastic_network
        ports:
            - 9201:${ES_PORT}
        environment:
            - node.name=es-masternode-01
            - node.roles=master,data
            - cluster.name=${CLUSTER_NAME}
            - cluster.initial_master_nodes=es-masternode-01,es-masternode-02,es-
masternode-03
            - discovery.seed_hosts=es-masternode-01,es-masternode-02,es-masternode-03
            - ELASTIC_PASSWORD=${ES_PASSWORD}
            - bootstrap.memory_lock=true
            - xpack.security.enabled=true
            - xpack.security.http.ssl.enabled=true
            - xpack.security.http.ssl.key=certs/es-masternode-01/es-masternode-01.key
            - xpack.security.http.ssl.certificate=certs/es-masternode-01/es-
masternode-01.crt
            - xpack.security.http.ssl.certificate_authorities=certs/ca/ca.crt
            - xpack.security.transport.ssl.enabled=true
            - xpack.security.transport.ssl.key=certs/es-masternode-01/es-masternode-
01.key
            - xpack.security.transport.ssl.certificate=certs/es-masternode-01/es-
masternode-01.crt
            - xpack.security.transport.ssl.certificate_authorities=certs/ca/ca.crt
            - xpack.security.transport.ssl.verification_mode=certificate
            - xpack.license.self_generated.type=${LICENSE}
            - ES_JAVA_OPTS=-Xms512m -Xmx512m
        mem_limit: ${ES_MEM_LIMIT}
        ulimits:
            memlock:
                soft: -1
                hard: -1
        healthcheck:
            test:
                [
                   "CMD-SHELL",
```

```
                    "curl -s --cacert config/certs/ca/ca.crt https://sheild-es-
masternode-01:${ES_PORT} | grep -q 'missing authentication credentials'"
                ]
            interval: 10s
            timeout: 10s
            retries: 120

    es-masternode-02:
        image: docker.elastic.co/elasticsearch/elasticsearch:${STACK_VERSION}
        hostname: sheild-es-masternode-02
        container_name: marvel-es-masternode-02
        depends_on:
            es-coord:
                condition: service_healthy
       volumes:
            - certs:/usr/share/elasticsearch/config/certs
            - es-data-02:/usr/share/elasticsearch/data
        networks:
            - elastic_network
        ports:
            - 9202:${ES_PORT}
        environment:
            - node.name=es-masternode-02
            - node.roles=master,data
            - cluster.name=${CLUSTER_NAME}
            - cluster.initial_master_nodes=es-masternode-01,es-masternode-02,es-
masternode-03
            - discovery.seed_hosts=es-masternode-01,es-masternode-02,es-masternode-03
            - ELASTIC_PASSWORD=${ES_PASSWORD}
            - bootstrap.memory_lock=true
            - xpack.security.enabled=true
            - xpack.security.http.ssl.enabled=true
            - xpack.security.http.ssl.key=certs/es-masternode-02/es-masternode-02.key
            - xpack.security.http.ssl.certificate=certs/es-masternode-02/es-
masternode-02.crt
            - xpack.security.http.ssl.certificate_authorities=certs/ca/ca.crt
            - xpack.security.transport.ssl.enabled=true
            - xpack.security.transport.ssl.key=certs/es-masternode-02/es-masternode-
02.key
            - xpack.security.transport.ssl.certificate=certs/es-masternode-02/es-
masternode-02.crt
            - xpack.security.transport.ssl.certificate_authorities=certs/ca/ca.crt
            - xpack.security.transport.ssl.verification_mode=certificate
            - xpack.license.self_generated.type=${LICENSE}
            - ES_JAVA_OPTS=-Xms512m -Xmx512m
        mem_limit: ${ES_MEM_LIMIT}
        ulimits:
            memlock:
                soft: -1
                hard: -1
        healthcheck:
            test:
                [
                   "CMD-SHELL",
                   "curl -s --cacert config/certs/ca/ca.crt https://sheild-es-
masternode-02:${ES_PORT} | grep -q 'missing authentication credentials'"
                ]
            interval: 10s
            timeout: 10s
            retries: 120
```

```
    es-masternode-03:
        image: docker.elastic.co/elasticsearch/elasticsearch:${STACK_VERSION}
        hostname: sheild-es-masternode-03
        container_name: marvel-es-masternode-03
        depends_on:
            es-coord:
                condition: service_healthy
        volumes:
            - certs:/usr/share/elasticsearch/config/certs
            - es-data-03:/usr/share/elasticsearch/data
        networks:
            - elastic_network
        ports:
            - 9203:${ES_PORT}
        environment:
            - node.name=es-masternode-03
            - node.roles=master,data
            - cluster.name=${CLUSTER_NAME}
            - cluster.initial_master_nodes=es-masternode-01,es-masternode-02,es-
masternode-03
            - discovery.seed_hosts=es-masternode-01,es-masternode-02,es-masternode-03
            - ELASTIC_PASSWORD=${ES_PASSWORD}
            - bootstrap.memory_lock=true
            - xpack.security.enabled=true
            - xpack.security.http.ssl.enabled=true
            - xpack.security.http.ssl.key=certs/es-masternode-03/es-masternode-03.key
            - xpack.security.http.ssl.certificate=certs/es-masternode-03/es-
masternode-03.crt
            - xpack.security.http.ssl.certificate_authorities=certs/ca/ca.crt
            - xpack.security.transport.ssl.enabled=true
            - xpack.security.transport.ssl.key=certs/es-masternode-03/es-masternode-
03.key
            - xpack.security.transport.ssl.certificate=certs/es-masternode-03/es-
masternode-03.crt
            - xpack.security.transport.ssl.certificate_authorities=certs/ca/ca.crt
            - xpack.security.transport.ssl.verification_mode=certificate
            - xpack.license.self_generated.type=${LICENSE}
            - ES_JAVA_OPTS=-Xms512m -Xmx512m
        mem_limit: ${ES_MEM_LIMIT}
        ulimits:
            memlock:
                soft: -1
                hard: -1
        healthcheck:
            test:
                [
                   "CMD-SHELL",
                   "curl -s --cacert config/certs/ca/ca.crt https://sheild-es-
masternode-03:${ES_PORT} | grep -q 'missing authentication credentials'"
                ]
            interval: 10s
            timeout: 10s
            retries: 120
```

Kibana Instances (kibana-01, kibana-02)

- **Purpose:** Provides a graphical interface for querying and visualizing data in Elasticsearch. There are two instances of Kibana for load balancing.
- **Image:** Official Kibana image from Elastic.
- **Volumes:** Uses the certs volume for certificates and kibana-data-01/kibana-data-02 for persistent Kibana data.

- **Ports:** Exposes Kibana on **${KIBANA_PORT}** (e.g., 5601 for kibana-01 and 5602 for kibana-02).
- **Environment Variables:**
  - **SERVER_SSL_ENABLED:** Enables SSL for secure communication.
  - **ELASTICSEARCH_HOSTS:** Connects Kibana to the Elasticsearch coordination node.
  - **ELASTICSEARCH_USERNAME** and **ELASTICSEARCH_PASSWORD:** Used for secure access to Elasticsearch.
- **Healthcheck:** Ensures Kibana is running and accessible via HTTPS.

```
    kibana-01:
        image: docker.elastic.co/kibana/kibana:${STACK_VERSION}
        hostname: sheild-kibana-01
        container_name: marvel-kibana-01
        depends_on:
            es-coord:
                condition: service_healthy
        volumes:
            - certs:/usr/share/kibana/config/certs
            - kibana-data-01:/usr/share/kibana/data
        networks:
            - elastic_network
        ports:
            - ${KIBANA_PORT}:${KIBANA_PORT}
        environment:
            - SERVER_NAME=kibana
            - ELASTICSEARCH_HOSTS=https://es-coord:${ES_PORT}
            - ELASTICSEARCH_USERNAME=${KIBANA_USER}
            - ELASTICSEARCH_PASSWORD=${KIBANA_PASSWORD}
            - SERVER_SSL_ENABLED=true
            - SERVER_SSL_CERTIFICATE=config/certs/kibana/kibana-01.crt
            - SERVER_SSL_KEY=config/certs/kibana/kibana-01.key
            - SERVER_SSL_CERTIFICATE_AUTHORITIES=config/certs/ca/ca.crt
            - ELASTICSEARCH_SSL_CERTIFICATEAUTHORITIES=config/certs/ca/ca.crt
            - SERVER_PUBLICBASEURL=https://kibana-01:${KIBANA_PORT}
        mem_limit: ${KB_MEM_LIMIT}
        healthcheck:
            test:
                [
                   "CMD-SHELL",
                   "curl -s --cacert /usr/share/kibana/config/certs/kibana/kibana-
01.crt --fail --insecure -o /dev/null https://sheild-kibana-01:${KIBANA_PORT} || exit
1"
                ]
            interval: 10s
            timeout: 10s
            retries: 300

    kibana-02:
        image: docker.elastic.co/kibana/kibana:${STACK_VERSION}
        hostname: sheild-kibana-02
        container_name: marvel-kibana-02
        depends_on:
            es-coord:
                condition: service_healthy
        volumes:
            - certs:/usr/share/kibana/config/certs
            - kibana-data-02:/usr/share/kibana/data
        networks:
            - elastic_network
```

```
        ports:
            - 5602:${KIBANA_PORT}
        environment:
            - SERVER_NAME=kibana
            - ELASTICSEARCH_HOSTS=https://es-coord:${ES_PORT}
            - ELASTICSEARCH_USERNAME=${KIBANA_USER}
            - ELASTICSEARCH_PASSWORD=${KIBANA_PASSWORD}
            - SERVER_SSL_ENABLED=true
            - SERVER_SSL_CERTIFICATE=config/certs/kibana/kibana-02.crt
            - SERVER_SSL_KEY=config/certs/kibana/kibana-02.key
            - SERVER_SSL_CERTIFICATE_AUTHORITIES=config/certs/ca/ca.crt
            - ELASTICSEARCH_SSL_CERTIFICATEAUTHORITIES=config/certs/ca/ca.crt
            - SERVER_PUBLICBASEURL=https://kibana-02:${KIBANA_PORT}
        mem_limit: ${KB_MEM_LIMIT}
        healthcheck:
            test:
                [
                   "CMD-SHELL",
                   "curl -s --cacert /usr/share/kibana/config/certs/kibana/kibana-
01.crt --fail --insecure -o /dev/null https://sheild-kibana-02:${KIBANA_PORT} || exit
1"
                ]
            interval: 10s
            timeout: 10s
            retries: 300
```

Logstash

- **Purpose:** Ingests data from Kafka and pushes it to Elasticsearch for indexing.
- **Build:** Custom build from the logstash directory with the provided ***Dockerfile***.
- **Networks:** Connected to both ***elastic_network*** and ***kafka_network*** to ingest data from Kafka and forward it to Elasticsearch.
- **Ports:** Exposes port **5044** for filebeat or other input connections.
- **Environment Variables:**
  - **LS_JAVA_OPTS:** Configures memory settings for Logstash.
  - **xpack.monitoring.enabled:** Disables monitoring to reduce overhead.
  - **Command:** Runs Logstash with a custom configuration file (**logstash.conf**) for Kafka-to-Elasticsearch processing.
- **Healthcheck:** Verifies Logstash's connection to Elasticsearch.

```
    logstash:
        build:
            context: ./logstash
            dockerfile: Dockerfile
        hostname: sheild-logstash
        container_name: marvel-logstash
        depends_on:
            es-coord:
                condition: service_healthy
            kafka:
                condition: service_healthy
        labels:
            co.elastic.logs/module: logstash
        user: root
        volumes:
```

```
            - certs:/usr/share/logstash/config/certs
        networks:
            - elastic_network
            - kafka_network
        ports:
            - 5044:5044
        environment:
            - NODE_NAME="logstash"
            - xpack.monitoring.enabled=false
            - LS_JAVA_OPTS=-Xmx1g -Xms1g
        command: logstash -f /usr/share/logstash/pipeline/logstash.conf
        healthcheck:
            test: ["CMD-SHELL", "curl --cacert /usr/share/logstash/config/certs/ca.crt
https://logstash:${ES_PORT} -u ${ES_USER}:${ES_PASSWORD} -o /dev/null -w
\"%{http_code}\" -s | grep -q 200"]
            interval: 10s
            timeout: 10s
            retries: 3
```

Zookeeper

- **Purpose:** Coordinates the Kafka brokers by managing the distributed configuration and ensuring fault-tolerance.
- **Image:** Confluent's Zookeeper image.
- **Ports:** Exposes Zookeeper on the default port (**2181**).
- **Environment Variables:**
  - **ZOOKEEPER_CLIENT_PORT:** Specifies the Zookeeper client port.
  - **ZOOKEEPER_TICK_TIME:** Defines the basic time unit for Zookeeper's heartbeat mechanism.
- **Healthcheck:** Pings the Zookeeper server to ensure it is running.

```
    zookeeper:
        image: confluentinc/cp-zookeeper:latest
        hostname: sheild-zookeeper
        container_name: marvel-zookeeper
        environment:
            - ZOOKEEPER_CLIENT_PORT=${ZK_PORT}
            - ZOOKEEPER_TICK_TIME=2000
        ports:
            - ${ZK_PORT}:${ZK_PORT}
        networks:
            - kafka_network
        healthcheck:
          test: [ "CMD", "bash", "-c", "echo 'ruok' | nc localhost 2181" ]
          interval: 10s
          retries: 3
          start_period: 30s
          timeout: 5s
```

Kafka

- **Purpose:** Acts as the message broker, receiving data from the Python banking app and allowing Logstash to consume the data.
- **Image:** Confluent Kafka image.
- **Ports:** Exposes Kafka on **${KAFKA_PORT}** for communication.

- **Environment Variables:**
  - **KAFKA_ZOOKEEPER_CONNECT:** Connects Kafka to Zookeeper.
  - **KAFKA_ADVERTISED_LISTENERS:** Defines how Kafka is accessible from within and outside the Docker network.
  - **Command:** Creates the Kafka topic **(${KAFKA_TOPIC_1})** before starting Kafka.
- **Healthcheck:** Verifies Kafka is running and accessible.

```
    kafka:
        hostname: sheild-kafka
        container_name: marvel-kafka
        depends_on:
            zookeeper:
                condition: service_healthy
        image: confluentinc/cp-kafka:latest
        ports:
            - ${KAFKA_PORT}:${KAFKA_PORT}
        environment:
            - KAFKA_BROKER_ID=1
            - KAFKA_ZOOKEEPER_CONNECT=zookeeper:${ZK_PORT}
            -
KAFKA_ADVERTISED_LISTENERS=PLAINTEXT://${KAFKA_BOOTSTRAP_SERVERS},PLAINTEXT_HOST://loc
alhost:29092
            -
KAFKA_LISTENER_SECURITY_PROTOCOL_MAP=PLAINTEXT:PLAINTEXT,PLAINTEXT_HOST:PLAINTEXT
            - KAFKA_INTER_BROKER_LISTENER_NAME=PLAINTEXT
            - KAFKA_OFFSETS_TOPIC_REPLICATION_FACTOR=1
        command: sh -c "((sleep 120 && kafka-topics --create --topic ${KAFKA_TOPIC_1}
--bootstrap-server ${KAFKA_BOOTSTRAP_SERVERS} --partitions 1 --replication-factor 1)&)
&& /etc/confluent/docker/run ">
        networks:
            - kafka_network
        healthcheck:
            test: ["CMD-SHELL", "nc -z kafka ${KAFKA_PORT} || exit 1"]
            interval: 30s
            retries: 3
            start_period: 60s
            timeout: 10s
```

Python Banking Application (banking-app)

- **Purpose:** Simulates the data producer, generating synthetic banking transactions and sending them to Kafka.
- **Build:** Built from the banking directory with the provided **Dockerfile**.
- **Networks:** Connected to the **kafka_network** for communication with Kafka.
- **Environment Variables:**
  - **KAFKA_BOOTSTRAP_SERVERS:** Defines the Kafka bootstrap server address.
  - **KAFKA_TOPIC:** Defines the Kafka topic where the banking transactions are published.
  - **Command:** Runs the Python script (banking_app.py) to generate and publish data.
- **Healthcheck:** Verifies Kafka connectivity to ensure proper data production.

```
    banking-app:
        hostname: sheild-banking-app
        container_name: marvel-banking-app
        depends_on:
            kafka:
                condition: service_healthy
```

```
        build:
            context: ./banking
            dockerfile: Dockerfile
        networks:
            - kafka_network
        working_dir: /usr/src/app
        environment:
            - KAFKA_BOOTSTRAP_SERVERS=${KAFKA_BOOTSTRAP_SERVERS}
            - KAFKA_TOPIC=${KAFKA_TOPIC_1}

        command: ["python3", "/usr/src/app/banking_app.py"]
        healthcheck:
            test: ["CMD-SHELL", "nc -z kafka ${KAFKA_PORT} || exit 1"]
            interval: 30s
            timeout: 10s
            retries: 3
```

9.2 .env [/project-diroctory]

The .env file is critical for configuring environment variables that are used throughout the ***docker-compose.yml*** file and Docker containers. It provides centralized settings that allow for dynamic configuration of the services without hardcoding values in the ***docker-compose.yml*** file. Here is a detailed breakdown of each environment variable used:

- **STACK_VERSION:** Specifies the version of the Elastic Stack products (Elasticsearch, Logstash, Kibana). Here, version 8.15.0 is used, which ensures all Elastic components run on the same compatible version.
- **COMPOSE_PROJECT_NAME:** Defines the project name for Docker Compose. In this case, techsavvyrc is used, which acts as a namespace for all containers and resources (e.g., network, volume names). It helps avoid conflicts with other projects running on the same Docker host.
- **CLUSTER_NAME:** Defines the name of the Elasticsearch cluster. Here, marvel is used, and this name helps to identify the cluster in a multi-cluster setup. All nodes belonging to this cluster will use this name for coordination.
- **LICENSE:** Specifies the type of Elastic Stack license. Setting it to basic enables the free tier of Elasticsearch and Kibana, which includes essential features. You could also set this to trial to enable the 30-day trial of enterprise features.
- **ES_USER** and **ES_PASSWORD:** Credentials for accessing Elasticsearch. These values (elastic and elastic) define the default user and password required for connecting to Elasticsearch and are used for both internal communication (Logstash, Kibana) and external API access.
- **ES_PORT:** Defines the port number on which Elasticsearch is exposed. The default port for Elasticsearch is 9200, and this is used by Kibana and Logstash to communicate with Elasticsearch.
- **ES_INDEX_1** and **ES_INDEX_2:** These variables define the indices (data storage units) for Elasticsearch. In this setup, bank_transactions and ecom_transactions are used as two separate indices for storing banking and e-commerce transaction data, respectively.
- **KIBANA_USER** and **KIBANA_PASSWORD:** These are the credentials for the kibana_system user, which Kibana uses to authenticate with Elasticsearch. The same password (elastic) is shared between Elasticsearch and Kibana for simplicity.
- **KIBANA_PORT:** Defines the port number on which Kibana will be exposed. Here, it is set to 5601, which is the default port for accessing Kibana's web interface.

- **ES_MEM_LIMIT:** Defines the memory limit for Elasticsearch containers. The value 4294967296 bytes translates to 4 GB of memory, which restricts the maximum memory that Elasticsearch can use, ensuring it does not exceed the available host memory.
- **KB_MEM_LIMIT:** Defines the memory limit for Kibana containers. Set to 1073741824 bytes, which equals 1 GB of memory for Kibana.
- **LS_MEM_LIMIT:** Defines the memory limit for Logstash containers. Like Kibana, it is also set to 1 GB (1073741824 bytes), which is sufficient for moderate ingestion workloads.
- **ZK_PORT:** Defines the port for Zookeeper, which is part of the Kafka infrastructure. The port 2181 is the default client port for Zookeeper, used for managing and coordinating Kafka brokers.
- **KAFKA_BOOTSTRAP_SERVERS:** Specifies the Kafka bootstrap server, which is the entry point for clients to connect to the Kafka cluster. In this setup, kafka:9092 means Kafka is accessible on the internal hostname kafka via port 9092.
- **KAFKA_PORT:** Defines the port number on which Kafka is exposed. Port 9092 is the standard port for Kafka communication and is used by Logstash and the Python banking app to send and receive messages.
- **KAFKA_TOPIC_1** and **KAFKA_TOPIC_2:** These variables define the Kafka topics used to categorize messages. In this setup, bank_transactions and ecom_transactions are the two Kafka topics where the banking and e-commerce transaction data is published, respectively.

```
# Version of Elastic products
STACK_VERSION=8.15.0

# Project namespace (defaults to the current folder name if not set)
COMPOSE_PROJECT_NAME=techsavvyrc

# Set the cluster name
CLUSTER_NAME=marvel

# Set to 'basic' or 'trial' to automatically start the 30-day trial
LICENSE=basic

# Elastic settings
ES_USER=elastic
ES_PASSWORD=elastic
ES_PORT=9200
ES_INDEX_1=bank_transactions
ES_INDEX_2=ecom_transactions

# Kibana settings
KIBANA_USER=kibana_system
KIBANA_PASSWORD=elastic
KIBANA_PORT=5601

# Increase or decrease based on the available host memory (in bytes)
ES_MEM_LIMIT=4294967296
KB_MEM_LIMIT=1073741824
LS_MEM_LIMIT=1073741824

# Zookeeper Settings
ZK_PORT=2181

# Kafka Settings
KAFKA_BOOTSTRAP_SERVERS=kafka:9092
KAFKA_PORT=9092
KAFKA_TOPIC_1=bank_transactions
KAFKA_TOPIC_2=ecom_transactions
```

9.3 .env [/project-directory/logstash]

This **.env** file under the **logstash** directory provides essential configuration details that Logstash uses to interact with both Elasticsearch and Kafka. These variables simplify the configuration of Logstash by centralizing key values that can be referenced within the Logstash configuration files (like **logstash.conf**). Here's a detailed breakdown of each environment variable:

- **ES_USER:** The username (*elastic*) for authenticating with Elasticsearch. This is used by Logstash to securely connect to Elasticsearch and push data into the defined indices.
- **ES_PASSWORD:** The password (*elastic*) for the Elasticsearch user. This ensures that Logstash can authenticate successfully with Elasticsearch when indexing data. This credential matches the one defined in the main .env file to ensure consistency across services.
- **ES_PORT:** Specifies the port number (**9200**) on which Elasticsearch is running. Logstash needs this to know where to send data for indexing. Port **9200** is the standard port for Elasticsearch's REST API, used for both searching and indexing data.
- **ES_INDEX_1 and ES_INDEX_2:** These variables define the Elasticsearch indices where Logstash will store ingested data.
  - **ES_INDEX_1 (bank_transactions):** Used to store data related to banking transactions.
- **KAFKA_BOOTSTRAP_SERVERS:** This defines the Kafka bootstrap server address (***kafka:9092***), which Logstash connects to for consuming messages. The kafka hostname refers to the internal service name in the Docker network, and port 9092 is Kafka's default communication port.
- **KAFKA_PORT:** Specifies the port number (**9092**) for Kafka communication. This is the port on which Kafka listens for incoming connections from clients, such as Logstash, which subscribes to Kafka topics to ingest data.
- **KAFKA_TOPIC_1 and KAFKA_TOPIC_2:** These define the Kafka topics that Logstash will consume from.
  - **KAFKA_TOPIC_1 (bank_transactions):** Logstash listens to this topic for banking transaction data generated by the Python banking app.

```
ES_USER=elastic
ES_PASSWORD=elastic
ES_PORT=9200
ES_INDEX_1=bank_transactions
KAFKA_BOOTSTRAP_SERVERS=kafka:9092
KAFKA_PORT=9092
KAFKA_TOPIC_1=bank_transactions
```

9.4 Dockerfile [/project-directory/logstash]

This ***Dockerfile*** defines the custom image and environment for running the Logstash service in your Docker-based ELK stack setup. The image builds on the official Logstash base image and customizes it by installing additional packages, copying configuration files, and setting up an entry point script. Here's a detailed explanation of each instruction:

- **Base Image:**

  ```
  FROM docker.elastic.co/logstash/logstash:8.15.0
  ```

  - This line pulls the official Logstash image, version 8.15.0, from the Elastic repository. This base image contains the core Logstash functionality and is used as the starting point for building a custom Logstash container.

- **Working Directory:**

```
WORKDIR /usr/share/logstash/pipeline
```

- Sets the working directory within the container to */usr/share/logstash/pipeline*. This is where all subsequent commands (like copying files) will be executed and is the directory where Logstash expects its configuration files (pipelines) to be located.

- **User Privileges:**

```
USER root
```

  - Switches to the root user to install additional system packages. The default user for the Logstash container does not have the necessary privileges to install packages, so this is required to perform system-level changes.

- **Package Installation:**

```
RUN apt-get update && apt-get install -y gettext-base vim net-tools inetutils-ping netcat-traditional
```

  - Installs several packages using **apt-get**. These packages provide additional tools needed for debugging, networking, and environment variable substitution:
    - **gettext-base:** Provides the envsubst tool, used for substituting environment variables into configuration files.
    - **vim:** A text editor, useful for debugging inside the container.
    - **net-tools, inetutils-ping:** Networking tools used to check network connections and interfaces.
    - **netcat-traditional:** Used for testing network connections, often helpful for verifying Kafka connections and other network-based services.

- **Copy Environment and Configuration Files:**

```
COPY .env /usr/share/logstash/pipeline
COPY logstash.template.conf /usr/share/logstash/pipeline
COPY entrypoint.sh /usr/share/logstash/pipeline
```

  - These commands copy important files from the local directory (where the ***Dockerfile*** is located) into the container's working directory (*/usr/share/logstash/pipeline*):
    - **.env:** The environment variables file. These variables are referenced in the Logstash configuration file and are used to dynamically configure Logstash.
    - **logstash.template.conf:** The Logstash pipeline configuration template, which contains placeholders for environment variables (e.g., Kafka topic names, Elasticsearch credentials). This file defines how data flows from Kafka to Elasticsearch.
    - **entrypoint.sh:** A script that will be executed when the container starts. It dynamically substitutes environment variables into the ***logstash.template.conf*** to create a final ***logstash.conf*** file that Logstash will use.

- **Set File Permissions:**

```
RUN chmod +x /usr/share/logstash/pipeline/entrypoint.sh
```

  - Grants execution permissions (+x) to the entrypoint.sh script, allowing it to be run when the container starts.

- **Entry Point:**

```
ENTRYPOINT ["/usr/share/logstash/pipeline/entrypoint.sh"]
```

  - Sets the entrypoint for the container. This means that when the container is run, it will execute the ***entrypoint.sh*** script. The script is responsible for:
    - Substituting environment variables in the ***logstash.template.conf***.

- Creating the final ***logstash.conf*** configuration file.
- Starting Logstash with the generated configuration.

```
# Use Logstash base image
FROM docker.elastic.co/logstash/logstash:8.15.0

# Set working directory
WORKDIR /usr/share/logstash/pipeline

# Switch to root user to install packages
USER root

# Install requied packages
RUN apt-get update && apt-get install -y gettext-base vim net-tools inetutils-ping
netcat-traditional

# Copy scripts and configuration templates
COPY .env /usr/share/logstash/pipeline
COPY logstash.template.conf /usr/share/logstash/pipeline
COPY entrypoint.sh /usr/share/logstash/pipeline

# Give execution rights to the script
RUN chmod +x /usr/share/logstash/pipeline/entrypoint.sh

# Substitute environment variables in the Python script
ENTRYPOINT ["/usr/share/logstash/pipeline/entrypoint.sh"]
```

9.5 entrypoint.sh [/project-directory/logstash]

The ***entrypoint.sh*** script is responsible for dynamically configuring Logstash at container startup. It reads environment variables from the ***.env*** file, substitutes these values into the Logstash configuration template, and then launches Logstash with the finalized configuration. This script is crucial for ensuring that Logstash operates correctly with dynamically set values (e.g., Kafka topics, Elasticsearch credentials).

The entrypoint.sh script performs the following key tasks:

1) Exports environment variables from the .env file, making them available for use in the script.
2) Substitutes the environment variables into the Logstash configuration template (***logstash.template.conf***), generating the final **logstash.conf** file.
3) Ensures correct permissions on the generated configuration file so that Logstash can access it.
4) Starts Logstash with the generated configuration file.

```
#!/bin/bash

# Export variables from .env file to environment variables
export $(cat /usr/share/logstash/pipeline/.env | xargs)

# Substitute variables in create-topic.sh and logstash.conf
envsubst < /usr/share/logstash/pipeline/logstash.template.conf >
/usr/share/logstash/pipeline/logstash.conf

# Ensure the substituted files have the correct permissions
chown root:root /usr/share/logstash/pipeline/logstash.conf

# Execute the Python script
exec logstash -f /usr/share/logstash/pipeline/logstash.conf
```

9.6 logstash.template.conf [/project-directory/logstash]

The ***logstash.template.conf*** file is a Logstash configuration template that defines how data flows from **Kafka** (as the input) to **Elasticsearch** (as the output). This template uses placeholders (environment variables) to dynamically configure Kafka and Elasticsearch settings at runtime, making the setup flexible and adaptable to different environments without needing to modify the configuration file directly.

Input Section: Kafka

```
input {
  kafka {
    bootstrap_servers => "${KAFKA_BOOTSTRAP_SERVERS}"
    topics => ["${KAFKA_TOPIC_1}"]
    codec => "json"
  }
}
```

This section defines Kafka as the input source for Logstash, meaning Logstash will consume data from Kafka topics. The key settings here are:

- **bootstrap_servers:**
  - The Kafka broker address is specified dynamically using the **${KAFKA_BOOTSTRAP_SERVERS}** environment variable. In this case, it points to the Kafka instance defined in the ***.env*** file (e.g., **kafka:9092**), allowing Logstash to connect to the Kafka cluster for consuming messages.

- **topics:**
  - Logstash will subscribe to the topic(s) specified in this configuration. Here, **${KAFKA_TOPIC_1}** is dynamically substituted with the actual Kafka topic name (e.g., **bank_transactions**), allowing Logstash to consume messages from the relevant Kafka topic. This topic is where the Python banking application sends the generated transaction data.

- **codec:**
  - Specifies the format of the incoming Kafka messages. In this case, json is used, meaning the data consumed from Kafka is in ***JSON format***. Logstash will parse these messages as JSON objects, making it easy to extract and transform fields for further processing.

Output Section: Elasticsearch

```
output {
  elasticsearch {
    hosts => ["https://es-coord:9200"]
    user => "${ES_USER}"
    password => "${ES_PASSWORD}"
    ssl_enabled => true
    cacert => "/usr/share/logstash/config/certs/ca/ca.crt"
    index => "${ES_INDEX_1}"
  }
}
```

This section defines Elasticsearch as the output destination for Logstash. After processing the data from Kafka, Logstash sends the data to Elasticsearch for indexing and storage. The key settings here are:

- **hosts:**
  - Specifies the Elasticsearch endpoint that Logstash will connect to. In this case, the host is the Elasticsearch coordination node **(es-coord:9200**), which routes requests to the master nodes for indexing.

- **user and password:**
  - These are dynamically populated from the environment variables **${ES_USER}** and **${ES_PASSWORD}**, respectively. They provide the credentials for Logstash to authenticate with Elasticsearch, using the default user (***elastic***) and password.

- **ssl_enabled:**
  - Ensures that Logstash uses SSL/TLS encryption when communicating with Elasticsearch. This setting is crucial for securing communication between Logstash and Elasticsearch, especially when handling sensitive data.

- **cacert:**
  - Points to the certificate authority (CA) certificate file ***(/usr/share/logstash/config/certs/ca/ca.crt***), which Logstash uses to verify the authenticity of the SSL connection to Elasticsearch. This certificate was generated during the setup process.

- **index:**
  - Defines the Elasticsearch index where the processed data will be stored. The index name is dynamically set using the ***${ES_INDEX_1}*** environment variable, which could be something like ***bank_transactions***. This makes it easy to route different data streams to different indices based on the environment or use case.

9.7 .env [/project-directory/banking]

This **.env** file under the banking directory defines the environment variables used by the **Python banking application**. The app simulates the generation of synthetic transaction data and sends it to Kafka for further processing by Logstash and Elasticsearch. These variables allow the banking application to connect to Kafka and specify the Kafka topics where the generated data will be published. Below is a detailed explanation of each environment variable:

- **KAFKA_BOOTSTRAP_SERVERS:**
  - Specifies the address of the Kafka broker that the banking application will connect to. In this case, **kafka:9092** refers to the Kafka broker running within the Docker network (the service name **kafka**), and **9092** is the default Kafka port for communication.
  - This allows the banking application to send transaction data to Kafka for ingestion.

- **KAFKA_PORT:**
  - Defines the port number (**9092**) for Kafka communication. This is the standard port Kafka uses to listen for incoming connections from producers (like the banking app) and consumers (like Logstash). This ensures that the app knows which port to use to send its data to Kafka.

- **KAFKA_TOPIC_1:**
  - Specifies the first Kafka topic (**bank_transactions**) to which the banking application will publish its generated banking transaction data.
  - Kafka topics are logical channels where producers (like the banking app) send data, and consumers (like Logstash) retrieve it. The use of **${KAFKA_TOPIC_1}** ensures that all banking-related transaction data is sent to the ***bank_transactions*** topic.

```
KAFKA_BOOTSTRAP_SERVERS=kafka:9092
KAFKA_PORT=9092
KAFKA_TOPIC_1=bank_transactions
```

9.8 Dockerfile [/project-directory/banking]

This **Dockerfile** defines the steps to build a Docker image for the **Python banking application**. The image is based on Python 3.9, and additional packages are installed to run the application, which generates and sends synthetic transaction data to Kafka. This ***Dockerfile*** includes steps to copy necessary files, install required Python libraries, and dynamically configure the Python script at runtime. Below is a detailed explanation of each instruction:

- **Base Image:**
  `FROM python:3.9`
  - This pulls the **official Python 3.9 image** from Docker Hub. This image includes Python and the necessary tools to run Python applications, making it a good starting point for building the banking app.
  - The Python banking application will run on this version of Python.

- **Working Directory:**
  `WORKDIR /usr/src/app`
  - Sets the working directory inside the container to ***/usr/src/app***. All subsequent commands, like copying files and running scripts, will be executed within this directory.
  - This helps organize the application files within the container.

- **Copy the Requirements File:**
  `COPY requirements.txt .`
  - Copies the ***requirements.txt*** file from the local directory (where the **Dockerfile** resides) into the container's working directory (***/usr/src/app***).
  - The **requirements.txt** file lists all the Python libraries the application needs.

- **Install Python Packages:**
  `RUN pip install --no-cache-dir -r requirements.txt`
  - Installs the required Python packages listed in **requirements.txt** using **pip**. The **--no-cache-dir** option prevents caching of installed packages, which reduces the size of the final image.
  - These libraries might include packages for Kafka integration, JSON handling, and other dependencies required by the banking app.

- **Install Additional System Packages:**
  `RUN apt-get update && apt-get install -y gettext-base vim net-tools inetutils-ping netcat-traditional`
  - Installs additional system packages needed for the container. These utilities are useful for debugging, networking, and environment variable substitution:
    - **gettext-base:** Provides the **envsubst** tool for substituting environment variables in files.
    - **vim:** A text editor for viewing/editing files inside the container.
    - **net-tools, inetutils-ping:** Networking tools to check connectivity, resolve DNS, and troubleshoot issues inside the container.
    - **netcat-traditional:** A utility for testing network connections (useful for debugging Kafka connections).

- **Copy Files into the Container:**
  `COPY .env /usr/src/app`
  `COPY banking_app.template.py /usr/src/app`
  `COPY entrypoint.sh /usr/src/app`
  - These commands copy the necessary files from the local directory into the container:

- **.env:** The environment variables file that contains Kafka configuration (e.g., Kafka broker address and topic names).
- **banking_app.template.py:** A template Python script for the banking app that generates synthetic transaction data and sends it to Kafka. This template will have placeholders for environment variables, such as Kafka topic names.
- **entrypoint.sh:** A shell script that substitutes environment variables into the Python script and runs it when the container starts.

- **Set File Permissions:**

  `RUN chmod +x /usr/src/app/entrypoint.sh`

  - Grants execution permissions to the **entrypoint.sh** script, allowing it to be executed when the container starts. This is necessary because the script will handle environment variable substitution and the execution of the Python application.

- **Entry Point:**

  `ENTRYPOINT ["/usr/src/app/entrypoint.sh"]`

  - Specifies the entry point for the container. When the container starts, it will execute the **entrypoint.sh** script.
  - This script will:
    - Substitute environment variables into the Python template script (**banking_app.template.py**).
    - Run the finalized Python script, which generates and sends synthetic transaction data to Kafka.

```
# Use official Python image
FROM python:3.9

# Set working directory
WORKDIR /usr/src/app

# Copy the requirements file
COPY requirements.txt .

# Install required Python packages
RUN pip install --no-cache-dir -r requirements.txt

# Install requied packages
RUN apt-get update && apt-get install -y gettext-base vim net-tools inetutils-ping
netcat-traditional

# Copy .env file and template Python script into the container
COPY .env /usr/src/app
COPY banking_app.template.py /usr/src/app
COPY entrypoint.sh /usr/src/app

# Give execution rights to the script
RUN chmod +x /usr/src/app/entrypoint.sh

# Substitute environment variables in the Python script
ENTRYPOINT ["/usr/src/app/entrypoint.sh"]
```

9.9 entrypoint.sh [/project-directory/banking]

The **entrypoint.sh** script is responsible for dynamically configuring the banking application at container startup. It reads environment variables from the **.env** file, substitutes these values into the Python application template, and then

launches the application with the finalized configuration. This script is crucial for ensuring that the banking application operates correctly with dynamically set values.

The entrypoint.sh script performs the following key tasks:

1) Exports environment variables from the **.env** file, making them available for use in the script.
   - The script reads the **.env** file and exports its variables to the environment. This ensures that all necessary configuration values are available as environment variables.
2) Substitutes the environment variables into the Python application template (**banking_app.template.py**), generating the final **banking_app.py** file.
   - Using the **envsubst** command, the script replaces placeholders in the template file with actual environment variable values, creating a fully configured **banking_app.py** file.
3) Ensures correct permissions on the generated Python file so that it can be executed.
   - The script sets execute permissions on the **banking_app.py** file to ensure it can be run as a script.
4) Starts the Python application with the generated configuration file.
   - Finally, the script executes the **banking_app.py** file using Python, launching the banking application with the dynamically configured settings.

```
#!/bin/bash

# Export variables from .env file to environment variables
export $(cat /usr/src/app/.env | xargs)

# Substitute variables in cbanking_app.py and logstash.conf
envsubst < /usr/src/app/banking_app.template.py > /usr/src/app/banking_app.py

# Ensure the substituted files have the correct permissions
chmod +x /usr/src/app/banking_app.py

# Ensure the substituted file has the correct permissions
chmod +x banking_app.py

# Execute the Python script
exec python3 banking_app.py
```

9.10 banking_app.template.py [/project-directory/banking]

The **banking_app.template.py** script is a template for generating a Python script that simulates banking transactions and publishes them to a Kafka topic. The environment variables in this template are replaced by the **entrypoint.sh** script at container startup, ensuring that the application is configured with the correct values. This script is crucial for generating realistic transaction data and testing the integration with Kafka.

The **banking_app.template.py** script performs the following key tasks:

1) Imports necessary libraries and initializes the logger.

```
import csv
import json
import time
import random
import os
import logging
```

```
from datetime import datetime, timedelta
from faker import Faker
from kafka import KafkaProducer
from random import choice, uniform, randint

# Initialize Logger
logging.basicConfig(filename="banking_app.log", level=logging.INFO,
format='%(asctime)s - %(levelname)s - %(message)s')
logger = logging.getLogger(__name__)
```

- **Purpose:** Imports various libraries required for generating transaction data, handling dates and times, logging, and interacting with Kafka.
- **Logger Initialization:** Sets up a logger to log information and errors to a file named **banking_app.log**.

2) Defines country, currency, and city data.

```
# Initialize Faker instance
fake = Faker()

# Define Country, Currency, and City Data
COUNTRIES_DATA = {
    "United States": {
        "currency": "USD",
        "cities": ["New York City", "Los Angeles", "Chicago", "Houston", "San
Francisco"],
        "country_code": "+1"
    },
    "Canada": {
        "currency": "CAD",
        "cities": ["Toronto", "Vancouver", "Montreal", "Calgary", "Ottawa"],
        "country_code": "+1"
    },
    "United Kingdom": {
        "currency": "GBP",
        "cities": ["London", "Manchester", "Birmingham", "Glasgow", "Edinburgh"],
        "country_code": "+44"
    },
    "Australia": {
        "currency": "AUD",
        "cities": ["Sydney", "Melbourne", "Brisbane", "Perth", "Adelaide"],
        "country_code": "+61"
    },
    "Germany": {
        "currency": "EUR",
        "cities": ["Berlin", "Munich", "Frankfurt", "Hamburg", "Cologne"],
        "country_code": "+49"
    },
    "France": {
        "currency": "EUR",
        "cities": ["Paris", "Marseille", "Lyon", "Toulouse", "Nice"],
        "country_code": "+33"
    },
    "Italy": {
        "currency": "EUR",
        "cities": ["Rome", "Milan", "Florence", "Venice", "Naples"],
        "country_code": "+39"
    },
    "Japan": {
        "currency": "JPY",
```

```
        "cities": ["Tokyo", "Osaka", "Kyoto", "Yokohama", "Nagoya"],
        "country_code": "+81"
    },
    "China": {
        "currency": "CNY",
        "cities": ["Beijing", "Shanghai", "Guangzhou", "Shenzhen", "Chengdu"],
        "country_code": "+86"
    },
    "India": {
        "currency": "INR",
        "cities": ["Delhi", "Mumbai", "Hyderabad", "Pune", "Dehradun"],
        "country_code": "+91"
    },
    "Brazil": {
        "currency": "BRL",
        "cities": ["São Paulo", "Rio de Janeiro", "Brasília", "Salvador",
"Fortaleza"],
        "country_code": "+55"
    },
    "South Africa": {
        "currency": "ZAR",
        "cities": ["Johannesburg", "Cape Town", "Durban", "Pretoria", "Port
Elizabeth"],
        "country_code": "+27"
    },
    "Mexico": {
        "currency": "MXN",
        "cities": ["Mexico City", "Guadalajara", "Monterrey", "Cancún", "Puebla"],
        "country_code": "+52"
    },
    "Russia": {
        "currency": "RUB",
        "cities": ["Moscow", "Saint Petersburg", "Novosibirsk", "Yekaterinburg",
"Kazan"],
        "country_code": "+7"
    },
    "Spain": {
        "currency": "EUR",
        "cities": ["Madrid", "Barcelona", "Valencia", "Seville", "Bilbao"],
        "country_code": "+34"
    },
    "South Korea": {
        "currency": "KRW",
        "cities": ["Seoul", "Busan", "Incheon", "Daegu", "Gwangju"],
        "country_code": "+82"
    },
    "Turkey": {
        "currency": "TRY",
        "cities": ["Istanbul", "Ankara", "Izmir", "Bursa", "Antalya"],
        "country_code": "+90"
    },
    "Saudi Arabia": {
        "currency": "SAR",
        "cities": ["Riyadh", "Jeddah", "Mecca", "Medina", "Khobar"],
        "country_code": "+966"
    },
    "Argentina": {
        "currency": "ARS",
        "cities": ["Buenos Aires", "Córdoba", "Rosario", "Mendoza", "Mar del
Plata"],
        "country_code": "+54"
    },
```

```
    "Egypt": {
        "currency": "EGP",
        "cities": ["Cairo", "Alexandria", "Giza", "Luxor", "Aswan"],
        "country_code": "+20"
    },
    "Thailand": {
        "currency": "THB",
        "cities": ["Bangkok", "Chiang Mai", "Phuket", "Pattaya", "Krabi"],
        "country_code": "+66"
    },
    "Indonesia": {
        "currency": "IDR",
        "cities": ["Jakarta", "Bali", "Surabaya", "Bandung", "Medan"],
        "country_code": "+62"
    },
    "Vietnam": {
        "currency": "VND",
        "cities": ["Hanoi", "Ho Chi Minh City", "Da Nang", "Haiphong", "Nha
Trang"],
        "country_code": "+84"
    }
}
```

- **Purpose:** Defines a dictionary **COUNTRIES_DATA** containing information about different countries, including their currency, cities, and country codes.

3) Generates a single banking transaction record.

```
# Function to generate a single banking transaction record
def generate_transaction():
    country = choice(list(COUNTRIES_DATA.keys()))
    city = choice(COUNTRIES_DATA[country]['cities'])
    currency = COUNTRIES_DATA[country]['currency']
    country_code = COUNTRIES_DATA[country]['country_code']

    transaction = {
        "transaction_id": fake.uuid4(),
        "transaction_timestamp": fake.iso8601(),
        "ingest_timestamp": datetime.now().strftime("%Y-%m-%dT%H:%M:%S"),
        "transaction_response_time": round(random.uniform(0.1, 2.5), 3),
        "mode_of_transaction": random.choice(["credit_card", "debit_card",
"online_transfer", "ATM_withdrawal"]),
        "currency": currency,
        "country": country,
        "city": city,
        "transaction_amount": round(random.uniform(5.0, 5000.0), 2),
        "transaction_type": random.choice(["deposit", "withdrawal", "transfer"]),
        "account_type": random.choice(["checking", "savings", "credit_card"]),
        "payment_method": random.choice(["cash", "card", "online_banking"]),
        "transaction_status": random.choice(["successful", "failed", "pending"]),
        "customer_info": {
            "name": fake.name(),
            "age": random.randint(18, 75),
            "occupation": fake.job(),
            "mobile_number": f"{country_code}{fake.msisdn()[len(country_code):]}",
            "email": fake.email()
        },
```

```
        "merchant_info": {
            "name": fake.company(),
            "category": random.choice(["grocery", "electronics", "fashion",
"entertainment", "food"]),
            "mobile_number": f"{country_code}{fake.msisdn()[len(country_code):]}",
            "email": fake.company_email()
        }
    }
    return transaction
```

- **Purpose:** The **generate_transaction** function creates a synthetic transaction record with various details such as transaction ID, timestamp, response time, mode of transaction, currency, country, city, transaction amount, transaction type, account type, payment method, transaction status, customer info, and merchant info.

4) Sets up Kafka producer.

```
# Kafka setup
def create_kafka_producer():
    retries = 5
    producer = None
    while retries > 0:
        try:
            producer =
KafkaProducer(bootstrap_servers=['${KAFKA_BOOTSTRAP_SERVERS}'],
value_serializer=lambda v: json.dumps(v).encode('utf-8'))
            logger.info("Kafka connection established")
            return producer
        except Exception as e:
            logger.warning(f"Kafka is not ready, retrying... ({5 - retries +
1}/5)")
            retries -= 1
            time.sleep(60)

    if producer is None:
        logger.error("Failed to connect to Kafka after multiple retries.")
        raise ConnectionError("Failed to connect to Kafka after multiple
retries.")
    return producer
```

- **Purpose:** The **create_kafka_producer** function attempts to create a Kafka producer that connects to the Kafka broker specified by the environment variable **${KAFKA_BOOTSTRAP_SERVERS}**.
- **Retries:** It retries the connection up to 5 times if the initial connection fails, logging warnings and errors as needed.

5) Publishes data to Kafka.

```
# Function to publish data to Kafka
def publish_to_kafka(producer, topic, message):
    try:
        producer.send(topic, message)
        producer.flush()
        logger.info(f"Data published to Kafka topic {topic}")
    except Exception as e:
        logger.error(f"Failed to publish message to Kafka: {str(e)}")
```

- **Purpose:** The **publish_to_kafka** function sends the generated transaction data to a specified Kafka topic and flushes the producer to ensure the data is sent. It logs the success or failure of each publish attempt.

6) Main execution block.

```
if __name__ == "__main__":
    producer = create_kafka_producer()

    while True:
        try:
            transactions = [generate_transaction() for _ in range(100)]
            for transaction in transactions:
                publish_to_kafka(producer, "${KAFKA_TOPIC_1}", transaction)
                time.sleep(0.5)

        except KeyboardInterrupt:
            logger.info("Script interrupted by user. Exiting...")
            break
        except Exception as e:
            logger.error(f"An error occurred: {str(e)}")
```

- **Purpose:** The script creates a Kafka producer and enters an infinite loop where it generates and publishes batches of 100 transactions to Kafka.
- **Publishing Transactions:** For each transaction in the batch, it publishes the transaction to the Kafka topic specified by the environment variable **${KAFKA_TOPIC_1}** and waits for 0.5 seconds before publishing the next transaction.
- **Error Handling:** The script handles interruptions and errors gracefully, logging an appropriate message if the script is interrupted by the user or if an error occurs.

9.11 requirements.txt [/project-directory/banking]

The **requirements.txt** file is a vital part of the project, listing all the Python dependencies needed for the application. It ensures that anyone working on the project can easily install the necessary packages, fostering a consistent development environment.

In the **Dockerfile**, this file is used to install the required Python packages during the Docker image build process. This guarantees that the Docker container has all the dependencies needed to run the application.

By managing the project's dependencies, the **requirements.txt** file simplifies the setup process for new developers and ensures consistent application performance across different environments. Its integration in the **Dockerfile** automates the installation of dependencies, making the Docker container ready to run the application with all necessary packages installed.

```
kafka-python
faker
```