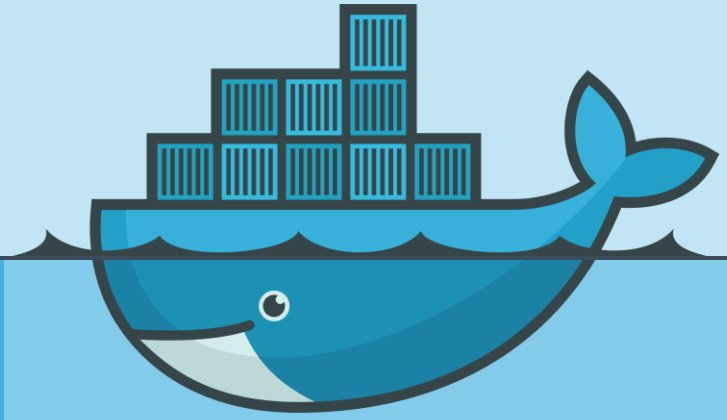

docker



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Introduction To Containerization

Introduction To Containerization

- **What is Containerization?**
  - **Containerization is a lightweight form of virtualization that packages your application and all its dependencies into a single unit called a container, so it can run reliably in different computing environments.**
  - **Imagine sending a package. A container ensures everything the app needs (like libraries, binaries, runtime) is inside the box. No matter where it gets shipped (Windows, Linux, AWS, a laptop), it will work the same.**

Introduction To Containerization

- **Key Characteristics:**
  - **Everything needed to run the app is bundled together**
  - **Containers share the host OS kernel, unlike VMs**
  - **Fast startup, minimal overhead**

Containers VS Virtual Machines

Feature	Containers	Virtual Machines (VMs)
Virtualization	OS-level	Hardware-level (Hypervisor)
Startup Time	Seconds (fast)	Minutes (slow)
Size	Lightweight (MBs)	Heavy (GBs)
Isolation	Process-level isolation	Full OS isolation
Resource Usage	Efficient (shares OS kernel)	Inefficient (each VM has full OS)
Portability	Highly portable (Docker image)	Limited portability

Benefits Of Containerization

- **Lightweight:**
  - **No need to ship full OS**
  - **Just your app and its dependencies**
  - **Typically 10–100x smaller than VMs**
- **Fast Startup:**
  - **Containers start in seconds**
  - **Ideal for microservices and CI/CD pipelines**

Benefits Of Containerization

- **Isolated:**
  - **Each container runs in its own environment**
  - **Reduces risk of conflicts (e.g., library version mismatch)**
- **Reproducible & Consistent:**
  - **"Works on my machine" problem is solved**
  - **Runs the same in dev, test, staging, and production**

Benefits Of Containerization

- **Portable:**
  - **Can be run anywhere Docker is installed (local machine, cloud, CI/CD servers)**
- **Efficient Resource Usage:**
  - **Shares OS kernel, less RAM & CPU required compared to VMs**
- **Simplifies deployment**
- **Easy rollback (just switch to previous container image)**

Introduction To docker

Introduction To Docker

- What is Docker?
  - Docker is an open-source containerization platform that enables you to build, ship, and run applications inside containers.
  - It's the industry standard for containerization today and works on any machine with Docker installed, from your laptop to cloud servers.

Docker as a Containerization Platform

- Docker provides:
  - Tools to create containers (e.g. docker build, docker run)
  - Standards for packaging apps (via Dockerfiles and images)
  - A registry (Docker Hub) to share images
  - A runtime engine that runs containers on any OS
  - With Docker, your entire development and deployment process becomes portable, consistent, and automated.

Docker Engine

- Docker is made of two main components:

1. Docker Client (docker command)

    - What you interact with on the terminal.
    - Sends requests to the Docker daemon.

2. Docker Daemon (dockerd)

    - Background service that actually:
    - Builds images
    - Runs containers
    - Manages networking, volumes, etc.
    - Listens on a Unix socket or REST API

Docker Hub

- Docker Hub is a public cloud-based registry where developers store and share container images.
- It’s like GitHub but for Docker images.
- Features:

1. Pull official images like node, mongo, nginx
2. Publish your own images (free & private options)
3. Versioning via image tags (e.g., node:18-alpine)

Docker Summary

Concept	Description
Docker	A platform to create, run, and manage containers
Docker Engine	The runtime that builds/runs containers
Docker Client	CLI tool you interact with (docker run)
Docker Daemon	Background service that does the work
Docker Hub	Online image registry (like GitHub for containers)

Docker Images

- What Is a Docker Image?
  - A Docker Image is a read-only, layered template used to create Docker containers. It includes:
    - Your application code
    - All of its dependencies
    - System libraries
    - Configuration files
    - Environment setup
    - Instructions on how to start your application
  - It's like a snapshot of a fully configured machine environment, except it's much smaller and only includes exactly what’s needed.

Docker Images

- How to create Docker Images:
- You build images using a Dockerfile, which is a list of step-by-step instructions (e.g. install packages, copy files).
- Each command in the Dockerfile creates a new layer. These layers are cached for performance and re-used when possible.

Create your .dockerfile

```
FROM node:22
WORKDIR /app
COPY package.json .
RUN npm install
COPY . .
CMD ["node", "index.js"]

```

Then build your image

```
docker build -t my-node-app .
```

Docker Images

- Immutable: Once built, an image never changes. If you need changes, you rebuild it.

- Layered (Union File System):
  - Each instruction = new layer.
  - Layers are cached = fast rebuilds.

- Only final image is used when running.

- Portable:
  - Images can be pushed/pulled to/from Docker Hub or other registries.

- Tagged:
  - Images are versioned via tags, e.g., my-api:1.0

Docker Containers

- **Useful Images Terminal Commands:**

```
docker pull node:20-alpine      # Pull the Node.js Docker image
docker images                   # List all Docker images
docker rmi node:20-alpine       # Remove the Node.js Docker image
docker rmi -f node:20-alpine    # Force remove the Node.js Docker image
docker image prune -a           # Remove all unused Docker images
```

Docker Containers

- What Is a Docker Container?
  - A Docker Container is a live, running instance of a Docker image. It’s what actually executes your app.
  - When you run a docker image, Docker takes the image my-app, starts it, and runs it inside a container.
  - This container:
    - Has its own isolated filesystem
    - Shares the host OS kernel (but not filesystem or environment)
    - Runs as a lightweight process
    - Can be stopped, restarted, deleted, or duplicated

Docker Containers

- **Container Behavior:**
  - **Ephemeral by default: if you don’t use volumes, data is lost when the container stops.**
  - **Isolated: Containers can’t see each other unless you connect them via Docker networks.**
  - **Restartable: You can pause, stop, and start containers at will.**

Docker Containers

- **Useful Container Terminal Commands:**

```
docker run -p 3000:3000 my-app   # Start container
docker ps                        # List running containers
docker stop <container_id>       # Stop a running container
docker start <container_id>      # Start a stopped one
docker exec -it <id> bash        # Enter the running container
docker rm <container_id>         # Delete the container
```

Docker Containers

- **Container Lifecycle:**

  - **Created: Container is defined but not running.**
  - **Running: Your app is live.**
  - **Paused: Execution is temporarily frozen.**
  - **Stopped: Container is off but still exists.**
  - **Removed: Deleted permanently.**

Docker Containers

- **Inside a Container:**

  - **Once running, a container:**

    1. **Has its own file system (copied from the image layers)**
    2. **Has isolated processes (doesn’t see host’s processes)**
    3. **Has its own IP address in a Docker network**
    4. **May mount host volumes for persistent or shared data**

Docker Containers VS Images

- **Key Differences in Summary:**

  - **A Docker image is the template: the code, the dependencies, the config, etc.**
  - **A Docker container is the live thing: it's what actually runs your app, using the image as its foundation.**
  - **You can run many containers from the same image.**
  - **If an image is like a class, the containers are like the objects (instances) created from that class.**

Port Mapping and Exposing

Port Exposing

- **EXPOSE in Dockerfile:**

  - **Declares which port(s) the container intends to use.**
  - **It’s informational only: it does not actually publish the port to the host.**
  - **Used for documentation and by tools like Docker Compose.**
  - **This tells Docker: “My app listens on port 3000”, But you still need to map it when running the container.**

Port Mapping

- -p in docker run:
  - This is what actually makes the port available from host to container. It maps a port on your machine to a port in the container.
  - Syntax:

```
1  docker run -d -p 3000:3000 --name node-app-container my-node-app
```

    - Maps host port 8080 to container port 3000, If your Node app is listening on 3000, you can now open http://localhost:8080 on your browser.

Working With Volumes

Docker Volumes

- What Are Docker Volumes?

  - Docker volumes are persistent storage mechanisms managed by Docker that exist outside of the container’s writable layer.
  - They allow data to persist even after a container is removed.
  - Unlike the container’s file system, volumes are not deleted when the container is deleted (unless explicitly told to).

Docker Volumes

- **Why use Docker Volumes?**

  - **Containers are ephemeral, when a container dies or is deleted, everything inside it is lost, including any data generated or stored inside. Volumes solve this by decoupling data from the container's lifecycle.**

Docker Volumes

- There are mainly two types of docker volumes, Anonymous and Named
  1. Anonymous Volumes
     - Docker creates these automatically if you use -v without specifying a name:

```
1  docker run -v /app/data my-image
```

     - Stored with a random hash-like name.
     - Hard to manage because you don’t know the volume’s name.
     - Use Case: Temporary data storage without managing the volume manually.

Docker Volumes

2. **Named Volumes**
   - **You explicitly provide a name:**

```
1  docker run -v mydata:/app/data my-image
```

   - **Easier to manage and reuse.**
   - **Can be shared across containers.**
   - **Use Case: Database files, uploads, persistent configs.**

Docker Volumes

- **Mounting Volumes into Containers**
  - **Docker supports two main ways to mount volumes into containers:**
    1. **With -v flag**

```
1  docker run -v myvolume:/app/data my-image
```

    2. **With --mount flag**

```
1  docker run \
2    --mount type=volume,source=myvolume,target=/app/data \
3    my-image
```

Docker Volumes

- **Use Cases of Docker Volumes**
  1. **Persisting database data:**
     - **If you run a database like PostgreSQL, MySQL, or MongoDB inside a container, you'll lose all your data when the container dies, unless you use a volume.**

```
1  docker run -v pgdata:/var/lib/postgresql/data postgres
```

•This ensures:

1.Your data survives container restarts
2.You can upgrade the container image without losing data

Docker Volumes

- Use Cases of Docker Volumes
    2. Code hot-reloading in development
        - If you're developing a Node.js app, you'd want changes in your code on the host machine to reflect inside the container instantly.

```
1  docker run -v $(pwd):/app -w /app node:20-alpine npm run dev
```

        - $(pwd):/app mounts your current working directory into the container.
        - Changes you make to source code on your host immediately show inside the container.
        - Combine this with nodemon for real-time dev experience.

Docker Volumes

- Use Cases of Docker Volumes

    3. Persisting logs, uploads, and configs

```
1  docker run -v logs:/var/log/myapp my-logging-app
```

    - This allows logs to persist outside of the container and be accessed, shipped, or analyzed even after the container is destroyed.

Docker Volumes

- We can manage attaching docker volumes automatically using a docker compose file:

```yaml
services:
  app:
    image: my-node-app
    volumes:
      - myvolume:/app/data

volumes:
  myvolume:
```

- This creates and manages the volume automatically.

Docker Compose

Docker Compose

- What is docker compose?

  - Docker Compose is a tool used to define and run multi-container Docker applications, using a single YAML file called docker-compose.yml.

  - Instead of typing many long docker run commands manually for each container, you define all services, volumes, ports, etc., in a readable file and run everything together.

Docker Compose

- **Example of Docker compose:**

```yaml
services:
  backend:
    build: .                                    # Uses Dockerfile in the current directory
    ports:
      - "3000:3000"                             # Maps localhost:3000 → container:3000
    volumes:
      - .:/app                                  # Mount source code into container
      - ./docker-uploads:/app/docker-uploads    # Persist uploaded files
    restart: unless-stopped

    ## docker-compose up to start the service
    ## docker-compose down to stop the service and remove containers
    ## docker-compose logs to view logs
```

Docker Compose

Term	Description
services	Define your containers (e.g., app, db)
ports	Maps container port to host (3000:3000)
volumes	Mounts local directories into container
networks	Optional: connect services together securely

Docker Compose

- **Why Use Docker Compose?**

  - **Simplicity: One command to start everything**
  - **Reproducibility: Same config across teams/devices**
  - **Isolation: Each service runs in its own container**
  - **Scalability: Easily add new services or scale them**

Docker Networking

Docker Networking

- Docker uses networking to allow containers to:
  - Communicate with each other
  - Talk to the outside world (e.g., your browser)
- Docker provides built-in drivers for different use cases
  - Types:
    - bridge
    - host
    - none
    - overlay (for Swarm)
    - macvlan (for advanced cases)

Docker Networking

- **Bridge Network (Default)**
  - **Docker's default network type for containers**
  - **Each container gets a private IP address**
  - **A virtual switch connects containers to each other**
  - **Containers can talk to each other if on the same bridge**

```
1  docker run -d --name app1 --network my-bridge node
2  docker run -d --name app2 --network my-bridge mongo
```

Docker Networking

- **Host Network:**
  - **Shares the host's network namespace**
  - **The container uses the host machine's IP and ports**
  - **No port mapping (-p) is needed**

```
1  docker run --network host nginx
```

- **Low latency**
- **Useful for performance-critical services**
- **No network isolation**
- **Port conflicts possible**

Docker Networking

- **None Network:**
  - **Disables networking completely for the container**

```
docker run --network none alpine
```

  - **Use cases:**
    - **Total isolation (security/sandboxing)**
    - **Testing behavior without any network access**

Docker Networking

- **Creating Custom Networks:**
  - **Custom networks allow:**
    - **Service name-based container communication (via DNS)**
    - **Improved isolation and control**

```
1  docker network create my-network
2  docker run -d --name app --network my-network node
3  docker run -d --name db --network my-network mongo
```

Docker Networking

- **Best Practices**

  - **Use bridge or custom networks for app-to-app communication**
  - **Use host only for performance-critical apps (and avoid in Compose)**
  - **Use none for isolated, no-network scenarios**
  - **Use custom bridge networks to enable clean DNS-based container naming**

Managing Environment Variables

Environment Variables In Docker

Ways to Set Environment Variables in Docker

Method	Context	When It Applies
ENV in Dockerfile	Build & Run	Sets default env vars inside image
--env or environment in Compose	Runtime only	Overrides Dockerfile, more flexible
.env file	Compose only	Used to inject vars into docker-compose.yml

Environment Variables In Docker

- **Env in Dockerfile:**

```
1  ENV PORT=3000
2  ENV UPLOAD_DIR=docker-uploads
```

- **Used when: You want default values baked into the image**
- **Used by: process.env.PORT in Node.js**
- **Limitation: Hard to change unless you rebuild the image**

Environment Variables In Docker

- **Overriding with Compose (environment in compose):**

```yaml
backend:
  environment:
    - PORT=4000
    - UPLOAD_DIR=docker-uploads
```

- **Used when: You want to override Dockerfile ENV at runtime**

- **Best Practice: Put all configuration in Compose, keep Dockerfile generic**

Environment Variables In Docker

- **Using .env File with Compose:**

```
PORT=3000
UPLOAD_DIR=docker-uploads
```

```
ports:
  - "${PORT}:${PORT}"
environment:
  - PORT=${PORT}
  - UPLOAD_DIR=${UPLOAD_DIR}
```

- **.env is automatically loaded by Compose**
- **Place it next to your docker-compose.yml**
- **Keeps secrets/configs out of your code**

Any Questions?