Docker (30 days)

Week 1: Basics and Foundations

Day 1:

- **Introduction to Docker**: Learn what Docker is, why it's used, and how it fits into the DevOps ecosystem.
- **Resources**: Watch introductory videos, read articles, or explore the Docker website.

Day 2:

- **Install Docker**: Set up Docker on your machine (Windows, Mac, or Linux).
- **Resources**: Follow the official installation guide.

Day 3:

- **Basic Docker Commands**: Familiarize yourself with docker version, docker info, docker help.
- **Practice**: Run docker version and docker info commands to check your setup.

Day 4-5:

- **Docker Images**: Learn what Docker images are, and explore Docker Hub.
- **Practice**: Pull a basic image like hello-world, run it, and check logs. Try using images like ubuntu or nginx.

Day 6:

- **Containers**: Understand what containers are and how they differ from virtual machines.
- **Practice**: Run containers interactively and in detached mode, using commands like docker run -it ubuntu and docker run -d nginx.

Day 7:

- **Container Management**: Practice stopping, starting, and deleting containers.
- **Practice**: Use docker ps, docker stop, docker start, and docker rm commands.

Week 2: Building and Managing Docker Containers

Day 8:

- **Docker Networks**: Learn the basics of Docker networking.
- **Practice**: Experiment with bridge and host networks using docker network ls.

Day 9-10:

- **Dockerfile Basics**: Understand what a Dockerfile is and how to create one.
- **Practice**: Write a simple Dockerfile for a basic web server (e.g., using nginx).

Day 11:

- **Build Images with Dockerfiles**: Learn to build custom images from Dockerfiles.
- **Practice**: Use docker build -t custom-nginx . to create your first image.

Day 12-13:

- **Working with Volumes**: Understand Docker volumes and how to persist data.
- **Practice**: Create a volume, mount it to a container, and verify data persistence.

Day 14:

- **Containerizing an Application**: Build a Docker image for a simple application (e.g., Python Flask app).
- **Practice**: Write a Dockerfile and run the containerized app.

Week 3: Intermediate Docker Concepts

Day 15-16:

- **Docker Compose Basics**: Learn what Docker Compose is and when to use it.
- **Practice**: Write a docker-compose.yml to define a multi-container application (e.g., web and database).

Day 17:

- **Scaling with Docker Compose**: Scale services using Docker Compose.
- **Practice**: Use docker-compose up --scale to add instances of a container.

Day 18:

- **Environment Variables and Secrets**: Manage configurations with environment variables and secrets.

- **Practice**: Pass environment variables to containers and explore how secrets are managed.

Day 19-20:

- **Managing Logs**: Learn about Docker logging, view container logs, and troubleshoot.
- **Practice**: Use docker logs <container_id> and experiment with logging drivers.

Day 21:

- **Inspecting Containers and Images**: Understand container and image metadata.
- **Practice**: Use docker inspect to view detailed information.

Week 4: Advanced Topics and Practical Applications

Day 22-23:

- **Docker Registries**: Explore Docker Hub and learn about private registries.
- **Practice**: Push an image to Docker Hub or a local/private registry.

Day 24:

- **Image Optimization**: Learn how to make Docker images smaller and more efficient.
- **Practice**: Use multi-stage builds and avoid unnecessary layers.

Day 25:

- **Container Orchestration Introduction**: Get an introduction to Kubernetes and Docker Swarm.

- **Resources**: Explore the basics of container orchestration.

Day 26:

- **Security Basics**: Understand basic security practices in Docker.
- **Practice**: Check image vulnerabilities and use Docker Bench for Security.

Day 27-28:

- **Hands-on Project**: Build and deploy a full application stack (e.g., a MERN or LAMP stack) using Docker Compose.

Day 29:

- **Review and Practice**: Revisit previous concepts and practice areas where you feel less confident.

Day 30:

- **Final Project**: Deploy an application with Docker on a cloud provider (AWS ECS, for example).

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- **Day 1: Introduction to Docker**
- Today's goal is to understand what Docker is, why it's used, and how it can benefit you as a DevOps professional. This foundational knowledge will give you a solid start and help you appreciate Docker's role in software development and deployment.

- ***Step 1: Understand What Docker Is***

- **Docker Overview:** Docker is a platform that allows developers to package applications and their dependencies into containers. Containers are lightweight, portable, and consistent across different environments, ensuring that an

application behaves the same way whether it's running on a developer's laptop, in testing, or on production servers.

- ***Step 2: Learn Why Docker Is Useful in DevOps***

- Docker is popular in DevOps for these key reasons:
- **Consistency**: Docker containers package everything an application needs, which helps avoid "it works on my machine" issues.
- **Portability**: Docker containers can run on any system with Docker installed, making them highly portable.
- **Scalability**: Docker works well with orchestration tools like Kubernetes, making it easy to scale applications.
- **Resource Efficiency**: Containers use fewer resources than virtual machines, making them more efficient and faster to start up.

- ***Step 3: Explore Key Docker Concepts***

- Here are some important terms in Docker that you'll encounter often:
- **Image**: A lightweight, standalone, and executable software package that includes everything needed to run a piece of software.
- **Container**: A running instance of an image. Containers are isolated from each other and the host machine.
- **Docker Engine**: The software that runs and manages containers.
- **Docker Hub**: A repository where Docker images can be stored and shared publicly or privately.

- ***Step 4: Explore Some Introductory Resources***

- Spend about 30-40 minutes exploring one or more of the following resources to get comfortable with Docker basics:
- Docker Overview Video: A quick, easy-to-understand introduction.
- Docker Official Documentation: Provides a more in-depth explanation.
- Docker in DevOps Overview: Gives insights into Docker's role in modern DevOps.

- ***Step 5: Recap and Reflect***

- After you've gone through the introductory resources, ask yourself:

- Why would I use Docker in a DevOps environment?
- How can Docker help solve common software deployment issues?
- Which Docker concepts seem most useful or interesting to explore?

Day 2: Installing Docker

Today, the goal is to install Docker on your machine and verify that it's set up correctly. This will set you up to start running Docker commands tomorrow.

Step 1: Choose Your Installation Method

Docker can be installed on different operating systems, so select the appropriate guide based on your OS:

- **Windows and Mac**: You'll install **Docker Desktop**, a user-friendly version of Docker with a graphical interface.
- **Linux**: You'll install **Docker Engine**, the core software for running containers on Linux.

Step 2: Install Docker

Here are the official guides for installation on each platform:

- **Windows**: Install Docker Desktop on Windows
- **Mac**: Install Docker Desktop on Mac
- **Linux**: Install Docker Engine on Linux

Note: For Windows and Mac, make sure your system meets the prerequisites listed in the guide. Docker Desktop requires WSL2 (Windows Subsystem for Linux 2) on Windows.

Step 3: Post-Installation Steps

After installation, there are a few steps to verify Docker is correctly installed:

1. **Check the Docker Version**: Open your terminal (or PowerShell on Windows) and run:

bash
Copy code
docker version

This command should display the Docker version information. If it doesn't, check the installation steps and troubleshooting section in the Docker documentation.

2. **Run the hello-world Container**: Docker provides a test container called hello-world. Running this verifies that Docker is set up correctly:

bash
Copy code
docker run hello-world

This command should pull the hello-world image from Docker Hub, create a container, and print a message.

3. **Verify Installation with Additional Commands**: Try a few more commands to explore Docker:

bash
Copy code
docker info   # Shows information about your Docker setup
docker images # Lists all images downloaded on your system
docker ps   # Lists running containers (there may be none yet)

Step 4: Basic Troubleshooting (If Needed)

If you encounter issues:

- **Restart Docker**: Sometimes a simple restart of Docker Desktop or the Docker service can resolve installation issues.

- **Check Permissions**: On Linux, Docker may require superuser permissions. You can add your user to the docker group with:

bash
Copy code
sudo usermod -aG docker $USER

After doing this, log out and log back in to apply the new group permissions.

Day 3: Basic Docker Commands

Now that you have Docker installed, today's goal is to get comfortable with some essential Docker commands. These will be the foundation for managing images and containers effectively as you progress.

Step 1: Familiarize Yourself with Docker Command Structure

Docker commands typically have the format:

bash
Copy code
docker <command> <options>

For example, docker run -it ubuntu runs a container with an interactive terminal.

Step 2: Try Some Basic Commands

1. **docker version**
2. Displays Docker version information. This confirms that Docker is correctly installed and shows your client and server versions.

bash
Copy code
docker version

3. **docker info**

Shows system-wide information about Docker, including the number of containers, images, and other statistics.

bash
Copy code
docker info

4. **docker pull <image_name>**

Downloads a Docker image from Docker Hub (e.g., the ubuntu image). Images are templates used to create containers.

bash
Copy code
docker pull ubuntu

5. **docker images**

Lists all downloaded images on your system. After pulling ubuntu, you should see it in this list.

bash
Copy code
docker images

6. **docker run**

Runs a container from a specified image. Try running a container using the following:

bash
Copy code
docker run hello-world

This command pulls the hello-world image if it’s not already downloaded, creates a container, and prints a welcome message.

7. **docker ps**

Shows all running containers. Since containers stop once they complete their task, you may not see any after running hello-world.

bash
Copy code
docker ps

8. **docker ps -a**

Shows all containers, including those that have stopped. Use this command to view any containers that have run and exited.

bash
Copy code
docker ps -a

9. **docker stop <container_id>**

Stops a running container by its ID or name. You’ll find container IDs listed when you run docker ps.

bash
Copy code
docker stop <container_id>

10. **docker rm <container_id>**

Deletes a stopped container. To keep your Docker environment clean, it’s good practice to remove containers you’re not using.

bash
Copy code

docker rm <container_id>

11. docker rmi <image_name>

Deletes an image. This is useful if you no longer need a particular image and want to save disk space.

bash
Copy code
docker rmi hello-world

Step 3: Practice with Interactive Containers

To get hands-on with containers, try running the ubuntu container interactively:

bash
Copy code
docker run -it ubuntu

This opens a command prompt inside the container, allowing you to use Linux commands directly. When you're ready to exit, type exit to close the container.

Step 4: Recap and Reflect

After practicing, make sure you're comfortable with:

- Pulling images (docker pull)
- Running containers (docker run)
- Checking container status (docker ps, docker ps -a)
- Stopping and deleting containers (docker stop, docker rm)

Step 5: Recap and Reflect

Once Docker is running and you've successfully run the hello-world container, you've completed today's goal! Take note of any questions or areas of the installation process you'd like to understand better.

Day 4: Understanding Docker Images

Today's focus is on understanding Docker images, which are essential for creating and running containers. You'll learn about how images work, where they come from, and how to interact with them.

Step 1: What is a Docker Image?

A Docker image is a read-only template that contains:

- The application code or binaries
- Any dependencies required to run the application
- Operating system libraries and files
- Environment settings

When you create a container, you're launching an instance of an image. Images are built in layers, where each layer represents a set of file system changes (like installing packages or adding files). This layer system makes Docker images lightweight and efficient, as multiple containers can share the same image layers.

Step 2: Explore Docker Hub

Docker Hub is a public registry where you can find official and community-created Docker images. You can search for images there or pull them directly using the Docker CLI.

Visit Docker Hub and search for a few popular images, such as:

- nginx (a web server)

- mysql (a database)
- redis (an in-memory data store)

Step 3: Working with Images in Docker

1. **Pulling an Image**

Let’s practice pulling an image. This command downloads the specified image from Docker Hub to your local machine.

bash
Copy code
docker pull nginx

2. **Listing Images**

Check all images downloaded to your system using:

bash
Copy code
docker images

3. **Inspecting an Image**

The docker inspect command provides detailed information about an image, including its size, layers, and metadata. Replace <image_name> with the name or ID of an image.

bash
Copy code
docker inspect nginx

4. **Removing an Image**

To clean up your Docker environment, you can delete images you no longer need. Use the docker rmi command followed by the image name or ID.

bash
Copy code
docker rmi nginx

Step 4: Run a Container from an Image

Try running a container using the nginx image you pulled earlier:

bash
Copy code
docker run -d -p 8080:80 nginx

Here's what each flag means:

- -d: Runs the container in detached mode (in the background).
- -p 8080:80: Maps port 8080 on your machine to port 80 in the container, so you can access nginx in a web browser at localhost:8080.

To verify, open a web browser and go to http://localhost:8080—you should see the default nginx welcome page.

Step 5: View Image Layers

Images are built in layers, and Docker caches these layers to make future builds faster. Use the docker history command to see the layers of an image:

bash
Copy code
docker history nginx

Step 6: Recap and Reflect

After today, you should understand:

- The role of Docker images

- How to find, pull, list, and inspect images
- How to launch a container from an image

Day 5: Understanding Docker Containers

Now that you're familiar with Docker images, today's focus will be on Docker containers. Containers are the running instances of images, and understanding how to manage and interact with them is key to mastering Docker.

Step 1: What is a Docker Container?

A Docker container is an isolated, lightweight environment where your application runs. It’s created from a Docker image but is a live, executable instance that can be started, stopped, and interacted with.

Key characteristics of containers:

- **Isolation**: Each container runs independently, with its own filesystem, network interfaces, and process space.
- **Portability**: Containers can run anywhere that Docker is installed, making them ideal for consistent development, testing, and production environments.
- **Efficiency**: Containers are lightweight and share the underlying OS kernel, which makes them more resource-efficient compared to traditional virtual machines.

Step 2: Running Containers

1. **Running a Container in Interactive Mode**

Interactive mode allows you to run a container and interact with it using a terminal (useful for debugging or development). For example, to run an ubuntu container interactively:

bash
Copy code

```
docker run -it ubuntu
```

This opens a shell within the ubuntu container. You'll see a prompt like this:

```
bash
Copy code
root@<container_id>:/#
```

Here, you can run Linux commands. For example:

```
bash
Copy code
apt update   # Update package lists
apt install curl  # Install curl
```

To exit the container, simply type exit.

2. **Running a Container in Detached Mode**

Detached mode runs the container in the background, allowing you to continue using the terminal. For example, run the nginx container in detached mode:

```
bash
Copy code
docker run -d -p 8080:80 nginx
```

This will run the nginx web server in the background, and you can access it by going to http://localhost:8080 in your web browser.

Step 3: Viewing Running Containers

To see all the containers that are currently running on your system:

```
bash
Copy code
```

docker ps

This will show the container ID, image, status, and other details for all running containers.

- **docker ps -a**: Lists all containers, including those that are stopped.
- **docker ps -q**: Lists only the container IDs (useful when scripting).

Step 4: Stopping, Starting, and Restarting Containers

1. **Stop a Running Container**

To stop a running container, use the docker stop command, followed by the container ID or name. For example:

bash
Copy code
docker stop <container_id_or_name>

2. **Start a Stopped Container**

To restart a stopped container, use the docker start command:

bash
Copy code
docker start <container_id_or_name>

3. **Restart a Container**

If you want to restart a container (stop it and start it again), use:

bash
Copy code
docker restart <container_id_or_name>

Step 5: Removing Containers

Once you're done with a container, it's good practice to clean up by removing it. You can remove a stopped container with the docker rm command:

bash
Copy code
docker rm <container_id_or_name>

If you want to remove a running container, you need to stop it first, or you can use the -f flag to forcefully remove a running container:

bash
Copy code
docker rm -f <container_id_or_name>

Step 6: Inspecting Containers

To inspect a container and get detailed information about its configuration and status, use the docker inspect command:

bash
Copy code
docker inspect <container_id_or_name>

This will return a JSON output with details like environment variables, network settings, and more.

Step 7: Recap and Reflect

Today, you learned:

- How to run containers in both interactive and detached modes.
- How to manage running containers (stop, start, restart).
- How to clean up containers by removing them.

Day 6: Understanding Docker Volumes

Today, we will focus on Docker volumes, which are crucial for managing persistent data in containers. Volumes allow you to store data outside of the container filesystem, making it persistent even after containers are stopped or removed.

Step 1: What is a Docker Volume?

A **Docker volume** is a mechanism for persisting data generated by and used by Docker containers. Volumes are stored outside the container's filesystem, meaning that they survive container restarts and deletions. They are particularly useful for databases or applications that need to retain state (e.g., files, logs, or databases).

Key advantages of using volumes:

- **Persistence**: Data remains even if the container is stopped or deleted.
- **Sharing data between containers**: Volumes can be shared and reused across multiple containers.
- **Isolation**: Volumes are isolated from the container filesystem, making them easier to manage.

Step 2: Create and Use Volumes

1. **Create a Docker Volume**

To create a volume, run the following command:

bash
Copy code
docker volume create my_volume

This command will create a volume called my_volume. You can see all created volumes with:

bash

Copy code
docker volume ls

2. **Run a Container with a Volume**

To use a volume, mount it into a container using the -v or --mount flag. For example, let's run an ubuntu container and mount a volume to a specific path inside the container:

bash
Copy code
docker run -it -v my_volume:/data ubuntu

Here, the my_volume is mounted to the /data directory in the container. Any data written to /data inside the container will be stored in the volume.

3. **Check the Data in the Volume**

To verify the volume is being used, let's create a file inside the container:

bash
Copy code
echo "Hello Docker!" > /data/hello.txt

Exit the container by typing exit, then inspect the contents of the volume:

bash
Copy code
docker run --rm -v my_volume:/data ubuntu cat /data/hello.txt

This command runs a new container, mounts the my_volume volume, and prints the contents of /data/hello.txt—you should see "Hello Docker!" displayed.

4. **Mount Volumes for Different Containers**

You can also mount the same volume in different containers, making it easy to share data between them. For example, running a container that writes to the volume:

bash
Copy code
```
docker run -it -v my_volume:/data ubuntu bash
echo "Another file" > /data/file2.txt
```

Then, you can inspect the volume again from a different container:

bash
Copy code
```
docker run --rm -v my_volume:/data ubuntu cat /data/file2.txt
```

Step 3: Inspect Volumes

You can inspect a volume to view detailed information about it:

bash
Copy code
```
docker volume inspect my_volume
```

This shows metadata about the volume, including its mount point on the host system.

Step 4: Remove Volumes

When you no longer need a volume, you can remove it using:

bash
Copy code
```
docker volume rm my_volume
```

Note: If the volume is still in use by a container, Docker will prevent you from deleting it until it's no longer mounted.

To remove all unused volumes, you can use:

bash
Copy code
docker volume prune

Step 5: Recap and Reflect

Today, you should now have a clear understanding of:

- How to create and use Docker volumes.
- How volumes persist data beyond the lifecycle of containers.
- How to share data between containers using volumes.

Day 7: Understanding Docker Networking

Today, we'll focus on Docker networking, which is essential for connecting containers and enabling communication between them. Docker provides several networking options that allow containers to interact securely and flexibly.

Step 1: What is Docker Networking?

Docker networking allows containers to communicate with each other, with other services, and with the outside world. Docker has a built-in network system that provides various network types to meet different requirements, such as isolating containers or allowing them to share data.

Docker has three main network types:

1. **Bridge** (default)
2. **Host**
3. **None**

Step 2: Explore the Default Docker Networks

To view all available networks, use:

bash
Copy code
docker network ls

You'll typically see these default networks:

- **bridge**: The default network for containers if no other network is specified. Containers on this network can communicate with each other using their IP addresses or container names.
- **host**: Only available on Linux, it allows containers to use the host's network stack directly. This network has no isolation from the host.
- **none**: Completely isolates the container with no network access.

Step 3: Bridge Network in Action

Let's explore the bridge network by connecting two containers.

1. **Run a Container on the Default Bridge Network**

Run a simple nginx container on the default bridge network:

bash
Copy code
docker run -d --name webserver nginx

2. **Run Another Container and Ping the Webserver**

Now run a second container and try to ping webserver by name:

bash
Copy code
docker run -it --rm --name test-container busybox
ping webserver

You should see successful ping responses, showing that both containers on the bridge network can communicate with each other by name. Type Ctrl+C to stop the ping.

Step 4: Custom Bridge Networks

Creating custom bridge networks provides additional benefits, like automatic DNS resolution by container name and isolation from other networks.

1. **Create a Custom Bridge Network**

To create a new network:

bash
Copy code
docker network create my_bridge

2. **Run Containers on the Custom Network**

Now, run containers on this custom network and test their connectivity:

bash
Copy code
docker run -d --name app1 --network my_bridge nginx
docker run -it --rm --network my_bridge busybox

From within the busybox container, try pinging app1:

bash
Copy code
ping app1

3. **Clean Up Custom Networks**

When done, remove the custom network with:

bash

Copy code
docker network rm my_bridge

Step 5: Host Network

The **host** network removes the network isolation between the container and the Docker host, allowing the container to use the host's IP address.

- **Usage**: This is mostly used for performance optimization in scenarios that require minimal network latency.
- **Limitation**: Containers on the host network cannot be isolated from each other, so it's best for specific use cases.

To run a container on the host network:

bash
Copy code
docker run --network host -d nginx

On Linux, this will make nginx accessible via the host machine's IP address on port 80.

Step 6: None Network

The **none** network disables all networking for a container, which can be useful if you don't want the container to have any network access.

To run a container with no network:

bash
Copy code
docker run --network none -it busybox

Step 7: Inspecting Networks

You can inspect any Docker network to see details like connected containers and IP address mappings:

bash
Copy code
docker network inspect bridge

Recap and Reflect

Today, you explored Docker networking and learned:

- The types of networks Docker provides and when to use each one.
- How to create and connect containers to custom networks.
- How to allow or restrict container communication.

Day 8: Introduction to Dockerfiles

Today, we'll start learning about Dockerfiles, which are essential for building custom Docker images. Dockerfiles define the instructions for creating an image, such as installing packages, copying files, and setting environment variables. Mastering Dockerfiles will allow you to create images tailored to your applications.

Step 1: What is a Dockerfile?

A **Dockerfile** is a simple text file that contains a set of instructions on how to build a Docker image. Each line in a Dockerfile is an instruction, such as:

- **Base image** selection (e.g., FROM ubuntu)
- **File copying** or **installing dependencies**
- **Setting up environment variables**

Step 2: Basic Structure of a Dockerfile

Let's look at the basic structure of a Dockerfile:

1. **FROM**: Specifies the base image.

dockerfile
Copy code
FROM ubuntu:latest

2. **RUN**: Executes commands inside the image. For example, to install updates:

dockerfile
Copy code
RUN apt-get update && apt-get install -y curl

3. **COPY**: Copies files or directories from your host system to the image.

dockerfile
Copy code
COPY . /app

4. **CMD** or **ENTRYPOINT**: Specifies the default command to run when a container starts. For example:

dockerfile
Copy code
CMD ["echo", "Hello World"]

Step 3: Create Your First Dockerfile

Let's create a simple Dockerfile to build a basic web server using **Nginx**.

1. **Create a Directory for Your Dockerfile**

Start by creating a new directory for this project:

bash
Copy code
```
mkdir my_docker_app
cd my_docker_app
```

2. **Create a New Dockerfile**

Inside this directory, create a file named Dockerfile (no extension):

dockerfile
Copy code
```
# Use the official Nginx image as the base image
FROM nginx:latest

# Copy custom HTML file to the default Nginx directory
COPY index.html /usr/share/nginx/html/index.html
```

3. **Add an HTML File**

In the same directory, create a simple index.html file:

html
Copy code
```
<!DOCTYPE html>
<html>
<head>
    <title>My Docker App</title>
</head>
<body>
    <h1>Welcome to My Dockerized Web Server!</h1>
</body>
</html>
```

Step 4: Build the Docker Image

Now that your Dockerfile and HTML file are ready, build the Docker image:

bash
Copy code
docker build -t my-web-server .

Here's what each part of the command means:

- **-t my-web-server**: Tags the image with the name my-web-server.
- **.**: Specifies the current directory as the build context, so Docker includes everything in this directory in the image.

Step 5: Run the Docker Container

Run a container from the newly built image:

bash
Copy code
docker run -d -p 8080:80 my-web-server

You can now open a web browser and go to http://localhost:8080 to see your HTML file served by Nginx!

Step 6: Inspecting the Image Layers

Each instruction in a Dockerfile creates a new layer in the image. To see these layers, use the docker history command:

bash
Copy code
docker history my-web-server

Step 7: Best Practices for Writing Dockerfiles

- **Use Minimal Base Images**: Start with the smallest possible base image for a smaller, faster image.
- **Combine Commands**: Use && to combine commands in a single RUN instruction to minimize the number of layers.
- **Leverage Caching**: Docker caches each layer, so minimizing changes helps improve build times.

Recap and Reflect

Today, you learned how to:

- Write a basic Dockerfile.
- Build and run a custom Docker image.
- Serve a simple web page using Nginx in Docker.

Day 9: Advanced Dockerfile Instructions and Best Practices

Today, we'll dive deeper into Dockerfile instructions and best practices to build more efficient, secure, and maintainable Docker images. Learning advanced Dockerfile techniques will help you create optimized images for real-world applications.

Step 1: Advanced Dockerfile Instructions

1. **ENV**: Sets environment variables in the container.
    a. Use ENV to define configuration values that you may need to change without altering the Dockerfile.

dockerfile
Copy code
ENV APP_ENV=production

2. **EXPOSE**: Documents the port(s) that the container listens on, making it clear which ports need to be published.

    a. For example, if your application listens on port 5000:

dockerfile
Copy code
EXPOSE 5000

3. **WORKDIR**: Sets the working directory for the container. It's recommended over RUN cd /path because it's simpler and more readable.

dockerfile
Copy code
WORKDIR /app

4. **ARG**: Sets build-time variables, which can be passed into the build process but are not retained in the final image.

dockerfile
Copy code
ARG VERSION=1.0

5. **ENTRYPOINT vs. CMD**: Both set the default command for a container, but they have differences.
    a. ENTRYPOINT specifies the main command that always runs.
    b. CMD provides default arguments to ENTRYPOINT or specifies the default command if no ENTRYPOINT is provided.

Example:

dockerfile
Copy code
ENTRYPOINT ["python3"]
CMD ["app.py"]

This will execute python3 app.py by default, but you can override the command at runtime.

Step 2: Building an Optimized Dockerfile

Let’s put these advanced instructions together in a Dockerfile for a simple Python application.

1. **Create a New Directory**

Start by creating a directory for the project:

bash
Copy code
mkdir my_python_app
cd my_python_app

2. **Create a Python File**

Create an app.py file with the following code:

python
Copy code
print("Hello from my Python Docker container!")

3. **Create the Dockerfile**

Write the Dockerfile with the following content:

dockerfile
Copy code
Use an official Python runtime as the base image
FROM python:3.9-slim

Set environment variables
ENV APP_ENV=production

Set a working directory
WORKDIR /usr/src/app

```
# Copy local files to the container
COPY . .

# Expose a port (if your app requires it, otherwise skip)
EXPOSE 5000

# Define default command
CMD ["python3", "app.py"]
```

4. **Build the Image**

Build the image:

bash
Copy code
```
docker build -t my-python-app .
```

5. **Run the Container**

Run a container from your image:

bash
Copy code
```
docker run my-python-app
```

You should see “Hello from my Python Docker container!” in the output.

Step 3: Dockerfile Best Practices

1. **Use Small Base Images**: Use slim or alpine versions of base images (e.g., python:3.9-slim instead of python:3.9), which reduces image size.
2. **Minimize Layers**: Combine commands where possible to minimize the number of layers.

dockerfile
Copy code

```
RUN apt-get update && apt-get install -y \
    package1 \
    package2
```

3. **Leverage Caching**: Place commands that change less frequently at the top of the Dockerfile, so Docker can cache layers effectively.
4. **Clean Up Temporary Files**: Clean up caches and temporary files in the same RUN statement to reduce image size.

dockerfile
Copy code

```
RUN apt-get update && apt-get install -y \
    curl && \
    rm -rf /var/lib/apt/lists/*
```

5. **Security**: Avoid storing sensitive information directly in Dockerfiles. Instead, use ENV or pass secrets securely using Docker's secret management features.

Step 4: Inspecting Image Size and Layers

After building the image, you can inspect its size and layers to see the impact of your optimizations:

bash
Copy code

```
docker image ls
docker history my-python-app
```

Recap and Reflect

Today, you learned:

- Advanced Dockerfile instructions like ENV, WORKDIR, EXPOSE, ARG, ENTRYPOINT, and CMD.

- How to write a more optimized and secure Dockerfile.
- Dockerfile best practices for efficient, maintainable images.

Day 10: Multi-Stage Builds for Optimized Docker Images

Today, we'll learn about **multi-stage builds**, an advanced Docker technique for creating smaller, optimized images. This approach is especially useful when building production-ready containers, as it allows you to separate build tools from the final image.

Step 1: What are Multi-Stage Builds?

Multi-stage builds use multiple FROM statements in a single Dockerfile. Each FROM creates a new build stage, allowing you to:

- Use different images for different stages of the build process.
- Copy only the necessary artifacts (e.g., binaries or compiled code) into the final image.
- Reduce the final image size by excluding development dependencies.

This is ideal for languages like Go, Java, or Node.js, where build dependencies are often unnecessary in the runtime environment.

Step 2: Multi-Stage Build Example

Let's build a production-ready Node.js application using multi-stage builds.

1. **Set Up a Project**

Create a directory for the project:

bash
Copy code

```
mkdir my_node_app
cd my_node_app
```

Inside this directory, create the following files:

a. **package.json**:

```
json
Copy code
{
  "name": "my-node-app",
  "version": "1.0.0",
  "main": "index.js",
  "scripts": {
    "start": "node index.js"
  },
  "dependencies": {
    "express": "^4.17.1"
  }
}
```

b. **index.js**:

```
javascript
Copy code
const express = require('express');
const app = express();

app.get('/', (req, res) => {
   res.send('Hello from my Dockerized Node.js app!');
});

const PORT = process.env.PORT || 3000;
app.listen(PORT, () => {
   console.log(`Server is running on port ${PORT}`);
```

});

2. **Write the Dockerfile**

Here’s a Dockerfile with multi-stage builds:

dockerfile
Copy code

```
# Stage 1: Build
FROM node:18 AS builder

# Set the working directory
WORKDIR /app

# Copy package files and install dependencies
COPY package*.json ./
RUN npm install

# Copy the rest of the application code
COPY . .

# Stage 2: Production
FROM node:18-slim

# Set the working directory
WORKDIR /app

# Copy only the necessary files from the builder stage
COPY --from=builder /app/node_modules /app/node_modules
COPY --from=builder /app/index.js /app/index.js

# Expose the application port
EXPOSE 3000

# Define the command to run the application
```

CMD ["npm", "start"]

3. **Build the Image**

Build the Docker image:

bash
Copy code
docker build -t my-node-app .

4. **Run the Container**

Run a container from the built image:

bash
Copy code
docker run -d -p 3000:3000 my-node-app

Access your app by navigating to http://localhost:3000 in your browser. You should see:

"Hello from my Dockerized Node.js app!"

Step 3: Benefits of Multi-Stage Builds

- **Smaller Images**: Only the runtime dependencies are included in the final image.
- **Security**: Reduces attack surface by excluding build tools and unnecessary files.
- **Modularity**: Clean separation between build and runtime environments.

Step 4: Analyze the Image

Inspect the size of your image and compare it with and without multi-stage builds:

bash
Copy code
docker image ls

To further analyze the layers:

bash
Copy code
docker history my-node-app

Notice that the final image only contains the minimal runtime environment, excluding files like package-lock.json or source code.

Step 5: Multi-Stage Builds in Other Languages

Multi-stage builds are versatile and work well for other programming languages, such as:

- **Go (Golang)**: Build the binary in one stage and copy it into a lightweight runtime image (like alpine).
- **Java**: Use a stage for compiling with tools like Maven or Gradle, then copy the .jar file to a runtime image.
- **Python**: Build wheels in one stage and install them in a minimal Python runtime.

Recap and Reflect

Today, you learned:

- What multi-stage builds are and their benefits.

- How to use multi-stage builds to optimize Docker images.
- How to apply multi-stage builds to a Node.js application.

Day 11: Introduction to Docker Compose

Today, we'll explore **Docker Compose**, a powerful tool for defining and managing multi-container applications. With Docker Compose, you can use a single YAML configuration file to define services, networks, and volumes, making it easier to work with complex applications.

Step 1: What is Docker Compose?

Docker Compose allows you to define and manage multiple containers as a single application. Instead of running docker run commands for each container, you can:

- Use a single YAML file to describe the entire application stack.
- Easily start, stop, and scale your services using simple commands.

Step 2: Install Docker Compose

If Docker Compose isn't already installed, check its version to confirm:

bash
Copy code
docker compose version

If it's not available, follow Docker's installation guide for your platform.

Step 3: Basic Docker Compose Example

We'll create a simple **web application** using Nginx and a custom static HTML file.

1. **Set Up the Project**

Create a directory for your project:

bash
Copy code
mkdir my_compose_app
cd my_compose_app

2. **Create Files for the Project**
    a. **docker-compose.yml**:

yaml
Copy code
version: '3.9'

services:
  web:
    image: nginx:latest
    ports:
      - "8080:80"
    volumes:
      - ./html:/usr/share/nginx/html

    b. Create a subdirectory for HTML files:

bash
Copy code
mkdir html

    c. **html/index.html**:

html
Copy code

```
<!DOCTYPE html>
<html>
<head>
  <title>Docker Compose App</title>
</head>
<body>
  <h1>Hello from Docker Compose!</h1>
</body>
</html>
```

3. **Start the Application**

Run the following command to start the application:

bash
Copy code
docker compose up

This will:

a. Pull the Nginx image if it's not already on your system.
b. Mount the html directory to the container.
c. Expose the application on http://localhost:8080.

4. **Stop the Application**

To stop the application, press Ctrl+C or use:

bash
Copy code
docker compose down

Step 4: Key Components of a Docker Compose File

Here's a breakdown of the docker-compose.yml file:

- **version**: Specifies the Docker Compose file format version. Use the latest (3.9) for modern features.
- **services**: Defines the containers in your application.
    - **web**: The service name for the Nginx container.
    - **image**: Specifies the image to use (e.g., nginx:latest).
    - **ports**: Maps host ports to container ports (8080:80).
    - **volumes**: Mounts directories or files from the host to the container.

Step 5: Explore Docker Compose Commands

Here are some common Docker Compose commands:

1. **Start Services**

bash
Copy code
docker compose up

Add -d to run in detached mode:

bash
Copy code
docker compose up -d

2. **Stop Services**

bash
Copy code
docker compose down

3. **View Logs**

bash
Copy code

```
docker compose logs
```

4. **Scale Services** For applications with multiple replicas:

```
bash
Copy code
docker compose up --scale web=3
```

5. **List Running Services**

```
bash
Copy code
docker compose ps
```

Step 6: Extend Docker Compose

Try adding more services to your application, such as a **Redis** cache.

1. Update docker-compose.yml to include Redis:

```
yaml
Copy code
version: '3.9'

services:
  web:
    image: nginx:latest
    ports:
      - "8080:80"
    volumes:
      - ./html:/usr/share/nginx/html

  redis:
    image: redis:latest
```

```
ports:
  - "6379:6379"
```

2. Start the updated stack:

bash
Copy code
```
docker compose up
```

Now, your application includes both Nginx and Redis containers!

Recap and Reflect

Today, you learned:

- How Docker Compose simplifies multi-container application management.
- The structure and components of a docker-compose.yml file.
- Useful Docker Compose commands for starting, stopping, and scaling services.

Day 12: Advanced Docker Compose Features

Today, we'll take Docker Compose to the next level by exploring networks, environment variables, and advanced service configurations. These features are essential for managing more complex, production-like environments.

Step 1: Networking with Docker Compose

Docker Compose automatically creates a network for all services in your application, allowing them to communicate using service names.

1. **Add Networking to the Compose File**

Let’s enhance our previous setup to include a **Redis-based backend** with networking.

Update docker-compose.yml:

yaml
Copy code

```
version: '3.9'

services:
  web:
    image: nginx:latest
    ports:
      - "8080:80"
    volumes:
      - ./html:/usr/share/nginx/html
    depends_on:
      - redis

  redis:
    image: redis:latest
    networks:
      - backend

networks:
  backend:
```

Key points:

a. **networks**: Defines a custom network named backend.
b. **depends_on**: Ensures the redis service starts before web.

2. Test Service Communication

Start the application:

bash
Copy code

docker compose up

Then, access the Redis service from within the web container:

bash
Copy code
docker exec -it <web-container-id> ping redis

You'll see a successful response, confirming that web can reach redis by its service name.

Step 2: Environment Variables in Docker Compose

Environment variables allow you to configure services dynamically without hardcoding values in the docker-compose.yml file.

1. **Create an .env File**

Create an .env file in your project directory:

plaintext
Copy code
REDIS_PORT=6379
WEB_PORT=8080

2. **Update docker-compose.yml**

Modify the compose file to use environment variables:

yaml
Copy code
version: '3.9'

services:

```
  web:
    image: nginx:latest
    ports:
      - "${WEB_PORT}:80"
    volumes:
      - ./html:/usr/share/nginx/html
    depends_on:
      - redis

  redis:
    image: redis:latest
    ports:
      - "${REDIS_PORT}:6379"
    networks:
      - backend

networks:
  backend:
```

3. **Start the Application**

When you run docker compose up, Docker Compose will automatically load variables from the .env file.

Step 3: Volumes for Persistent Data

Use volumes to persist data, ensuring that it survives container restarts.

1. **Add a Volume for Redis**

Update the docker-compose.yml file:

yaml
Copy code

```
services:
  redis:
    image: redis:latest
    volumes:
      - redis-data:/data
    networks:
      - backend

volumes:
  redis-data:
```

2. Test Data Persistence

Start the application:

bash
Copy code
docker compose up

Then, interact with Redis:

bash
Copy code
docker exec -it <redis-container-id> redis-cli
> SET mykey "hello"
> GET mykey

Stop the application:

bash
Copy code
docker compose down

Restart it:

bash
Copy code
docker compose up

Connect to Redis again and verify that your key is still there:

bash
Copy code
> GET mykey

Step 4: Docker Compose Override Files

Docker Compose supports override files (docker-compose.override.yml) for environment-specific configurations (e.g., development vs. production).

1. **Create an Override File**

Create a docker-compose.override.yml file:

yaml
Copy code
```
version: '3.9'

services:
  web:
    environment:
      - ENVIRONMENT=development
```

This will add the ENVIRONMENT variable to the web container.

2. **Run the Application**

Docker Compose automatically loads override files:

bash

Copy code
docker compose up

Verify the environment variable inside the web container:

bash
Copy code
docker exec -it <web-container-id> env | grep ENVIRONMENT

Step 5: Scaling Services

For load-balanced setups or replicated services, use the --scale flag.

1. **Scale the Web Service**

Run multiple replicas of the web service:

bash
Copy code
docker compose up --scale web=3

2. **Check Running Containers**

List all running containers to verify scaling:

bash
Copy code
docker compose ps

Docker Compose automatically connects all replicas to the same network.

Recap and Reflect

Today, you learned:

- How Docker Compose manages networks for inter-service communication.
- The use of environment variables for dynamic configurations.
- How to persist data using Docker volumes.
- The role of override files for environment-specific configurations.
- How to scale services with Docker Compose.

Day 13: Introduction to Docker Swarm

Today, we'll learn about **Docker Swarm**, which is Docker's native solution for orchestrating and managing clusters of Docker containers. Swarm allows you to manage multiple Docker engines across several hosts, providing features like load balancing, service discovery, scaling, and rolling updates.

Step 1: What is Docker Swarm?

Docker Swarm enables you to:

- **Cluster multiple Docker hosts** into a single virtual host.
- **Deploy applications across multiple nodes**.
- **Automatically load balance** between services.
- **Scale applications** horizontally.
- **Perform rolling updates** to minimize downtime.

Docker Swarm works by managing a cluster of Docker Engines (hosts) where one or more nodes act as a **manager** and others as **workers**.

Step 2: Setting Up Docker Swarm

1. **Initialize Docker Swarm on the Manager Node**

On your first machine (this will be the manager), initialize Swarm:

bash
Copy code
docker swarm init

The output will show you a **join token** that worker nodes will use to join the swarm:

bash
Copy code
docker swarm join --token <token> <manager-ip>:2377

2. **Add Worker Nodes to the Swarm**

On the worker node(s), run the command provided by the manager node:

bash
Copy code
docker swarm join --token <token> <manager-ip>:2377

Verify the nodes are added to the swarm:

bash
Copy code
docker node ls

Step 3: Deploying Services with Docker Swarm

1. **Create a Simple Service**

Let’s deploy a simple **Nginx service** that can be scaled across multiple nodes.

On the manager node, run:

bash
Copy code
docker service create --name nginx-service --replicas 3 -p 8080:80 nginx

This will:

a. Create a service named nginx-service.
b. Run 3 replicas of the Nginx container.
c. Expose port 8080 on the manager node to access the service.

2. **Check the Service**

To verify the service and its replicas:

bash
Copy code
docker service ls
docker service ps nginx-service

You should see that the service is running on multiple nodes (if you have multiple worker nodes).

3. **Access the Service**

Open your browser and navigate to http://<manager-ip>:8080. You should see the default Nginx welcome page, and the load balancer will distribute traffic to the available replicas.

Step 4: Scaling Services

One of Docker Swarm's core features is the ability to scale services up or down easily.

1. **Scale the Service**

To scale the nginx-service to 5 replicas:

bash
Copy code
docker service scale nginx-service=5

2. **Verify Scaling**

Check the updated status:

bash
Copy code
docker service ps nginx-service

You should now have 5 replicas of the Nginx container running.

Step 5: Rolling Updates with Docker Swarm

Docker Swarm allows you to update services without downtime using **rolling updates**.

1. **Update the Service**

Let’s update the nginx-service to use a different version of the Nginx image.

Run:

bash
Copy code
docker service update --image nginx:latest nginx-service

Docker Swarm will automatically perform a rolling update, gradually replacing the old containers with the new version without taking the service down.

2. **Check the Update**

To check the update progress:

bash
Copy code
docker service ps nginx-service

Swarm will update one container at a time and ensure the service remains available during the update.

Step 6: Docker Swarm Networking

By default, Docker Swarm creates a **virtual network** that allows containers in the same service to communicate securely across multiple nodes.

1. **Inspect the Network**

To view the networks in your Swarm:

bash
Copy code
docker network ls

2. **Create a Custom Network for the Service**

You can create a custom overlay network for services to communicate over:

bash
Copy code
docker network create --driver overlay my-network

Then, deploy a service using this custom network:

bash
Copy code

docker service create --name nginx-service --network my-network --replicas 3 -p 8080:80 nginx

This ensures the service is part of the custom network.

Step 7: Docker Swarm in Production

In production, Docker Swarm offers features like:

- **High availability**: Services are replicated across multiple nodes, ensuring your app is resilient to node failures.
- **Service discovery**: Services can automatically discover each other via DNS-based resolution within the swarm.
- **Automatic load balancing**: Docker Swarm automatically distributes traffic among replicas, balancing the load.

Recap and Reflect

Today, you learned:

- What Docker Swarm is and how it enables multi-node orchestration.
- How to initialize a swarm, add nodes, and deploy services.
- How to scale and update services in Docker Swarm.
- How to create custom networks for communication between services.

Day 14: Docker Swarm Security Best Practices

Today, we'll focus on securing your Docker Swarm cluster and the services running within it. Security is critical, especially when deploying to production environments, and Docker Swarm provides several features to enhance the security of both the cluster and your containers.

Step 1: Swarm Manager Node Security

1. **Use TLS for Communication**

By default, Docker Swarm secures communication between the manager and worker nodes using **Transport Layer Security (TLS)**. This prevents unauthorized access and man-in-the-middle attacks. Docker automatically generates and uses the necessary certificates when you initialize the swarm.

2. **Restrict Access to the Manager Node**

The manager node has control over the entire Swarm, so it is crucial to protect it:

   a. Ensure that only trusted users can SSH into the manager node.
   b. Use **firewalls** and **security groups** to restrict access to ports required by Swarm (e.g., 2377 for cluster management, 7946 for communication, and 4789 for overlay networks).

3. **Role-Based Access Control (RBAC) for Swarm**

Docker Swarm doesn't come with built-in RBAC for managing permissions, but you can limit access using external tools like **Docker Enterprise** or integrate with **external identity providers** that support authorization.

Step 2: Securing Worker Nodes

1. **Keep Docker Up to Date**

Always update Docker to the latest stable version to ensure that security patches are applied to the Docker Engine running on worker nodes.

2. **Use User Namespaces**

By default, containers run as root inside the container, but using user namespaces allows Docker to map container users to non-privileged users on the host. This reduces the risk of privilege escalation in case of a container compromise.

To enable user namespaces, modify /etc/docker/daemon.json:

json
Copy code
```
{
  "userns-remap": "default"
}
```

3. **Limit Worker Node Access**
    a. Restrict worker nodes from accepting Docker API requests from external sources.
    b. Use **firewalls** to ensure that only the manager nodes can communicate with worker nodes over the Swarm control port (2377).

Step 3: Service-Level Security

1. **Use Secrets Management**

Docker Swarm has built-in support for **secrets management**, which allows you to securely store and manage sensitive data, such as API keys, passwords, and certificates, and provide them to services when needed.

To add a secret to Docker Swarm:

bash
Copy code
```
echo "my-secret-password" | docker secret create my_secret -
```

To use the secret in a service:

bash
Copy code
```
docker service create --name web --secret my_secret nginx
```

Secrets are made available as files inside the container at /run/secrets/my_secret.

2. **Use Configs for Configuration Data**

Docker Swarm also supports **configs**, which are similar to secrets but for non-sensitive configuration files. You can store configurations centrally and ensure they are updated across all service instances.

To create a config:

bash
Copy code
echo "nginx.conf content" | docker config create my_nginx_conf -

Then, use the config in a service:

bash
Copy code
docker service create --name web --config my_nginx_conf nginx

Configs and secrets are distributed securely within the swarm and are not exposed to unauthorized containers.

Step 4: Network Security

1. **Overlay Networks for Secure Communication**

Docker Swarm uses **overlay networks** for communication between services across different nodes. Overlay networks are encrypted by default, ensuring that data exchanged between services is secure.

To create an encrypted overlay network:

bash
Copy code
docker network create --driver overlay --opt encrypted my_secure_network

2. **Isolate Services Using Network Policies**

Use network policies to isolate services, restricting communication between containers. For example, if you only want a service to communicate with another specific service, you can configure custom networks and limit inter-service communication using service names.

yaml
Copy code

```
version: '3.9'

services:
  web:
    image: nginx
    networks:
      - web_net

  db:
    image: mysql
    networks:
      - db_net

networks:
  web_net:
  db_net:
```

Step 5: Docker Content Trust

Docker provides **Content Trust** (DCT) to ensure that images you pull are signed and verified. This protects you from downloading malicious images from untrusted sources.

1. **Enable Content Trust**

Set the DOCKER_CONTENT_TRUST environment variable to 1 to enable signing and verification of images:

bash

Copy code
export DOCKER_CONTENT_TRUST=1

Once enabled, Docker will only pull images that are signed. If the image is not signed, Docker will prevent the operation.

Step 6: Protecting Your Docker Host

1. **Limit Container Capabilities**

By default, Docker containers have more capabilities than they need. You can limit these capabilities using Docker's --cap-drop and --cap-add options.

Example of dropping capabilities:

bash
Copy code
docker run --cap-drop=ALL --cap-add=NET_ADMIN nginx

2. **Run Containers with a Non-Root User**

Whenever possible, avoid running containers as the root user. You can specify a non-root user for containers in the Dockerfile or using the --user option when running containers.

In a Dockerfile:

Dockerfile
Copy code
USER nonrootuser

Or when running a container:

bash
Copy code

docker run --user 1000:1000 nginx

Step 7: Monitoring and Auditing

1. **Enable Docker Logging**

Docker provides logging drivers that allow you to forward container logs to external systems for monitoring and auditing. This is essential for tracking activities and potential security incidents.

Example of enabling the syslog logging driver:

bash
Copy code
docker run --log-driver=syslog nginx

2. **Use Third-Party Tools for Security Monitoring**

You can integrate Docker with third-party security tools such as **Sysdig**, **Aqua Security**, and **Twistlock** for real-time monitoring of containers, images, and network traffic.

Recap and Reflect

Today, you learned:

- How to secure the Swarm manager and worker nodes.
- Using Docker secrets and configs for managing sensitive data and configurations securely.
- The importance of encrypted overlay networks and network policies for service isolation.
- Docker Content Trust for ensuring image authenticity.

- Best practices for container security, such as limiting container capabilities and running containers as non-root users.
- The importance of logging and monitoring for security.

Day 15: Advanced Docker Swarm Topics

Today, we'll explore advanced Docker Swarm concepts and practices that will help you manage Swarm clusters in production environments. These concepts include **rolling updates**, **health checks**, **replica management**, and **service constraints**. These are essential when managing production-grade services and ensuring high availability and resilience.

Step 1: Rolling Updates and Rollbacks

Docker Swarm enables you to perform **rolling updates** on services to minimize downtime and ensure continuous availability. You can also **rollback** an update if something goes wrong.

1. **Performing a Rolling Update**

Let's update a service to a new version of the image. For example, update the nginx-service to use a newer version of Nginx.

Update the service:

bash
Copy code
docker service update --image nginx:latest nginx-service

Docker will replace the running containers one by one (without downtime), ensuring there's always an instance of the service available.

2. **Configuring Rolling Update Parameters**

You can control the behavior of rolling updates with these options:

a. **--update-parallelism**: The number of containers to update at a time.
b. **--update-delay**: The time delay between updates to containers.

For example, update 2 containers at a time with a 10-second delay:

bash
Copy code
docker service update --update-parallelism 2 --update-delay 10s nginx-service

3. **Rolling Back an Update**

If the update fails or you want to revert to the previous version, you can perform a rollback:

bash
Copy code
docker service rollback nginx-service

Step 2: Health Checks

Docker supports **health checks** to monitor the health of containers. A health check can detect if a service is down or unresponsive and restart it if needed.

1. **Defining Health Checks in Dockerfile**

You can define a health check directly in the Dockerfile using the HEALTHCHECK instruction. For example, for an Nginx container:

Dockerfile
Copy code
FROM nginx:latest
HEALTHCHECK --interval=30s --timeout=10s --retries=3 CMD curl --fail http://localhost || exit 1

This health check runs a curl command every 30 seconds to ensure Nginx is responding. If the health check fails three times in a row, Docker will mark the container as unhealthy.

2. **Using Health Checks in Docker Compose**

You can also define health checks in a docker-compose.yml file:

yaml
Copy code

```
version: '3.9'

services:
  web:
    image: nginx:latest
    healthcheck:
      test: ["CMD", "curl", "--fail", "http://localhost"]
      interval: 30s
      retries: 3
```

3. **Checking the Health of Containers**

To check the health status of a container:

bash
Copy code

```
docker ps
```

The STATUS column will show something like Up 10 minutes (healthy) or Up 5 minutes (unhealthy) depending on the health of the container.

Step 3: Service Replication and Scaling

In a Docker Swarm, you can manage the **number of replicas** for each service to ensure high availability. Swarm will automatically distribute replicas across nodes to balance the load and ensure service availability.

1. **Scaling Services**

To scale the nginx-service to 5 replicas:

bash
Copy code
docker service scale nginx-service=5

2. **Monitoring Service Replicas**

To check the number of replicas and their status:

bash
Copy code
docker service ps nginx-service

Swarm will distribute the replicas automatically across available nodes. If a node fails, Docker Swarm will reschedule the containers on healthy nodes.

3. **Scaling Down**

To scale the service back down:

bash
Copy code
docker service scale nginx-service=2

Step 4: Service Constraints

Constraints allow you to control where specific services run in the swarm based on available resources or labels. This can be useful when you want certain services to run only on specific nodes (e.g., high-performance nodes or nodes with specific hardware).

1. **Using Node Labels**

First, you can label nodes with custom metadata. For example:

bash
Copy code
docker node update --label-add type=high-performance <node-name>

2. **Setting Service Constraints**

When creating a service, you can specify constraints based on the node labels. For example, to ensure a service runs only on nodes labeled type=high-performance:

bash
Copy code
docker service create --name high-performance-service --constraint 'node.labels.type == high-performance' nginx

This will ensure that the service only runs on nodes with the type=high-performance label.

Step 5: Network and Service Discovery

Docker Swarm provides automatic **service discovery** using DNS, making it easy for services to communicate with each other by using the service name instead of IP addresses.

1. **Create an Overlay Network for Services**

For communication between services across nodes, Docker Swarm uses overlay networks. Create an overlay network:

bash
Copy code
docker network create --driver overlay my-overlay-network

2. **Connect Services to the Network**

When you create a service, you can specify that it should be connected to an overlay network:

bash
Copy code
docker service create --name my-service --network my-overlay-network nginx

Now, services in the same network can discover each other using DNS. For example, my-service can communicate with other services by referring to their names as hostnames (e.g., my-other-service).

Step 6: Log Management in Docker Swarm

For production environments, it's essential to centralize and manage logs from all containers in your Swarm cluster.

1. **Enable Centralized Logging**

Docker supports multiple logging drivers, such as syslog, fluentd, or journald. To enable a logging driver:

bash
Copy code
docker service create --name nginx --log-driver=syslog nginx

2. **Using ELK Stack or Other Tools**

Many organizations use the **ELK Stack** (Elasticsearch, Logstash, and Kibana) or other tools like **Prometheus** and **Grafana** to collect and visualize logs and metrics across a Swarm cluster.

Recap and Reflect

Today, you learned:

- How to perform rolling updates and rollbacks for your services.
- The importance of health checks and how to configure them in Dockerfile and Docker Compose.
- How to scale services and manage replicas in Docker Swarm.
- Using service constraints to control where services run based on node labels.
- How Docker Swarm automatically handles service discovery with networks.
- Best practices for log management in production environments.

Day 16: Docker Swarm Monitoring and Metrics

Today, we'll dive into **monitoring** and **metrics** for Docker Swarm clusters. Monitoring is crucial to ensure your containers and services are running efficiently, helping you detect and troubleshoot issues early. We'll explore various tools and techniques for gathering and analyzing performance data from your Docker Swarm environment.

Step 1: Introduction to Monitoring in Docker Swarm

Monitoring a Docker Swarm involves tracking:

- **Resource usage** (CPU, memory, disk, etc.).
- **Container health**.

- **Service performance** (e.g., response time, availability).
- **Node health** and **status**.

While Docker Swarm provides some basic insights, integrating external tools is recommended for advanced monitoring and alerting.

Step 2: Monitoring with Docker Stats

1. **Using Docker Stats**

Docker provides a simple built-in tool for monitoring container-level resource usage called docker stats. This command gives real-time statistics for each running container, including CPU usage, memory usage, network I/O, and block I/O.

To view stats for all running containers:

bash
Copy code
docker stats

This will show something like:

mathematica
Copy code
CONTAINER ID NAME CPU % MEM USAGE / LIMIT MEM %
NET I/O BLOCK I/O PIDS
4e1c1c7cfa84 nginx 0.02% 5.46MiB / 1.953GiB 0.27% 10MB / 8MB
3MB / 0B 3

You can also view stats for a specific container:

bash
Copy code
docker stats <container-name-or-id>

2. **Understanding Docker Stats Metrics**
    a. **CPU %**: Shows the percentage of CPU the container is using.
    b. **Memory Usage/Limit**: Displays the memory usage and the limit allocated for the container.
    c. **Network I/O**: Measures the data sent and received over the network by the container.
    d. **Block I/O**: Displays the amount of data read from and written to the container's storage.
    e. **PIDs**: The number of processes running inside the container.

Step 3: Centralized Monitoring with Prometheus

For more advanced monitoring and metrics collection, **Prometheus** is a popular open-source tool that can collect and store metrics from Docker containers, Swarm nodes, and services. Prometheus integrates well with Docker and can be configured to scrape metrics from Docker Daemon, containers, and Swarm services.

1. **Setting Up Prometheus for Docker Swarm**
    a. First, you need to deploy Prometheus in your Docker Swarm. You can use Docker Compose or Docker Stack for this.

Example of a basic Prometheus docker-compose.yml configuration:

yaml
Copy code

```
version: '3.7'

services:
  prometheus:
    image: prom/prometheus
    volumes:
      - ./prometheus.yml:/etc/prometheus/prometheus.yml
    ports:
      - "9090:9090"
```

Create a prometheus.yml file to specify which metrics to scrape:

yaml
Copy code

```
global:
  scrape_interval: 15s

scrape_configs:
  - job_name: 'docker'
    static_configs:
      - targets: ['<docker-swarm-manager-ip>:9323']
```

2. **Prometheus Metrics Endpoint**

Prometheus can scrape Docker daemon metrics through the **Docker Exporter**. You'll need to deploy **docker-exporter** on your Docker Swarm nodes. This exporter collects and exposes Docker metrics in a format Prometheus can scrape.

Install and configure **docker-exporter** on each Swarm node:

bash
Copy code

```
docker run -d -p 9323:9323 --name=docker_exporter --restart always -v /var/run/docker.sock:/var/run/docker.sock prom/docker-exporter
```

3. **Accessing Prometheus Dashboard**

After setting up Prometheus, open your browser and go to http://<swarm-manager-ip>:9090 to access the Prometheus UI. You can now query and visualize Docker container metrics.

Step 4: Using Grafana for Visualization

While Prometheus collects and stores metrics, **Grafana** is a popular tool for creating dashboards and visualizing those metrics.

1. **Deploying Grafana**

You can deploy Grafana in your Docker Swarm alongside Prometheus:

yaml
Copy code

```
version: '3.7'

services:
  grafana:
    image: grafana/grafana
    ports:
      - "3000:3000"
    environment:
      - GF_SECURITY_ADMIN_PASSWORD=admin
    volumes:
      - grafana-storage:/var/lib/grafana
```

2. **Connecting Grafana to Prometheus**

After Grafana is deployed, open your browser and go to http://<swarm-manager-ip>:3000 to access the Grafana dashboard. The default login is admin/admin. Once logged in:

   a. Go to **Configuration → Data Sources**.
   b. Add **Prometheus** as the data source.
   c. Set the URL to http://<prometheus-service-name>:9090 (this is where Prometheus is running).

3. **Creating Dashboards**

Once Prometheus is set up as a data source in Grafana, you can create custom dashboards to visualize Docker Swarm metrics. You can either create them from scratch or import pre-built Docker Swarm dashboards from the **Grafana Dashboard Directory**.

Step 5: Setting Up Alerts

Prometheus allows you to set up alerts for specific conditions (e.g., when CPU usage is high or when a container is unhealthy). Alerts can trigger notifications via different channels such as email, Slack, or PagerDuty.

1. **Setting Up Prometheus Alerting Rules**

In prometheus.yml, add a section for alert rules:

yaml
Copy code

```
alerting:
  alertmanagers:
    - static_configs:
        - targets:
            - 'alertmanager:9093'
```

Then, create an alert.rules file for defining alert conditions:

yaml
Copy code

```
groups:
- name: docker
  rules:
  - alert: HighCpuUsage
    expr: avg(rate(container_cpu_usage_seconds_total[1m])) by (container_name) >
0.9
    for: 1m
    labels:
      severity: critical
    annotations:
      summary: "CPU usage is above 90% for container
{{ $labels.container_name }}"
```

2. **Integrating with Alertmanager**

Set up **Alertmanager** to manage and route alerts to notification channels like email or Slack.

Step 6: Docker Swarm Logs and Metrics Aggregation

For production environments, it's critical to aggregate logs and metrics to centralize monitoring and troubleshooting. **ELK Stack** (Elasticsearch, Logstash, and Kibana) is a common choice for logging, while **Prometheus** and **Grafana** handle metrics.

1. **Centralized Log Aggregation with ELK Stack**

Set up an ELK Stack to collect and analyze logs from Docker containers and services in your Swarm. Use **Filebeat** or **Logstash** to forward logs to Elasticsearch for indexing and then visualize them in Kibana.

Recap and Reflect

Today, you learned:

- How to monitor Docker containers using docker stats.
- How to set up **Prometheus** for centralized metrics collection from your Docker Swarm cluster.
- How to integrate **Grafana** for visualizing Docker Swarm metrics in dashboards.
- How to set up **alerts** in Prometheus to be notified about critical events.
- The importance of aggregating logs and metrics for troubleshooting and performance monitoring in Docker Swarm.

Day 17: Docker Swarm Backup and Disaster Recovery

Today, you'll learn how to back up and restore your Docker Swarm environment. Disaster recovery ensures that your data and configurations are safe and can be restored in case of hardware failure, data corruption, or other emergencies.

Step 1: Understanding What to Back Up

In Docker Swarm, the following components are crucial for backups:

1. **Swarm Cluster State**:
    a. The Raft database contains all the state information of the Swarm, including services, tasks, and secrets.
    b. Located on the manager nodes at: /var/lib/docker/swarm.
2. **Volumes**:
    a. Persistent data created using Docker volumes (e.g., databases, application data).
3. **Container Images**:
    a. Custom images used in your services.
4. **Configuration Files**:
    a. Any Docker Compose files, scripts, or service definitions.

Step 2: Backing Up the Swarm State

1. **Stop the Docker Service**

To ensure consistency, stop Docker on the Swarm manager node before backing up the Raft database:

bash
Copy code
sudo systemctl stop docker

2. **Create a Backup of the Swarm Directory**

Copy the /var/lib/docker/swarm directory to a backup location:

bash
Copy code
sudo tar -czvf swarm-backup.tar.gz /var/lib/docker/swarm

3. **Restart the Docker Service**

After the backup is complete, restart Docker:

bash
Copy code
sudo systemctl start docker

4. **Store the Backup Securely**

Move the swarm-backup.tar.gz file to a secure location, such as a cloud storage bucket or a network backup server.

Step 3: Backing Up Docker Volumes

1. **Identify the Volumes to Back Up**

List all Docker volumes:

bash
Copy code
docker volume ls

2. **Back Up a Specific Volume**

Use the docker run command to back up a volume:

bash
Copy code

docker run --rm -v <volume-name>:/data -v $(pwd):/backup busybox tar -czvf /backup/<volume-name>.tar.gz /data

Replace <volume-name> with the name of your volume.

3. **Verify and Store the Backup**

Confirm that the tarball (<volume-name>.tar.gz) is created and move it to a secure location.

Step 4: Backing Up Container Images

1. **List Custom Container Images**

Use the docker images command to list all images:

bash
Copy code
docker images

2. **Export Custom Images**

Save a Docker image as a tarball:

bash
Copy code
docker save -o <image-name>.tar <image-name>:<tag>

Example:

bash
Copy code
docker save -o myapp.tar myapp:latest

3. **Store the Image Backup**

Transfer the image tarballs to your backup location.

Step 5: Restoring the Swarm Cluster

If a disaster occurs, follow these steps to restore the Swarm cluster:

1. **Stop Docker**

On the Swarm manager node, stop Docker:

bash
Copy code
sudo systemctl stop docker

2. **Restore the Swarm Directory**

Extract the backed-up Swarm state to /var/lib/docker/swarm:

bash
Copy code
sudo tar -xzvf swarm-backup.tar.gz -C /

3. **Restart Docker**

Start the Docker service:

bash
Copy code
sudo systemctl start docker

4. **Reinitialize the Swarm**

Docker should automatically recognize the restored Swarm state. Verify by running:

bash
Copy code
docker node ls

Step 6: Restoring Docker Volumes

1. **Create a New Volume**

Recreate the volume:

bash
Copy code
docker volume create <volume-name>

2. **Restore the Volume Data**

Use the docker run command to restore the data:

bash
Copy code
docker run --rm -v <volume-name>:/data -v $(pwd):/backup busybox tar -xzvf /backup/<volume-name>.tar.gz -C /data

Step 7: Restoring Container Images

1. **Import a Backed-Up Image**

Load the saved Docker image:

bash
Copy code

docker load -i <image-name>.tar

2. **Verify the Image**

Confirm that the image is available:

bash
Copy code
docker images

Step 8: Automating Backups

1. **Use Cron Jobs**

Automate backups using cron jobs. For example, create a cron job to back up the Swarm state daily:

bash
Copy code
0 2 * * * tar -czvf /backup/swarm-backup-$(date +\%Y-\%m-\%d).tar.gz /var/lib/docker/swarm

2. **Leverage Backup Tools**

Use third-party tools such as **Velero** (for container-based backups) or cloud-native backup solutions for automated and managed backups.

Step 9: Testing Your Backups

1. **Test Restorations Regularly**

Periodically test restoring your Swarm cluster, volumes, and images in a staging environment to ensure the backups are reliable.

2. **Document Recovery Steps**

Maintain a clear disaster recovery playbook that outlines the restoration steps, tools, and locations of backup files.

Recap and Reflect

Today, you learned:

- The components to back up in a Docker Swarm environment.
- How to back up and restore the Swarm cluster state, Docker volumes, and container images.
- Automation techniques for regular backups.
- The importance of testing your backups and maintaining a disaster recovery playbook.

Day 18: Docker Networking

Step 1: Introduction to Docker Networking

Docker containers need to communicate with each other, the host machine, and the outside world. Docker handles networking automatically, but you can configure and customize networking for various use cases.

1. **Default Docker Networks:**
    a. **Bridge** (default for single-container setups)
    b. **Host** (share the host's network namespace)
    c. **None** (no networking, used for isolated containers)

To see the available networks:

bash
Copy code
docker network ls

2. **Network Drivers:**
    a. **bridge**: Used for containers running on a single Docker host.
    b. **host**: The container shares the host's network stack.
    c. **overlay**: Used for multi-host networking in Swarm mode.
    d. **macvlan**: Assigns a MAC address to containers, allowing them to appear as physical devices on the network.
    e. **none**: No networking.

Step 2: Creating Custom Networks

1. **Creating a Custom Bridge Network**

You can create custom networks to enable communication between containers:

bash
Copy code
docker network create --driver bridge my_custom_network

2. **Using an Overlay Network in Docker Swarm**

When running Docker Swarm, you'll typically use overlay networks to enable communication between containers across different nodes in the Swarm.

bash
Copy code

docker network create --driver overlay my_overlay_network

This command creates a network that can span across multiple nodes in a Swarm.

Step 3: Network Configuration in Docker Compose

1. **Defining Networks in Docker Compose**

Docker Compose allows you to define custom networks to control how containers communicate within the app. For example:

yaml
Copy code

```
version: "3"
services:
  web:
    image: nginx
    networks:
      - frontend
  app:
    image: myapp
    networks:
      - backend
      - frontend
networks:
  frontend:
  backend:
```

2. **Exposing Ports in Compose**

You can expose container ports to the host machine or to other containers within a specific network. For instance:

yaml
Copy code
```
services:
  web:
    image: nginx
    ports:
      - "8080:80"
```

Step 4: Port Mapping and DNS Resolution in Docker

1. **Port Mapping**

You can map container ports to host machine ports to access containerized services from the outside:

bash
Copy code
```
docker run -p 8080:80 nginx
```

2. **DNS Resolution**

Docker automatically sets up DNS resolution for containers. Containers on the same network can refer to each other by service name or container name.

Step 5: Advanced Networking with Docker

1. **Macvlan Networks**

Macvlan allows containers to get their own IP addresses on the physical network, which can be useful for certain use cases like legacy applications.

bash
Copy code
docker network create -d macvlan --subnet=192.168.0.0/24 --gateway=192.168.0.1 my_macvlan_network

2. **Inspecting Network Configuration**

You can inspect network details using:

bash
Copy code
docker network inspect <network-name>

Recap and Next Steps:

Today, you learned:

- The default and custom Docker networks.
- How to configure networks in Docker, including bridge, overlay, and macvlan networks.
- Using Docker Compose to define networks for container communication.
- Port mapping and DNS resolution in Docker containers.

Day 19: Docker Security

Today, you will learn how to secure your Docker environment, ensuring that your containers are isolated and protected from potential vulnerabilities. Docker security involves several key practices: isolating containers, securing images, managing user permissions, and securing sensitive data.

Step 1: Understanding Docker Security Concepts

1. **Namespaces and Isolation:**
    a. **Namespaces**: Docker uses Linux namespaces to provide isolation between containers. The main namespaces used in Docker are:
        i. **PID namespace**: Isolates process IDs.
        ii. **Network namespace**: Isolates network interfaces and IP addresses.
        iii. **Mount namespace**: Isolates file system mount points.
        iv. **UTS namespace**: Isolates hostnames and domain names.
        v. **IPC namespace**: Isolates inter-process communication.
        vi. **User namespace**: Isolates user and group IDs.
2. **Cgroups:**
    a. **Control Groups (Cgroups)**: Used by Docker to limit and prioritize resources (CPU, memory, disk I/O) for containers, ensuring that one container cannot consume all the host's resources.
3. **Seccomp, AppArmor, and SELinux:**
    a. These Linux security modules are used to restrict the actions of containers. Docker has built-in support for using seccomp profiles to limit system calls that containers can make, as

well as AppArmor and SELinux for additional access controls.

Step 2: Securing Docker Containers

1. **Run Containers as a Non-Root User:** By default, containers run as the root user inside the container. However, it's a good practice to run containers as a non-root user to reduce the risk of privilege escalation.
    a. You can specify the user to run as inside the Dockerfile using the USER instruction:

Dockerfile
Copy code
FROM node:14
USER node

    b. Alternatively, you can specify the user when running a container:

bash
Copy code
docker run -u 1001 myimage

2. **Use the Least Privilege Principle:** Limit the privileges of containers. For example, avoid running containers with --privileged, which gives them full access to the host system.
3. **Limit Container Capabilities:** Docker allows you to control the capabilities of a container using the --cap-drop and --cap-add flags. For example, you can drop unnecessary capabilities:

bash
Copy code

```
docker run --cap-drop=ALL --cap-add=NET_ADMIN myimage
```

4. **Read-Only Filesystem:** Running containers with a read-only filesystem reduces the risk of tampering. You can set a container's filesystem as read-only:

bash
Copy code
```
docker run --read-only myimage
```

Step 3: Securing Docker Images

1. **Use Official and Trusted Images:** Always pull images from trusted sources, such as Docker Hub's official repository or a private registry with images you've verified. Avoid using unofficial images from untrusted sources.
2. **Scan for Vulnerabilities:** Use Docker's security scanning tools to identify vulnerabilities in images:
    a. **Docker Scout**: Helps you scan images for known vulnerabilities.
    b. **Clair**: Open-source tool for static analysis of vulnerabilities in container images.
    c. **Trivy**: A simple and comprehensive vulnerability scanner for containers.

Example using Trivy:

bash
Copy code
```
trivy image myimage:latest
```

3. **Minimize Image Size and Attack Surface:**
    a. Use **multi-stage builds** to reduce the size of the final image, removing unnecessary dependencies from the build image.
    b. For example:

Dockerfile
Copy code
```
# Stage 1: Build
FROM node:14 AS build
WORKDIR /app
COPY . .
RUN npm install

# Stage 2: Production image
FROM node:14-slim
WORKDIR /app
COPY --from=build /app .
RUN npm prune --production
```

4. **Sign Docker Images:** Docker Content Trust (DCT) enables image signing to ensure the authenticity and integrity of images. To enable Docker Content Trust, set the environment variable DOCKER_CONTENT_TRUST=1.

Step 4: Securing Docker Daemon and Host

1. **Use TLS to Secure Docker Daemon:** It's important to secure Docker's remote API with TLS (Transport Layer Security) to ensure that communication between Docker clients and the Docker daemon is encrypted.
    a. Generate TLS certificates for the Docker daemon and client.

b. Configure the Docker daemon to use TLS by setting the appropriate flags in /etc/docker/daemon.json:

json
Copy code
```
{
  "hosts": ["tcp://0.0.0.0:2376"],
  "tlsverify": true,
  "tlscacert": "/etc/docker/ca.pem",
  "tlscert": "/etc/docker/cert.pem",
  "tlskey": "/etc/docker/key.pem"
}
```

2. **Limit Access to Docker Daemon:** Only trusted users should have access to the Docker daemon. By default, Docker adds users to the docker group, which allows them to access the Docker daemon. You should consider creating a more restricted user policy.
3. **Enable Docker's User Namespace Feature:** The user namespace feature allows you to map container users to non-root users on the host. This increases security by isolating container processes and users.
    a. Enable this feature by editing /etc/docker/daemon.json:

json
Copy code
```
{
  "userns-remap": "default"
}
```

4. **Audit Docker Logs:** Enable logging for the Docker daemon, and regularly review logs for suspicious activity. Docker logs can be

found in /var/log/upstart/docker.log or /var/log/syslog depending on the OS.

Step 5: Docker Secrets and Sensitive Data Management

1. **Storing Secrets in Docker Swarm:** Docker Swarm has built-in support for managing secrets securely. Docker stores secrets encrypted and makes them available only to services that need them.
    a. To create a secret:

bash
Copy code
```
echo "my_secret_password" | docker secret create my_secret -
```

2. **Using Secrets in Services:** When deploying services in Docker Swarm, you can refer to secrets:

yaml
Copy code
```
version: "3.7"
services:
  web:
    image: nginx
    secrets:
      - my_secret
secrets:
  my_secret:
    external: true
```

3. **Avoid Storing Secrets in Dockerfiles or Environment Variables:** Never hard-code secrets directly in Dockerfiles or environment variables. Always use Docker secrets or external tools like HashiCorp Vault for managing secrets.

Step 6: Best Practices for Docker Security

1. **Regularly Update Docker and Dependencies:** Keep Docker and its components up to date to minimize vulnerabilities. Also, ensure that your base images are regularly updated.
2. **Monitor Container Activity:** Use tools like **Falco** (a runtime security monitoring tool) and **Docker Bench for Security** to monitor container activities and security posture.
3. **Use Docker in a CI/CD Pipeline:** Use a CI/CD pipeline to automate the building and testing of Docker images. This ensures that images are scanned for vulnerabilities before they are deployed.
4. **Limit Container Resource Usage:** Define resource limits for containers to prevent resource exhaustion attacks.

bash
Copy code
docker run --memory=512m --cpus=1 myimage

Recap and Next Steps:

Today, you learned:

- How Docker achieves container isolation through namespaces and cgroups.

- Best practices for securing Docker containers, images, and the Docker daemon.
- Managing sensitive data with Docker secrets.
- Tools for scanning vulnerabilities and hardening your Docker environment.

Day 20: Docker Volumes and Persistent Storage

Today, you'll learn how to work with Docker volumes, which are crucial for persisting data across container restarts. Docker containers are ephemeral by nature, meaning any data inside them is lost once the container stops or is removed. Volumes allow you to manage persistent data separately from the container lifecycle.

Step 1: Introduction to Docker Volumes

1. **What Are Docker Volumes?**
    a. Docker volumes are storage mechanisms that are managed by Docker and are used to persist data outside of containers.
    b. Volumes are stored in the Docker host filesystem, but they are independent of the container's lifecycle, meaning they persist even after the container is removed.
2. **Volume vs Bind Mounts**
    a. **Volumes**: Managed by Docker, typically stored in /var/lib/docker/volumes/ on the host machine. Volumes are a better choice for most use cases because they are portable and easier to back up.

b. **Bind Mounts**: Directly map a file or directory on the host machine to a container. This is useful for development environments but not ideal for production environments.

Example of a volume:

bash
Copy code
docker volume create my_volume

Step 2: Creating and Using Docker Volumes

1. **Creating a Volume:**
    a. Volumes are created using the docker volume create command.

bash
Copy code
docker volume create my_volume

2. **Using Volumes in Containers:**
    a. When running a container, you can mount a volume to a container's directory using the -v or --mount option.

bash
Copy code
docker run -d -v my_volume:/data my_image

This mounts the my_volume volume to the /data directory inside the container.

b. **Volumes in Docker Compose**: You can define volumes in Docker Compose files to share data between services. For example:

yaml
Copy code

```
version: "3"
services:
  app:
    image: myapp
    volumes:
      - my_volume:/data
volumes:
  my_volume:
```

Step 3: Inspecting Volumes

1. **Inspecting a Volume:**
    a. To see detailed information about a volume, including its mount point on the host:

bash
Copy code

```
docker volume inspect my_volume
```

2. **Listing Volumes:**
    a. To list all volumes on your system:

bash
Copy code

```
docker volume ls
```

3. **Pruning Unused Volumes:**
    a. Volumes that are no longer in use can take up space. You can remove unused volumes with:

bash
Copy code
docker volume prune

Step 4: Data Persistence with Volumes

1. **Volume Persistence Across Container Restarts:**
    a. Docker volumes are useful for persisting data. If you remove and recreate a container, the data stored in volumes remains intact.
2. **Backups and Restores Using Volumes:**
    a. You can use volumes to back up data by copying data from the volume to a backup location on the host:

bash
Copy code
```
docker run --rm -v my_volume:/data -v $(pwd):/backup alpine \
  tar cvf /backup/backup.tar /data
```

    b. To restore data, you can copy the backup data back into the volume:

bash
Copy code
```
docker run --rm -v my_volume:/data -v $(pwd):/backup alpine \
  tar xvf /backup/backup.tar -C /data
```

Step 5: Using Named and Anonymous Volumes

1. **Named Volumes:**
    a. Volumes that you create with a specific name are named volumes. For example, my_volume in the commands above.
    b. These volumes are easy to refer to and manage.
2. **Anonymous Volumes:**
    a. When you use volumes without specifying a name, Docker automatically assigns a unique name to them. These volumes are often used for temporary storage, and Docker manages them automatically.

bash
Copy code
```
docker run -d -v /data my_image
```

Step 6: Docker Volume Drivers

1. **Volume Drivers:**
    a. Docker supports using different volume drivers for managing volumes on external systems, such as NFS, GlusterFS, or cloud storage.
    b. For example, using an NFS volume driver:

bash
Copy code
```
docker volume create --driver local --opt type=nfs --opt
o=addr=192.168.1.100,rw --opt device=:/data my_nfs_volume
```

2. **Common Volume Drivers:**
    a. **local**: The default driver, stores data on the local disk.
    b. **nfs**: Mounts an NFS share as a volume.

c. **cloud storage drivers**: Integrate with cloud storage systems (e.g., AWS EBS, GCP persistent disks).

Step 7: Docker Compose with Volumes

Docker Compose makes managing volumes across multiple services easier. Here's an example of a Compose file that defines multiple services and volumes:

yaml
Copy code

```
version: "3"
services:
  app:
    image: myapp
    volumes:
      - app_data:/data
  db:
    image: postgres
    volumes:
      - db_data:/var/lib/postgresql/data
volumes:
  app_data:
  db_data:
```

This Compose file defines two services (app and db) that each use separate named volumes (app_data and db_data).

Step 8: Best Practices for Docker Volumes

1. **Separate Data and Application Layers:**
    a. Keep application logic separate from data storage. This ensures that your data is not tied to the lifecycle of a specific container.
2. **Use Volumes for Persistent Storage:**
    a. Always use Docker volumes for persistent data (e.g., databases, application logs). Avoid using bind mounts for persistent data in production environments, as bind mounts tie data to the host filesystem.
3. **Backup Volumes Regularly:**
    a. Ensure regular backups of volumes that store critical data, especially for production systems. Use scripts or automation tools for periodic backups.

Recap and Next Steps:

Today, you learned:

- How to create, manage, and use Docker volumes for persistent storage.
- The difference between volumes and bind mounts, and when to use each.
- How to back up and restore data stored in volumes.
- How to use Docker Compose with volumes to manage data across multiple services.

Day 21: Docker Orchestration Alternatives: Kubernetes

Today, you'll learn about **Kubernetes**, a container orchestration platform that is often used in conjunction with Docker. While Docker provides powerful containerization features, Kubernetes helps manage and scale Docker containers in a production environment, particularly for large-scale applications and microservices.

We'll also briefly touch on **Docker Swarm**, Docker's own orchestration tool, to understand the difference between the two.

Step 1: Introduction to Container Orchestration

1. **What is Container Orchestration?**
    a. Container orchestration is the management of containerized applications across multiple hosts.
    b. It automates tasks like container deployment, scaling, load balancing, service discovery, and container health monitoring.
2. **Why Orchestration?**
    a. In large-scale applications, managing containers manually becomes complex. Orchestration tools like Kubernetes help automate the management of container lifecycles, scaling, and high availability.

Step 2: Introduction to Kubernetes

1. **What is Kubernetes?**
    a. Kubernetes is an open-source platform for automating the deployment, scaling, and management of containerized applications.

b. It was originally developed by Google and is now maintained by the Cloud Native Computing Foundation (CNCF).

2. **Core Concepts of Kubernetes:**
    a. **Pod**: The smallest unit in Kubernetes, which can hold one or more containers.
    b. **Node**: A physical or virtual machine in the Kubernetes cluster where containers (pods) run.
    c. **Cluster**: A group of nodes running Kubernetes. The cluster is the foundation for running containerized applications.
    d. **Deployment**: A controller that manages the deployment of applications across the cluster, ensuring the desired state (e.g., number of replicas) is maintained.
    e. **Service**: A logical abstraction that defines a set of Pods and provides a stable network endpoint for accessing them.
    f. **Namespace**: A way to organize and isolate resources within a Kubernetes cluster.

Step 3: Kubernetes vs Docker Swarm

While Kubernetes is the most widely used container orchestrator, Docker Swarm is Docker's own native orchestration solution. Here's a brief comparison:

1. **Ease of Use:**
    a. **Docker Swarm**: Easier to set up and use, especially for smaller environments or teams already familiar with Docker.
    b. **Kubernetes**: More complex to set up and manage but offers greater flexibility and features for large-scale applications.
2. **Scaling:**

a. **Docker Swarm**: Can scale services up and down, but Kubernetes offers more advanced features, such as auto-scaling, and better management of resources.
b. **Kubernetes**: Provides advanced scaling features such as horizontal pod autoscaling, cluster autoscaling, and more.

3. **Networking:**
    a. **Docker Swarm**: Uses a simpler networking model and supports overlay networks for service communication.
    b. **Kubernetes**: Uses a more advanced networking model with network policies, services, ingress controllers, and DNS-based service discovery.
4. **Use Case:**
    a. **Docker Swarm**: Better for small to medium-scale projects and teams who need quick deployment without needing too many advanced features.
    b. **Kubernetes**: Preferred for large-scale applications with complex microservices architectures that require high availability, self-healing, and other advanced features.

Step 4: Basic Kubernetes Setup

1. **Installing Kubernetes:**
    a. You can install Kubernetes on your local machine using tools like **Minikube** or **Docker Desktop** (which includes Kubernetes support).
    b. **Minikube** creates a single-node Kubernetes cluster locally, which is great for learning and testing.

bash
Copy code
minikube start

c. **Docker Desktop**: If you are using Docker Desktop, you can enable Kubernetes from the preferences, and it will set up a local Kubernetes cluster for you.

2. **Kubeconfig:**
    a. Kubernetes uses a configuration file (kubeconfig) that defines cluster information, authentication details, and namespaces.
    b. When you set up a Kubernetes cluster, the configuration is stored in ~/.kube/config.

Step 5: Kubernetes Objects

1. **Pods:**
    a. A **Pod** is the smallest deployable unit in Kubernetes, and it represents one or more containers running in a cluster.
    b. Pods can be created using a YAML configuration file:

yaml
Copy code

```
apiVersion: v1
kind: Pod
metadata:
  name: mypod
spec:
  containers:
  - name: mycontainer
    image: nginx
```

    c. To create a pod, use:

bash
Copy code

```
kubectl apply -f pod.yaml
```

2. **Services:**
    a. A **Service** is an abstraction that defines a set of Pods and provides a stable IP address or DNS name for accessing them.
    b. Services can be created to expose Pods externally (e.g., through LoadBalancer or NodePort) or internally (ClusterIP).

yaml
Copy code

```
apiVersion: v1
kind: Service
metadata:
  name: myservice
spec:
  selector:
    app: myapp
  ports:
    - protocol: TCP
      port: 80
      targetPort: 8080
  type: LoadBalancer
```

3. **Deployments:**
    a. A **Deployment** defines how to run Pods, including the number of replicas and updates to Pods.
    b. It ensures that the desired state is maintained across the cluster, meaning the specified number of Pods is always running.

yaml
Copy code

```
apiVersion: apps/v1
kind: Deployment
```

```
metadata:
  name: myapp-deployment
spec:
  replicas: 3
  selector:
    matchLabels:
      app: myapp
  template:
    metadata:
      labels:
        app: myapp
    spec:
      containers:
      - name: myapp
        image: myapp:latest
        ports:
        - containerPort: 8080
```

4. **Namespaces:**
    a. **Namespaces** allow you to isolate resources in a Kubernetes cluster.
    b. You can use namespaces to separate environments (e.g., development, staging, production) or teams within a single cluster.

```
bash
Copy code
kubectl create namespace dev
```

Step 6: Managing Kubernetes Resources

1. **Viewing Resources:**
    a. Use kubectl to interact with your Kubernetes cluster and view the status of your resources.
    b. List Pods:

bash
Copy code
kubectl get pods

    c. List Services:

bash
Copy code
kubectl get services

    d. View detailed information about a specific resource:

bash
Copy code
kubectl describe pod mypod

2. **Scaling Deployments:**
    a. You can scale a deployment up or down using kubectl scale.

bash
Copy code
kubectl scale deployment myapp-deployment --replicas=5

3. **Rolling Updates:**
    a. Kubernetes allows you to update your application smoothly with **rolling updates**. This means new Pods will be gradually

created, and old Pods will be terminated once the new ones are running.

bash
Copy code
kubectl apply -f deployment.yaml

Step 7: Kubernetes Networking

1. **Cluster Networking:**
    a. Kubernetes uses **CNI (Container Network Interface)** plugins for networking between Pods. Common CNI plugins include **Calico**, **Weave**, and **Flannel**.
2. **Ingress Controllers:**
    a. An **Ingress** resource provides HTTP and HTTPS routing to services within a cluster. An Ingress controller is a component that manages ingress traffic.
    b. You can create an ingress resource to route external traffic to services within the cluster.

yaml
Copy code

```
apiVersion: networking.k8s.io/v1
kind: Ingress
metadata:
  name: myapp-ingress
spec:
  rules:
  - host: myapp.example.com
    http:
      paths:
      - path: /
```

```
    pathType: Prefix
    backend:
      service:
        name: myapp-service
        port:
          number: 80
```

Step 8: Kubernetes vs Docker Swarm: Final Thoughts

1. **Kubernetes**:
    a. Best for large-scale, complex applications.
    b. Provides more advanced features like auto-scaling, rolling updates, self-healing, and high availability.
    c. Steeper learning curve but highly scalable and flexible.
2. **Docker Swarm**:
    a. Simpler and easier to set up.
    b. Good for small to medium-scale applications.
    c. Integrated tightly with Docker, but fewer features than Kubernetes.

Recap and Next Steps:

Today, you learned:

- The differences between **Docker Swarm** and **Kubernetes**.
- How to set up and use **Kubernetes** with basic objects like Pods, Deployments, Services, and Namespaces.
- Basic management of Kubernetes resources using kubectl.
- Networking in Kubernetes using **Ingress** and **CNI plugins**.

Day 22: Docker Compose - Advanced Concepts and Best Practices

Today, we'll dive deeper into **Docker Compose**, which allows you to define and manage multi-container Docker applications. We'll cover advanced features of Docker Compose, best practices for managing complex setups, and how to integrate Docker Compose with your development and production workflows.

Step 1: Introduction to Docker Compose

1. **What is Docker Compose?**
    a. Docker Compose is a tool for defining and running multi-container Docker applications. Using a simple YAML file (docker-compose.yml), you can define all the services, networks, and volumes needed for your application.
    b. Docker Compose allows you to easily manage the lifecycle of an entire application stack, from local development to testing and production environments.
2. **How Docker Compose Works:**
    a. With Docker Compose, you can run multi-container applications with a single command.
    b. The docker-compose.yml file describes the services, networks, and volumes used by your application, simplifying container management.

Step 2: Docker Compose File Structure

1. **Basic Structure of a docker-compose.yml file:**
    a. The file is usually structured in three main sections:
        i. **services**: Defines the application containers.

ii. **volumes**: Defines data volumes shared between services.
iii. **networks**: Defines custom networks for communication between containers.

Example of a basic docker-compose.yml:

yaml
Copy code

```
version: "3"
services:
  web:
    image: nginx
    ports:
      - "8080:80"
  app:
    image: myapp
    depends_on:
      - db
  db:
    image: postgres
    environment:
      POSTGRES_PASSWORD: example
```

b. This example defines three services: web, app, and db. The app service depends on the db service, ensuring that db starts before app.

Step 3: Advanced Docker Compose Features

1. **Environment Variables in Compose:**

a. Docker Compose allows you to pass environment variables to services, making it easier to configure the application dynamically.
b. Environment variables can be defined in the docker-compose.yml file or loaded from a .env file.

Example:

yaml
Copy code

```
version: "3"
services:
  app:
    image: myapp
    environment:
      - DATABASE_URL=${DATABASE_URL}
```

c. You can create a .env file containing values for the environment variables:

bash
Copy code

```
DATABASE_URL=postgres://db:5432/mydb
```

2. **Service Dependencies and Health Checks:**
   a. **depends_on**: You can define service dependencies to ensure one service starts before another. However, this doesn't wait for a service to be fully ready—just for it to start.
   b. **healthcheck**: You can specify a health check for services to ensure they are ready before they are used by other services.

yaml
Copy code

```
services:
  db:
    image: postgres
    healthcheck:
      test: ["CMD", "pg_isready", "-U", "postgres"]
      interval: 30s
      retries: 5
```

3. **Scaling Services:**
    a. Docker Compose allows you to scale services up or down easily by specifying the --scale option.

bash
Copy code
```
docker-compose up --scale web=3
```

    b. This would scale the web service to 3 replicas, running multiple containers for the web service.
4. **Build and Volume Mounting in Compose:**
    a. You can build images directly from a Dockerfile within the docker-compose.yml file using the build directive.
    b. You can also mount host volumes to containers to facilitate development.

yaml
Copy code
```
services:
  app:
    build: ./app
    volumes:
      - ./app:/usr/src/app
```

5. **Custom Networks:**
    a. Docker Compose automatically creates a network for your services, but you can also define custom networks for specific use cases (e.g., separating frontend and backend services).

yaml
Copy code

```
version: "3"
services:
  app:
    image: myapp
    networks:
      - front
  db:
    image: postgres
    networks:
      - back
networks:
  front:
  back:
```

Step 4: Managing Multi-Environment Setups with Compose

1. **Multiple Compose Files:**
    a. You can manage different environments (e.g., development, staging, production) using multiple Compose files. Each file can specify configurations for different environments.
    b. Use the -f flag to specify which Compose files to use. For example:

bash

Copy code
docker-compose -f docker-compose.yml -f docker-compose.override.yml up

2. **Profiles and Selective Service Running:**
    a. Docker Compose allows you to define **profiles** to enable or disable services based on the environment.

yaml
Copy code
```
services:
  web:
    image: nginx
    profiles:
      - front
  api:
    image: myapi
    profiles:
      - back
```

    b. You can then run only the services for a specific profile:

bash
Copy code
docker-compose --profile front up

Step 5: Best Practices for Using Docker Compose

1. **Use .env Files for Configurations:**

a. Externalize sensitive information like passwords, API keys, or environment-specific configurations by using .env files. This keeps your docker-compose.yml file clean and secure.

2. **Leverage Multi-Stage Builds:**
    a. When building images from a Dockerfile, use multi-stage builds to reduce the size of the final image and ensure only necessary artifacts are included in the container.

Dockerfile
Copy code

```
# Stage 1: Build
FROM node:14 AS build
WORKDIR /app
COPY . .
RUN npm install && npm run build

# Stage 2: Production image
FROM nginx:alpine
COPY --from=build /app/dist /usr/share/nginx/html
```

3. **Use Named Volumes for Persistent Data:**
    a. When working with databases or services that need to retain data, use **named volumes** instead of bind mounts. Named volumes ensure that data is preserved even if the container is removed.

yaml
Copy code

```
version: "3"
services:
  db:
    image: postgres
    volumes:
```

```
    - db_data:/var/lib/postgresql/data
volumes:
  db_data:
```

4. **Keep Services Lightweight:**
    a. Keep each service in Docker Compose as lightweight as possible. Follow the **single responsibility principle**, meaning each container should run only one service or application component.
5. **Version Control for docker-compose.yml:**
    a. Treat your docker-compose.yml file as part of your version-controlled codebase. This file defines your application architecture, and keeping it in version control allows for easy collaboration and reproducibility.

Step 6: Using Docker Compose in Development and Production

1. **Development Workflows:**
    a. Docker Compose is great for local development setups. It simplifies running multiple containers and dependencies (e.g., databases, caching systems) locally.
    b. Use volume mounts to sync code between your local machine and containers for a smoother development experience.
2. **Production Workflows:**
    a. In production environments, consider using **Docker Swarm** or **Kubernetes** for orchestration. Docker Compose is great for development and testing, but for high availability and scaling, orchestration platforms like Swarm or Kubernetes are preferred.

b. **Docker Compose** can still be used in production for smaller applications or as part of a hybrid workflow.

Step 7: Integrating Docker Compose with CI/CD

1. **CI/CD Integration:**
    a. Docker Compose is commonly used in CI/CD pipelines to set up environments for testing and integration.
    b. For example, in a **Jenkins pipeline**, you can use Docker Compose to spin up the required services for testing.

bash
Copy code
```
docker-compose -f docker-compose.yml up -d
docker-compose exec app npm test
docker-compose down
```

2. **Testing with Compose:**
    a. You can run your application in isolated environments for integration testing with Docker Compose. Spin up services, run tests, and tear them down with each pipeline.

Recap and Next Steps:

Today, you learned:

- Advanced features of **Docker Compose**, such as environment variables, health checks, scaling, and custom networks.
- How to manage multi-environment setups using multiple Compose files.

- Best practices for using Docker Compose in development and production workflows.
- How Docker Compose integrates into **CI/CD pipelines**.

Tomorrow, we will dive into **Docker Security**, including best practices for securing your Docker containers, images, and overall Docker environment.

Day 23: Docker Security – Best Practices and Key Concepts

Today, we'll focus on **Docker Security**. Docker offers an excellent platform for running containers, but securing your Docker containers, images, and environment is crucial to ensure that your applications and infrastructure remain safe from vulnerabilities and attacks.

We'll discuss best practices for securing Docker in various contexts—containers, images, networks, and the Docker host—and explore Docker security tools.

Step 1: Overview of Docker Security

1. **Why is Docker Security Important?**
    a. Docker containers share the host OS kernel, meaning that vulnerabilities in the Docker platform, containers, or images could allow attackers to escape a container and gain control of the underlying host or other containers.
    b. It's essential to harden your Docker environment to avoid privilege escalation, network attacks, and container escape vulnerabilities.
2. **Key Areas of Docker Security:**

a. **Container Security**: Securing the containers themselves.
b. **Image Security**: Ensuring that Docker images do not contain vulnerabilities or malicious code.
c. **Host Security**: Protecting the underlying system where containers run.
d. **Network Security**: Securing container communication and access.

Step 2: Secure Docker Containers

1. **Limit Container Privileges:**
    a. By default, containers run with limited privileges, but you can further restrict them to improve security.
    b. **Use the --no-new-privileges flag** to prevent the container from gaining new privileges.

bash
Copy code
```
docker run --no-new-privileges mycontainer
```

    c. **Avoid Running as Root**: Containers should run as a non-root user unless absolutely necessary. You can specify a user inside the Dockerfile using the USER directive.

Dockerfile
Copy code
```
USER appuser
```

2. **Use Docker's Built-In Security Features:**
    a. **AppArmor**: An effective mandatory access control (MAC) system that can be used to restrict Docker container actions.

b. **Seccomp**: Provides a way to limit the system calls that containers can make to the kernel. Docker allows you to use a pre-configured seccomp profile, which can be customized.

bash
Copy code
```
docker run --security-opt seccomp=seccomp.json mycontainer
```

3. **Limit Resources for Containers:**
    a. Limit container resources (CPU, memory, etc.) to prevent denial-of-service (DoS) attacks or containers consuming excessive resources on the host.

bash
Copy code
```
docker run -m 256m --cpus="1.0" mycontainer
```

4. **Enable User Namespaces:**
    a. **User Namespaces** help prevent privilege escalation attacks by isolating the container's user IDs from the host.
    b. To enable user namespaces, edit the Docker daemon configuration (/etc/docker/daemon.json):

json
Copy code
```
{
  "userns-remap": "default"
}
```

Step 3: Secure Docker Images

1. **Use Trusted Base Images:**

a. Start with minimal, trusted base images (e.g., alpine, debian, ubuntu) that are well-maintained and free of unnecessary packages, which can reduce the attack surface.
b. Avoid using "latest" tags in Dockerfiles because they can introduce unexpected versions or vulnerabilities.

2. **Scan Images for Vulnerabilities:**
    a. Use tools to scan Docker images for known vulnerabilities. Some popular tools include:
        i. **Clair**: An open-source project that provides static analysis of vulnerabilities in container images.
        ii. **Anchore**: A tool for deep inspection and analysis of Docker images.
        iii. **Trivy**: A simple and comprehensive vulnerability scanner for containers.

Example of running Trivy on an image:

bash
Copy code
trivy image myimage:latest

3. **Minimize Image Size and Dependencies:**
    a. Remove unnecessary files and dependencies in your images to minimize the attack surface.
    b. Use **multi-stage builds** in Dockerfiles to separate the build environment from the runtime environment and reduce the final image size.

Dockerfile
Copy code
Build stage
FROM node:14 AS build

```
WORKDIR /app
COPY . .
RUN npm install

# Final stage
FROM node:14-slim
COPY --from=build /app /app
```

4. **Signing and Verifying Images:**
    a. Docker supports **Content Trust** with image signing to ensure that images haven't been tampered with.
    b. You can enable Docker Content Trust (DCT) to verify the authenticity of images pulled from a registry:

bash
Copy code
```
export DOCKER_CONTENT_TRUST=1
docker pull myimage:latest
```

Step 4: Securing Docker Host and Network

1. **Securing the Docker Host:**
    a. Keep your Docker host OS up to date with the latest security patches.
    b. Limit direct access to the Docker daemon. Use **Docker Socket Proxy** or enable TLS encryption to secure communication with the Docker daemon.
    c. **Disable Remote Docker Daemon Access** if not needed.
    d. Use a firewall to block unnecessary access to the Docker API.
2. **Docker Networking Best Practices:**

a. **Isolate containers**: Use Docker's network modes like bridge, host, or none to isolate containers and reduce unnecessary exposure to other containers and the outside world.
b. **User-Defined Networks**: Use **user-defined networks** in Docker Compose and docker network commands to control communication between containers more securely.

bash
Copy code
docker network create --driver bridge mynetwork

3. **Use Docker Swarm for Secure Orchestration:**
    a. When deploying containers across multiple hosts, use **Docker Swarm** to manage service discovery, load balancing, and network encryption between nodes in a cluster.
    b. Swarm provides automatic encryption for container traffic, ensuring secure communication between services.
4. **Limit Container Communication:**
    a. Use **network policies** to restrict container communication. This allows you to control which containers can talk to each other, preventing unauthorized access.
    b. You can specify network rules when running containers by specifying --network and controlling access via firewalls.

Step 5: Logging and Monitoring Docker Containers

1. **Centralized Logging:**
    a. It's important to have proper logging mechanisms for monitoring containers and detecting potential security incidents.

b. Use logging drivers like json-file or external logging services such as **Fluentd**, **Logstash**, or **ELK stack** for centralized logging.

2. **Monitor Docker Daemon:**
    a. Regularly monitor Docker's performance and daemon logs for suspicious activities or potential breaches.
    b. Tools like **Prometheus** and **Grafana** can be used for container performance monitoring.

bash
Copy code
docker stats

3. **Security Audits:**
    a. Regularly audit the Docker host, containers, and images for vulnerabilities.
    b. Use tools like **Lynis** (open-source security auditing tool) for system-level audits.

Step 6: Docker Security Tools

1. **Docker Bench for Security:**
    a. Docker provides a security auditing tool called **Docker Bench for Security** that checks the Docker configuration against best practices.

bash
Copy code
git clone https://github.com/docker/docker-bench-security
cd docker-bench-security
sudo ./docker-bench-security.sh

2. **Sysdig Falco:**
    a. **Falco** is an open-source security monitoring tool that detects abnormal behavior in Docker containers and Kubernetes clusters. It watches for suspicious activity and generates alerts.

bash
Copy code
docker run --runtime=runsc --net=host --pid=host -v /var/run/docker.sock:/var/run/docker.sock sysdig/falco

Step 7: Docker Security Best Practices Checklist

- Use **trusted images** from verified sources.
- Regularly **scan images** for vulnerabilities and patch them.
- Run containers with **limited privileges** (e.g., --no-new-privileges).
- **Restrict container communication** with network policies.
- Use **user namespaces** for additional isolation.
- Implement **resource limits** for containers.
- Enable **content trust** for image verification.
- Keep Docker and its dependencies up to date.
- **Monitor and log** container activity for security events.

Recap and Next Steps:

Today, you learned:

- Best practices for **securing Docker containers, images, networks, and hosts**.

- Tools like **Trivy**, **Docker Bench**, and **Falco** to assist with security scanning and auditing.
- How to apply **Docker security options** such as seccomp profiles and user namespaces.
- The importance of **monitoring** and **centralized logging** in securing Docker environments

Day 24: Docker with Kubernetes - Orchestration and Scaling

Today, we'll explore how Docker integrates with **Kubernetes**, a powerful container orchestration tool. Kubernetes allows you to manage and scale containerized applications efficiently across a cluster of machines. We'll cover key Kubernetes concepts, its architecture, and how Docker containers fit into the Kubernetes ecosystem.

Step 1: Introduction to Kubernetes

1. **What is Kubernetes?**
    a. Kubernetes (K8s) is an open-source container orchestration platform designed to automate deployment, scaling, and management of containerized applications.
    b. It provides high availability, fault tolerance, and scalability for your applications.
2. **Why Use Kubernetes with Docker?**
    a. While Docker handles containerization, Kubernetes manages multiple containers in distributed systems.
    b. It enables features like load balancing, self-healing, automated rollouts/rollbacks, and service discovery.
3. **Kubernetes vs. Docker Swarm:**

a. Docker Swarm is simpler and built into Docker for orchestration, while Kubernetes offers more advanced features and broader community support.

Step 2: Kubernetes Architecture

1. **Key Components of Kubernetes:**
    a. **Master Node**: Controls and manages the cluster.
        i. **API Server**: Acts as the interface for communication with the cluster.
        ii. **Controller Manager**: Ensures desired cluster states (e.g., scaling).
        iii. **Scheduler**: Allocates workloads to worker nodes.
        iv. **etcd**: Stores cluster configuration and state.
    b. **Worker Node**: Runs application containers.
        i. **Kubelet**: Agent that ensures containers are running as specified by the API server.
        ii. **Kube Proxy**: Manages networking and load balancing for services.
        iii. **Container Runtime**: Executes containers (e.g., Docker).
2. **Key Kubernetes Resources:**
    a. **Pod**: The smallest deployable unit, usually a single container or tightly coupled containers.
    b. **Service**: Provides stable networking and load balancing for Pods.
    c. **Deployment**: Manages the desired state of Pods (e.g., number of replicas).
    d. **ConfigMap**: External configuration for applications.
    e. **Secret**: Manages sensitive data like API keys and passwords.

Step 3: Kubernetes Setup

1. **Setting Up Kubernetes Locally:**
    a. Use **Minikube** or **Kind** (Kubernetes in Docker) to set up a local Kubernetes cluster for development and learning.
        i. Install **Minikube**:

bash
Copy code
curl -LO https://storage.googleapis.com/minikube/releases/latest/minikube-linux-amd64
sudo install minikube-linux-amd64 /usr/local/bin/minikube

        ii. Start Minikube:

bash
Copy code
minikube start

2. **Installing kubectl:**
    a. Kubernetes command-line tool (kubectl) is used to interact with the cluster.

bash
Copy code
curl -LO "https://dl.k8s.io/release/$(curl -L -s https://dl.k8s.io/release/stable.txt)/bin/linux/amd64/kubectl"
chmod +x kubectl
sudo mv kubectl /usr/local/bin/

3. **Cloud-Based Kubernetes Options:**

a. Popular Kubernetes services include **Google Kubernetes Engine (GKE)**, **Amazon Elastic Kubernetes Service (EKS)**, and **Azure Kubernetes Service (AKS)**.

Step 4: Deploying Docker Containers in Kubernetes

1. **Create a Deployment:**
   a. A **Deployment** ensures that the desired number of Pods is running.
   b. Example YAML file for a Deployment:

yaml
Copy code

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: nginx-deployment
spec:
  replicas: 3
  selector:
    matchLabels:
      app: nginx
  template:
    metadata:
      labels:
        app: nginx
    spec:
      containers:
      - name: nginx
        image: nginx:1.21
        ports:
```

```
    - containerPort: 80
```

c. Apply the Deployment:

bash
Copy code
```
kubectl apply -f nginx-deployment.yaml
```

2. **Expose a Service:**
    a. Services allow Pods to communicate with each other and external traffic.
    b. Example YAML for a Service:

yaml
Copy code
```
apiVersion: v1
kind: Service
metadata:
  name: nginx-service
spec:
  selector:
    app: nginx
  ports:
  - protocol: TCP
    port: 80
    targetPort: 80
  type: LoadBalancer
```

c. Apply the Service:

bash
Copy code

kubectl apply -f nginx-service.yaml

3. **Verify Deployment and Service:**

bash
Copy code
kubectl get deployments
kubectl get pods
kubectl get services

Step 5: Scaling and Updating Applications

1. **Scaling Pods:**
    a. Scale your application up or down to meet demand.

bash
Copy code
kubectl scale deployment/nginx-deployment --replicas=5

2. **Rolling Updates:**
    a. Update an application without downtime using rolling updates.
    b. Modify the Deployment to use a new image version:

yaml
Copy code
spec:
  containers:
  - name: nginx
    image: nginx:1.22

c. Apply the update:

bash
Copy code
kubectl apply -f nginx-deployment.yaml

d. Check rollout status:

bash
Copy code
kubectl rollout status deployment/nginx-deployment

Step 6: Monitoring and Debugging Kubernetes

1. **Viewing Logs:**
   a. Access logs of a specific Pod:

bash
Copy code
kubectl logs <pod-name>

2. **Debugging Pods:**
   a. Connect to a Pod for troubleshooting:

bash
Copy code
kubectl exec -it <pod-name> -- /bin/bash

3. **Monitoring Tools:**
   a. Use tools like **Prometheus** and **Grafana** for cluster and application monitoring.

b. Kubernetes also supports **kubectl top** for basic resource metrics:

bash
Copy code
kubectl top pods
kubectl top nodes

Step 7: Next Steps with Kubernetes

1. **Kubernetes Configuration Management:**
   a. Learn about **ConfigMaps**, **Secrets**, and how to mount them into Pods.
   b. Study how Kubernetes handles persistent storage with **Persistent Volumes (PVs)** and **Persistent Volume Claims (PVCs)**.
2. **Workload Types:**
   a. Explore advanced Kubernetes objects like **Jobs**, **CronJobs**, and **DaemonSets** for specialized workloads.
3. **Networking:**
   a. Study Kubernetes networking concepts like **Ingress** for routing external traffic to services.

Recap and Next Steps:

Today, you:

- Learned the basics of Kubernetes architecture and components.
- Set up a Kubernetes cluster locally or on the cloud.
- Deployed a Docker container to Kubernetes, scaled it, and updated it.

- Explored basic Kubernetes monitoring and debugging tools.

Day 25: Docker in CI/CD Pipelines

Today, we will focus on using Docker to improve **Continuous Integration (CI)** and **Continuous Deployment (CD)** pipelines. Docker plays a crucial role in modern DevOps workflows by ensuring consistency, scalability, and rapid deployment of applications.

We'll explore:

1. Setting up Docker in CI/CD pipelines.
2. Integrating Docker with popular CI/CD tools like Jenkins, GitHub Actions, and GitLab CI.
3. Building and deploying Docker images as part of the pipeline.

Step 1: Role of Docker in CI/CD

1. **Why Use Docker in CI/CD?**
    a. Docker containers ensure consistency across development, testing, and production environments.
    b. Building and testing applications in Docker containers allows for isolated and repeatable workflows.
    c. Docker images provide a lightweight way to package applications with all dependencies.
2. **Key Benefits:**
    a. Environment parity between developers and CI/CD systems.
    b. Faster builds and deployments by caching layers in Docker images.
    c. Easier rollback to previous versions using versioned images.

Step 2: Setting Up Docker in a CI/CD Pipeline

1. **CI/CD Workflow with Docker:**
    a. **Build Stage**: Build the application into a Docker image.
    b. **Test Stage**: Run unit tests and integration tests in a containerized environment.
    c. **Deploy Stage**: Push the Docker image to a container registry and deploy to production.
2. **Required Components:**
    a. **Source Code Repository**: GitHub, GitLab, or Bitbucket.
    b. **CI/CD Tool**: Jenkins, GitHub Actions, or GitLab CI.
    c. **Docker Registry**: Docker Hub, AWS Elastic Container Registry (ECR), or Google Container Registry (GCR).

Step 3: Docker in Jenkins Pipeline

1. **Jenkinsfile Example:**
    a. A simple Jenkins pipeline to build, test, and deploy a Docker image.

groovy
Copy code

```
pipeline {
    agent {
        docker {
            image 'docker:20.10'
        }
    }
    environment {
        DOCKER_IMAGE = 'myapp:latest'
        REGISTRY_URL = 'docker.io/myrepo'
    }
```

```
    stages {
        stage('Checkout Code') {
            steps {
                checkout scm
            }
        }
        stage('Build Image') {
            steps {
                script {
                    sh "docker build -t $DOCKER_IMAGE ."
                }
            }
        }
        stage('Test Image') {
            steps {
                script {
                    sh "docker run --rm $DOCKER_IMAGE pytest tests/"
                }
            }
        }
        stage('Push Image') {
            steps {
                withDockerRegistry([credentialsId: 'docker-credentials', url:
"]) {
                    sh "docker tag $DOCKER_IMAGE
$REGISTRY_URL/$DOCKER_IMAGE"
                    sh "docker push $REGISTRY_URL/$DOCKER_IMAGE"
                }
            }
        }
    }
```

}

2. **Steps in the Pipeline:**
    a. **Checkout Code**: Pull the code from the Git repository.
    b. **Build Image**: Build a Docker image using the Dockerfile.
    c. **Test Image**: Run unit tests inside a container using the newly built image.
    d. **Push Image**: Push the Docker image to a container registry.

Step 4: Docker in GitHub Actions

1. **GitHub Actions Workflow File:**
    a. A simple workflow to build and push a Docker image:

yaml
Copy code

```
name: CI/CD Pipeline

on:
  push:
    branches:
      - main

jobs:
  build:
    runs-on: ubuntu-latest
    steps:
      - name: Checkout code
        uses: actions/checkout@v3

      - name: Log in to Docker Hub
        uses: docker/login-action@v2
```

```
      with:
        username: ${{ secrets.DOCKER_USERNAME }}
        password: ${{ secrets.DOCKER_PASSWORD }}

    - name: Build and tag Docker image
      run: |
        docker build -t myrepo/myapp:latest .

    - name: Push Docker image
      run: |
        docker push myrepo/myapp:latest
```

2. **Workflow Breakdown:**
    a. Triggered on a push to the main branch.
    b. Logs into Docker Hub using credentials stored as GitHub secrets.
    c. Builds and pushes the Docker image.

Step 5: Docker in GitLab CI

1. **GitLab CI/CD Pipeline:**
    a. Example .gitlab-ci.yml file:

yaml
Copy code

```
stages:
  - build
  - test
  - deploy

variables:
  IMAGE_TAG: latest
```

```
  REGISTRY: registry.gitlab.com
  PROJECT_PATH: mynamespace/myproject

build:
  stage: build
  script:
    - docker build -t $REGISTRY/$PROJECT_PATH:$IMAGE_TAG .
    - docker login -u $CI_REGISTRY_USER -p
$CI_REGISTRY_PASSWORD $REGISTRY
    - docker push $REGISTRY/$PROJECT_PATH:$IMAGE_TAG

test:
  stage: test
  script:
    - docker run --rm $REGISTRY/$PROJECT_PATH:$IMAGE_TAG
pytest tests/

deploy:
  stage: deploy
  script:
    - echo "Deploying $REGISTRY/$PROJECT_PATH:$IMAGE_TAG"
```

2. **Workflow:**
    a. Builds the Docker image, logs in to the GitLab Container Registry, and pushes the image.
    b. Runs tests using the container.
    c. Deploys the application (custom deployment script needed).

Step 6: Best Practices for Docker in CI/CD

1. **Use Multi-Stage Builds:**

    a. Reduce the size of Docker images by separating build and runtime stages.
2. **Cache Dependencies:**
    a. Cache dependencies to speed up subsequent builds.
    b. Use Docker layer caching effectively by organizing the Dockerfile with static layers first.
3. **Secure Your Pipelines:**
    a. Store sensitive data (e.g., Docker credentials) securely using tools like Jenkins credentials, GitHub secrets, or GitLab CI variables.
4. **Tag Images Properly:**
    a. Use semantic versioning or include commit hashes to create unique image tags.

bash
Copy code
docker build -t myrepo/myapp:1.0.0 -t myrepo/myapp:latest .

5. **Test in Isolated Environments:**
    a. Run unit and integration tests in isolated containers to avoid interference.

Recap and Next Steps

Today, you learned:

- How Docker integrates with CI/CD pipelines to streamline application builds, testing, and deployments.
- How to set up Docker in Jenkins, GitHub Actions, and GitLab CI.
- Best practices for using Docker in CI/CD workflows.

Day 26: Docker in Production Environments

Today's focus is on deploying and managing Docker containers in production. We'll cover key practices, deployment strategies, optimization techniques, and monitoring tools to ensure your applications run efficiently and reliably.

Step 1: Key Considerations for Docker in Production

1. **Why Use Docker in Production?**
    a. Simplified deployments.
    b. Consistent environments across development, staging, and production.
    c. Efficient resource utilization and scaling.
2. **Challenges in Production:**
    a. Orchestrating multiple containers.
    b. Monitoring container health and performance.
    c. Ensuring container security.

Step 2: Docker Deployment Strategies

1. **Standalone Docker Deployment:**
    a. Suitable for small-scale applications.
    b. Use Docker Compose for multi-container setups.

bash
Copy code
docker-compose -f docker-compose.prod.yml up -d

2. **Container Orchestration:**
    a. For large-scale deployments, use orchestration tools like:

i. **Kubernetes**: Preferred for enterprise-grade deployments.
ii. **Docker Swarm**: Lightweight alternative for simpler setups.
iii. **AWS ECS (Elastic Container Service)**: Cloud-managed container service.

3. **Blue-Green Deployment:**
    a. Deploy a new version alongside the existing version and switch traffic once verified.
4. **Canary Deployment:**
    a. Gradually route a small percentage of traffic to the new version before full rollout.

Step 3: Optimizing Docker Containers for Production

1. **Minimize Image Size:**
    a. Use lightweight base images (e.g., alpine).
    b. Remove unnecessary dependencies in the Dockerfile.

dockerfile
Copy code
FROM python:3.9-alpine
RUN apk add --no-cache gcc musl-dev

2. **Use Multi-Stage Builds:**
    a. Separate build and runtime stages to reduce the final image size.

dockerfile
Copy code
Build stage
FROM node:16 AS builder

```
WORKDIR /app
COPY package.json .
RUN npm install
COPY . .
RUN npm run build

# Runtime stage
FROM nginx:alpine
COPY --from=builder /app/build /usr/share/nginx/html
```

3. **Set Resource Limits:**
    a. Prevent resource contention by defining CPU and memory limits.

bash
Copy code
```
docker run --memory="512m" --cpus="1" myapp
```

4. **Enable Logging:**
    a. Configure Docker to forward logs to centralized systems like **ELK Stack** or **CloudWatch**.

bash
Copy code
```
docker run --log-driver=json-file myapp
```

Step 4: Securing Docker in Production

1. **Best Practices:**
    a. Use non-root users in your containers:

dockerfile

Copy code
RUN adduser -D myuser
USER myuser

b. Regularly scan images for vulnerabilities using tools like:
    i. **Docker Scout**
    ii. **Trivy**
c. Limit container privileges:

bash
Copy code
docker run --cap-drop=ALL myapp

2. **Sign and Verify Images:**
    a. Use Docker Content Trust (DCT) to ensure image integrity:

bash
Copy code
export DOCKER_CONTENT_TRUST=1

3. **Secrets Management:**
    a. Avoid hardcoding secrets in images or environment variables.
    b. Use tools like **AWS Secrets Manager**, **HashiCorp Vault**, or **Kubernetes Secrets**.

Step 5: Monitoring and Logging in Production

1. **Container Health Monitoring:**
    a. Use health checks in your Dockerfile:

dockerfile
Copy code

HEALTHCHECK CMD curl -f http://localhost:8080/health || exit 1

2. **Monitoring Tools:**
    a. **Prometheus**: Metrics collection.
    b. **Grafana**: Visualization dashboards.
    c. **Datadog**: Comprehensive monitoring for infrastructure and containers.
3. **Centralized Logging:**
    a. Forward container logs to tools like **Fluentd**, **Logstash**, or cloud-native solutions like AWS CloudWatch.

Step 6: Deploying Docker with Orchestration Tools

1. **Deploying with Kubernetes:**
    a. Use Kubernetes for managing multiple containers across a cluster.
        i. Define **Deployments** for scaling.
        ii. Use **Services** for networking and load balancing.
    b. Example Deployment:

yaml
Copy code

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: app-deployment
spec:
  replicas: 3
  selector:
    matchLabels:
      app: myapp
```

```
  template:
    metadata:
      labels:
        app: myapp
    spec:
      containers:
      - name: app
        image: myrepo/myapp:latest
        ports:
        - containerPort: 80
        resources:
          requests:
            memory: "256Mi"
            cpu: "0.5"
          limits:
            memory: "512Mi"
            cpu: "1"
```

2. **Scaling with Kubernetes:**
    a. Horizontal Pod Autoscaling:

```
yaml
Copy code
apiVersion: autoscaling/v1
kind: HorizontalPodAutoscaler
metadata:
  name: app-autoscaler
spec:
  scaleTargetRef:
    apiVersion: apps/v1
    kind: Deployment
    name: app-deployment
```

```
  minReplicas: 2
  maxReplicas: 10
  targetCPUUtilizationPercentage: 80
```

Step 7: Docker Deployment in the Cloud

1. **AWS ECS:**
    a. Use Elastic Container Service to manage containers on AWS.
    b. Example ECS Task Definition:

```
json
Copy code
{
  "containerDefinitions": [
    {
      "name": "myapp",
      "image": "myrepo/myapp:latest",
      "memory": 512,
      "cpu": 256,
      "essential": true
    }
  ]
}
```

2. **Azure Container Instances:**
    a. Deploy standalone containers on Azure for simplicity.
3. **Google Kubernetes Engine (GKE):**
    a. Fully managed Kubernetes solution from Google Cloud.

Recap and Next Steps

Today, you:

- Learned about Docker deployment strategies in production.
- Explored ways to optimize containers for performance and security.
- Understood how to monitor and log containers effectively.
- Deployed containers using orchestration tools and cloud platforms

Day 27: Advanced Docker Networking

In this session, we'll delve deeper into Docker networking, covering topics like overlay networks, service discovery, securing container communication, and managing complex multi-container deployments.

Step 1: Docker Networking Basics (Recap)

1. **Network Types:**
    a. **Bridge Network**: Default network for containers on a single host.
        i. Containers can communicate using IPs or assigned names.
    b. **Host Network**: Shares the host's network namespace. No network isolation.
    c. **None Network**: No networking; used for isolated containers.
2. **Inspecting Networks:**

bash
Copy code

docker network ls
docker network inspect <network_name>

Step 2: Custom Bridge Networks

1. **Why Use Custom Bridge Networks?**
    a. Enables automatic DNS-based communication between containers.
    b. Provides better control over container networking.
2. **Creating and Using a Custom Network:**

bash
Copy code
docker network create my_bridge_network
docker run --network my_bridge_network --name app1 -d nginx
docker run --network my_bridge_network --name app2 alpine ping app1

Step 3: Overlay Networks (Multi-Host Networking)

1. **What Are Overlay Networks?**
    a. Allow containers across different Docker hosts to communicate securely.
    b. Used in **Docker Swarm** and other orchestrators.
2. **Setting Up an Overlay Network:**
    a. Initialize Docker Swarm:

bash
Copy code
docker swarm init

b. Create an overlay network:

bash
Copy code
```
docker network create -d overlay my_overlay_network
```

c. Deploy containers to the overlay network:

bash
Copy code
```
docker service create --name my_app --network my_overlay_network nginx
```

3. **Benefits:**
    a. Built-in encryption for communication between nodes.
    b. Simplified networking for distributed systems.

Step 4: Service Discovery and Load Balancing

1. **Built-In DNS Service:**
    a. Docker provides DNS-based service discovery for containers in the same network.
    b. Containers can resolve each other using container names.
2. **Load Balancing in Docker Swarm:**
    a. Docker Swarm provides automatic load balancing for services.
    b. Example:

bash
Copy code
```
docker service create --replicas 3 --name web --publish 8080:80 nginx
```

3. **Third-Party Tools:**

a. **Traefik** and **HAProxy** for advanced service discovery and load balancing.

Step 5: Securing Docker Networks

1. **Encrypting Overlay Networks:**
    a. Overlay networks in Swarm mode are encrypted by default.
    b. To manually enforce encryption:

bash
Copy code
```
docker network create \
  --opt encrypted \
  --driver overlay \
  secure_overlay_network
```

2. **Restricting Inter-Container Communication:**
    a. Use **network policies** to isolate containers.
    b. Example:

bash
Copy code
```
docker network create \
  --internal \
  isolated_network
```

3. **Using Firewalls and Security Groups:**
    a. Define rules to allow only necessary communication between hosts.

Step 6: Multi-Container Networking with Docker Compose

1. **Docker Compose Networking:**
    a. Services in the same docker-compose.yml file automatically communicate using a shared network.
2. **Example Compose File with Networking:**

yaml
Copy code

```
version: '3.8'
services:
  app:
    image: my_app
    networks:
      - frontend
      - backend
  db:
    image: postgres
    networks:
      - backend
networks:
  frontend:
  backend:
```

3. **Testing Connectivity:**
    a. From app container, you can ping db using its service name.

Step 7: Debugging and Monitoring Docker Networks

1. **Inspect Network Traffic:**
    a. Use tcpdump inside containers:

bash
Copy code
docker exec -it <container_id> tcpdump

2. **Network Performance Monitoring Tools:**
    a. **Wireshark**: For packet analysis.
    b. **cAdvisor**: Monitors container resource usage, including networking.
3. **Network Troubleshooting:**
    a. Check container logs for errors:

bash
Copy code
docker logs <container_name>

    b. Test connectivity between containers:

bash
Copy code
docker exec <container_name> ping <target_container_name>

Step 8: Advanced Networking with Kubernetes

1. **Kubernetes Pod Networking:**
    a. Pods in Kubernetes communicate using a flat network model.
    b. CNI (Container Network Interface) plugins like **Calico** or **Weave** manage networking.
2. **Service Networking:**
    a. Expose services with **ClusterIP**, **NodePort**, or **LoadBalancer** types.
    b. Example Service:

yaml
Copy code

```
apiVersion: v1
kind: Service
metadata:
  name: my-service
spec:
  selector:
    app: my-app
  ports:
  - protocol: TCP
    port: 80
    targetPort: 8080
```

Recap and Next Steps

Today, you learned about:

- Docker's networking capabilities: bridge, host, none, and overlay networks.
- Service discovery and load balancing in Docker.
- Securing Docker networks and debugging connectivity issues.

Day 28: Scaling and Managing Docker Swarm Clusters

Docker Swarm is a native clustering and orchestration tool that enables you to manage a group of Docker hosts as a single virtual system. Today, you'll learn how to set up, scale, and manage a Swarm cluster, handle node failures, and deploy services.

Step 1: Setting Up a Docker Swarm Cluster

1. **Initialize Swarm Mode:**
    a. Run the following command on the manager node to initialize the Swarm:

bash
Copy code
docker swarm init

    b. Note the join token for worker nodes, which will look like this:

bash
Copy code
docker swarm join-token worker

2. **Join Worker Nodes:**
    a. On each worker node, run the provided command:

bash
Copy code
docker swarm join --token <worker_token> <manager_ip>:2377

3. **List Nodes in the Cluster:**
    a. Check the status of all nodes in the Swarm:

bash
Copy code
docker node ls

Step 2: Deploying Services in Swarm

1. **Deploy a Service:**
    a. Deploy a simple service with replicas:

bash
Copy code
```
docker service create --name web --replicas 3 -p 8080:80 nginx
```

2. **Inspect the Service:**
    a. Check the status of the service:

bash
Copy code
```
docker service ps web
```

3. **Scaling the Service:**
    a. Adjust the number of replicas:

bash
Copy code
```
docker service scale web=5
```

4. **Remove a Service:**
    a. To stop and remove the service:

bash
Copy code
```
docker service rm web
```

Step 3: Handling Node Failures

1. **Simulate a Node Failure:**

a. Stop the Docker daemon on a worker node to simulate a failure:

bash
Copy code
sudo systemctl stop docker

2. **Automatic Rescheduling:**
    a. Swarm will reschedule tasks from the failed node to healthy nodes automatically.
3. **Remove an Unavailable Node:**
    a. Forcefully remove an offline node from the cluster:

bash
Copy code
docker node rm --force <node_id>

4. **Promoting and Demoting Nodes:**
    a. Promote a worker node to a manager:

bash
Copy code
docker node promote <node_id>

b. Demote a manager to a worker:

bash
Copy code
docker node demote <node_id>

Step 4: Rolling Updates and Rollbacks

1. **Perform a Rolling Update:**

a. Update a service to a new image version:

bash
Copy code
```
docker service update --image nginx:1.23 web
```

2. **Monitor the Update:**
    a. Check the update progress:

bash
Copy code
```
docker service ps web
```

3. **Rollback to Previous Version:**
    a. If the update fails, rollback the service:

bash
Copy code
```
docker service rollback web
```

Step 5: Configurations and Secrets in Swarm

1. **Store Secrets:**
    a. Create a secret:

bash
Copy code
```
echo "my_secret_password" | docker secret create db_password -
```

b. Use the secret in a service:

bash
Copy code

```
docker service create --name db \
  --secret db_password \
  mysql:5.7
```

2. **Manage Configurations:**
    a. Create a configuration file:

bash
Copy code
```
echo "server { listen 80; }" | docker config create nginx_conf -
```

    b. Use the configuration in a service:

bash
Copy code
```
docker service create --name web \
  --config nginx_conf \
  nginx
```

Step 6: Monitoring and Logging Swarm Clusters

1. **Inspect Swarm Health:**
    a. Check the status of all nodes:

bash
Copy code
```
docker node ls
```

2. **Centralized Logging:**
    a. Forward logs from all nodes to a centralized system like ELK Stack or Fluentd.
    b. View service logs:

bash
Copy code
docker service logs web

3. **Monitor Resource Usage:**
    a. Use tools like **Docker Dashboard**, **Prometheus**, or **Datadog** to monitor node and service performance.

Step 7: Best Practices for Docker Swarm

1. **Design for Fault Tolerance:**
    a. Distribute manager and worker nodes across availability zones.
    b. Use an odd number of manager nodes (e.g., 3, 5) to ensure quorum.
2. **Secure the Swarm:**
    a. Enable mutual TLS encryption between nodes (default in Swarm mode).
    b. Rotate join tokens periodically:

bash
Copy code
docker swarm join-token --rotate worker

3. **Use Constraints and Affinities:**
    a. Assign tasks to specific nodes based on labels:

bash
Copy code
docker service create --constraint 'node.labels.type == web' nginx

4. **Load Balancing:**
    a. Swarm automatically balances traffic among replicas, but consider using external load balancers (e.g., Traefik or HAProxy) for advanced routing.

Recap and Next Steps

Today, you:

- Learned how to set up and scale Docker Swarm clusters.
- Explored deploying, updating, and managing services.
- Understood how Swarm handles node failures and fault tolerance.
- Discovered best practices for running Swarm in production.

Day 29: Transitioning from Docker Swarm to Kubernetes

Today's focus is on understanding Kubernetes and its differences from Docker Swarm. You'll learn how to transition workloads, Kubernetes architecture, and basic application deployment.

Step 1: Kubernetes vs. Docker Swarm

1. **Key Differences:**
    a. **Complexity**: Kubernetes is more complex but offers advanced features like autoscaling, self-healing, and custom resource definitions.
    b. **Declarative Configuration**: Kubernetes uses declarative YAML manifests, while Swarm focuses on CLI commands.
    c. **Extensibility**: Kubernetes integrates with tools like Helm, custom controllers, and external storage providers.

d. **Orchestration**: Kubernetes supports advanced orchestration features like rolling updates, blue-green deployments, and canary releases.

2. **When to Use Kubernetes:**
    a. Large-scale applications.
    b. Advanced orchestration needs.
    c. Multi-cloud or hybrid environments.

Step 2: Kubernetes Architecture Overview

1. **Control Plane Components:**
    a. **API Server**: Frontend for the Kubernetes API.
    b. **Controller Manager**: Manages controllers that regulate cluster states.
    c. **Scheduler**: Assigns pods to nodes based on resource availability.
    d. **etcd**: Stores cluster state data.
2. **Node Components:**
    a. **Kubelet**: Manages containers on individual nodes.
    b. **Kube-proxy**: Handles networking for service communication.
    c. **Container Runtime**: Runs containers (e.g., Docker, containerd).
3. **Key Kubernetes Objects:**
    a. **Pod**: Smallest deployable unit, contains one or more containers.
    b. **Deployment**: Manages pod replicas and updates.
    c. **Service**: Exposes pods internally or externally.
    d. **ConfigMap** and **Secret**: Manage configuration and sensitive data.

Step 3: Installing Kubernetes

1. **Minikube (Single Node Cluster):**
    a. Install and start Minikube:

bash
Copy code
minikube start
kubectl get nodes

2. **Kubernetes via Cloud Providers:**
    a. Use managed services like **AWS EKS**, **Azure AKS**, or **Google GKE** for production.

Step 4: Transitioning Workloads to Kubernetes

1. **Converting Docker Compose to Kubernetes Manifests:**
    a. Use **kompose** to convert docker-compose.yml:

bash
Copy code
kompose convert

2. **Example Docker Compose File:**

yaml
Copy code
version: '3.8'
services:
  web:
    image: nginx
    ports:

```
    - "8080:80"
```

3. **Converted Kubernetes Manifest:**

```
yaml
Copy code
apiVersion: apps/v1
kind: Deployment
metadata:
  name: web
spec:
  replicas: 3
  selector:
    matchLabels:
      app: web
  template:
    metadata:
      labels:
        app: web
    spec:
      containers:
      - name: web
        image: nginx
        ports:
        - containerPort: 80
---
apiVersion: v1
kind: Service
metadata:
  name: web
spec:
```

```
  selector:
    app: web
  ports:
  - protocol: TCP
    port: 80
    targetPort: 80
  type: NodePort
```

4. **Deploy to Kubernetes:**

```
bash
Copy code
kubectl apply -f web-deployment.yaml
kubectl get pods
```

Step 5: Scaling and Rolling Updates

1. **Scale Pods:**
    a. Adjust replicas in the Deployment:

```
bash
Copy code
kubectl scale deployment web --replicas=5
```

2. **Rolling Update:**
    a. Update the image version:

```
bash
Copy code
kubectl set image deployment/web web=nginx:1.23
```

3. **Rollback:**
    a. If the update fails, rollback to the previous state:

bash
Copy code
kubectl rollout undo deployment/web

Step 6: Kubernetes Networking

1. **Expose a Service:**
    a. Create a service to expose the deployment:

bash
Copy code
kubectl expose deployment web --type=LoadBalancer --name=web-service

2. **Ingress Controller:**
    a. Use an Ingress Controller (e.g., Traefik or NGINX) for advanced routing.

Step 7: Kubernetes Configuration and Secrets

1. **Create a ConfigMap:**

bash
Copy code
kubectl create configmap app-config --from-literal=APP_ENV=production

2. **Create a Secret:**

bash
Copy code
kubectl create secret generic db-secret --from-literal=DB_PASSWORD=supersecret

3. **Use ConfigMap and Secret in Deployment:**

yaml
Copy code
```
spec:
  containers:
  - name: app
    image: myapp
    envFrom:
    - configMapRef:
        name: app-config
    - secretRef:
        name: db-secret
```

Recap and Next Steps

Today, you:

- Explored Kubernetes architecture and its differences from Docker Swarm.
- Learned how to transition workloads using tools like **kompose**.
- Deployed and managed applications using Kubernetes.