

A Practical Analysis of Docker and Cloud Service Models

Module: Cloud Engineering Principles and Practice

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1. Introduction

The most revolutionary domain of the current computing is cloud engineering, which, therefore, allows organisations to develop, deploy and administer applications more efficiently and at a scale that legacy infrastructures had previously failed to offer. Cloud engineering gives those architectural bases, operational approaches and technology bases needed to facilitate this shift. Virtualisation and containerisation are among such tools that have become fundamental in terms of their capacity to ensure optimal utilisation of resources. Virtualisation enables several operating systems and applications to execute through the identical physical resources and the utilisation rate is significantly enhanced as well as the cost of running the operation is minimised. Docker as a containerisation platform leader has significantly contributed to the development of the cloud-native practise.

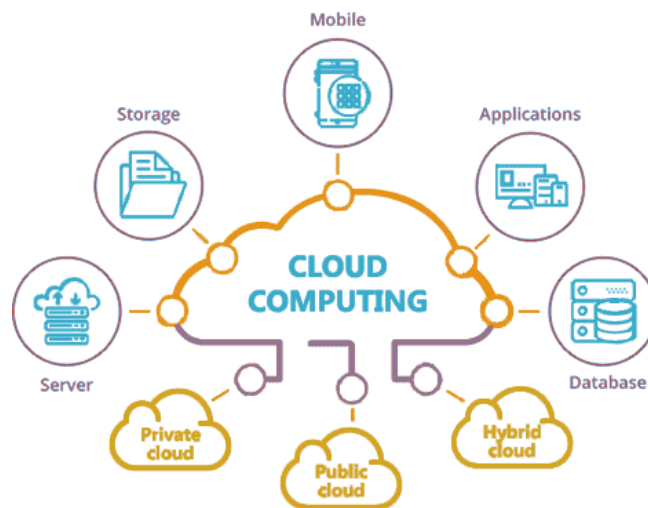


Figure: Cloud computing [3].

2. Principles of Virtualisation

Virtualisation and its Substantive Ideas

Virtualisation can be described as the process of abstraction of computing resources, which can be implemented to allow multiple virtual machines on the same physical system. Workloads are isolated in this abstraction but allow the real-time sharing of CPU, memory and storage resources. It develops the base of cloud infrastructure by ensuring full utilisation and minimisation of physical hardware constraints [1]. In such a way, organisations gain better efficiency, manageability, good workload consistency with environments [2], [9].

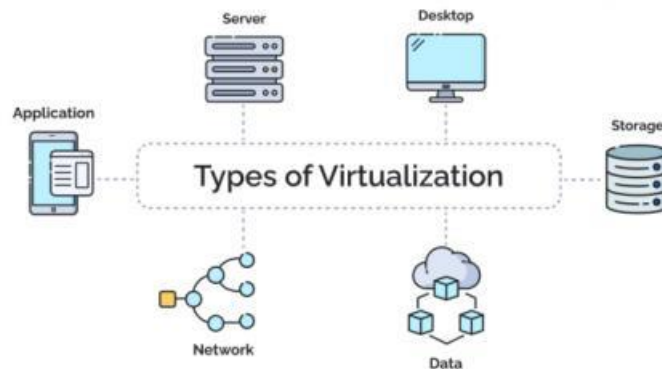


Figure: Types of Virtualizations [9].

Historical Development of Virtualisation

Virtualisation developed starting with primitive partitioning of mainframes, then continuing on to architecture work implemented by hypervisor. With time, hardware-assisted virtualisation performance and security improved and this saw the adoption becoming vast within the enterprise systems [1]. Its development made it reliable and scalable enough in cloud platforms, which shapes architecture choices in computing clusters and massive data centres [8]. Virtualisation today still forms a part of a cloud-native and hybrid deployment model.

Virtualisation in Cloud Systems

There are many types of virtualisations that include hardware virtualisation, storage virtualisation, network virtualisation and desktop virtualisation. The most common, software virtualisation founded hardware virtualisation, which establishes virtual machines with the help of hypervisors which effectively schedule resources. Storage virtualisation consolidates data resources to improve in their performance and resilience. desktop virtualisation increases the ability of remote access and centralised management to organisations [3].

Hypervisors and Virtual Machines Monitors

Hypervisors take care of the inception and control of virtual machines; they provide isolation between the guest operating systems. Hypervisor The type 1 hypervisor operates directly on hardware, which is more performant and has lower latency. Type 2 hypervisors are implemented on host OS platforms and give flexibility to testing and development [4]. Hypervisors streamline the scheduling, resource management and security policies, which allows effective implementation of workloads on cloud infrastructures [11].



Figure: Multi-Tenant vs Single Tenant [2].

Virtualisation in Multi-Tenant Cloud ENV

Cloud service providers make use of virtualisation in order to serve a number of tenants using the shared hardware but maintaining secure isolation. The providers dynamically allocate the virtual resource as per demand increasing their elasticity and cost efficiency. Such isolation allows organisations to operate mission critical applications on shared infrastructures with no impact on performance and security [9].

Advantages: Efficiency and Cost-cutting of Resources

Virtualisation enhances the utilisation of hardware equipment, since it enables the centralisation of workloads on a limited number of servers, which minimises energy utilisation and overhead expenses. Cloud platforms employ virtual machines which in turn allow provisioning to be flexible and accordingly the business can rapidly scale to different workloads [12]. Such efficiencies promote the use of virtualisation as a core element of a cloud cost-optimisation plan [18].



Figure: System performance [13].

Virtualised Systems Performance

Despite the overhead that virtualisation brings, the progress in CPU virtualisation extensions and I/O acceleration has significantly enhanced the performance. To accommodate various workloads, cloud providers scale VM instances to support general-purpose as well as the high-performance scientific workloads [8]. There are also load balancing and auto-scaling features which assist in the distribution of resource use and this avoids bottlenecks in virtualised environments [12].

Virtualisation security implications

Virtualisation improves security by isolating the virtual machines and also eliminating cross-tenant interference. This isolation restricts the propagation of attacks and contributes to formidable practises of segmentation. Monitoring of guests with unusual behaviour, restrictive access controls enhance cloud resilience by hypervisors [3]. Nevertheless, the vulnerabilities of hypervisor still remain a point of concern that needs regular updates and appropriate secure configuration strategies. Nevertheless, cloud computing is a safe pillar on virtualisation despite the threats [19].



Figure: Virtualization security [19].

3. Principles and Benefits of Containerisation

Essential principles of Containerisation

Containerisation is a lightweight virtualisation technology, which groups an application with its dependencies into an isolated entity called a container. The design increases consistency and portability because there is a uniformity in the execution of the applications when run in different environments [3], [4]. The predictability of such behaviour makes the work of development simplified and enables the development to occur faster in cloud-native ecosystems.

Virtual Machines to Containers Evolution

Containers were formed to overcome the weightiness and inflexibility of the older, virtual machines. The VMs offer a high level of isolation, but the entire operating systems are required, which makes their use more resource-intensive. To counter this problem, containers provide a shared-kernel model which is smaller in size and has a shorter startup time [3], [6]. This change is coincidental with the current microservices practise where developers are now able to break a large application into small independent units [11].

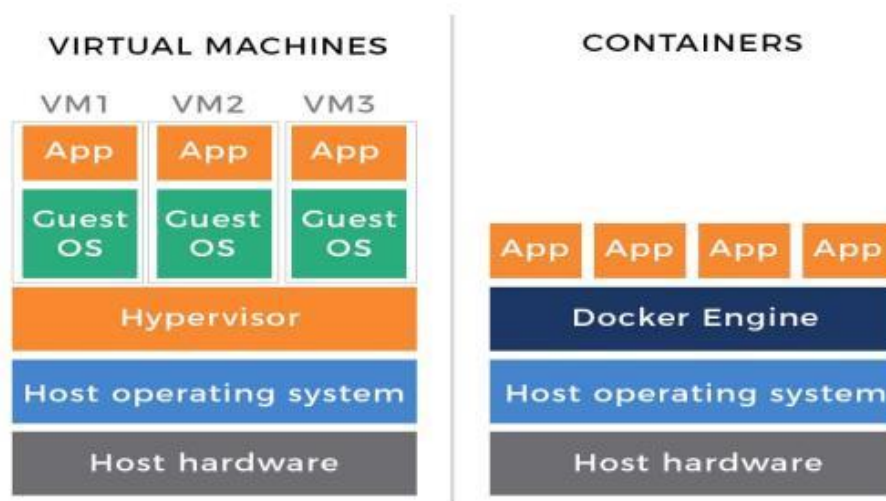
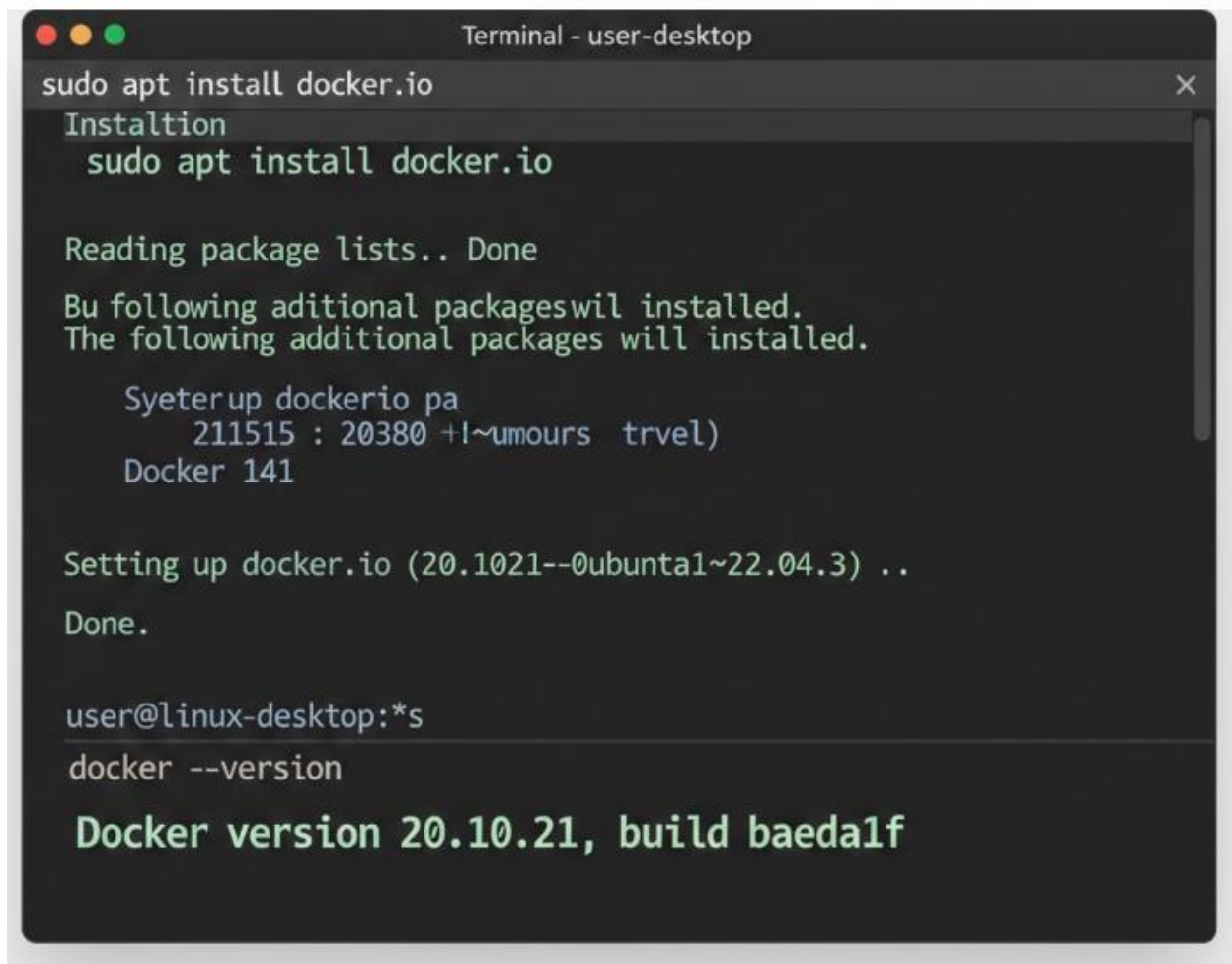


Figure: Machine & containers [5].

Docker Architecture Overview

Docker has brought out an easy-to-use system to construct, run and give control to the containers. Its structure comprises of Docker Engine which carries out container execution and a daemon which undertakes tasks related to the system level. Other elements such as Docker CLI and registries make creation and distribution of images easier [6], [7]. This multi-layered architecture has also become a norm in the DevOps processes enhancing automation and reducing the complexity of integration between the development and the operations team.

A terminal window titled "Terminal - user-desktop" with standard macOS window controls (red, yellow, green buttons). The terminal shows the command "sudo apt install docker.io" being executed. The output includes "Instaltion" (sic), "Reading package lists.. Done", and a list of additional packages to be installed: "Syeterup dockerio pa" (sic), "211515 : 20380 +l~umours trvel)" (sic), and "Docker 141". It then shows "Setting up docker.io (20.10.21--0ubuntu1~22.04.3) .." and "Done.". The prompt changes to "user@linux-desktop:~\$". The final command "docker --version" is executed, resulting in the output "Docker version 20.10.21, build baeda1f" (sic).

```
Terminal - user-desktop
sudo apt install docker.io
Instaltion
sudo apt install docker.io

Reading package lists.. Done

Bu following additional packageswil installed.
The following additional packages will installed.

Syeterup dockerio pa
211515 : 20380 +l~umours trvel)
Docker 141

Setting up docker.io (20.10.21--0ubuntu1~22.04.3) ..
Done.

user@linux-desktop:~$
docker --version

Docker version 20.10.21, build baeda1f
```

Figure: Verification of Docker installation on the local machine [4].

Portability to All Environments

A major strength of containerisation is that it supports the execution of the applications across different setups. Containers package the library and dependencies required, and it does not create problems when there are variations in system setups [3]. This portability minimises integration failures when developing an application, testing and deploying it. It also favours hybrid cloud plans which can help organisations to shift between the on-premise and the cloud applications more easily [4].

Rapid and Portable Implementation

Containers are very lightweight and can even begin in milliseconds owing to the fact that they do not offer a complete operating system. This is unlike the virtual machines which require booting complete OS setup. More rapid bootstrapping enhances rapid scaling of scenarios and the ability to create microservices structs that demand rapid containerization [6], [9]. The speed benefit is also helpful in the high level of productivity of developers and economical utilisation of cloud resources.

Isolation and lack of Security in Implementation

Containerisation offers process isolation to the level of its processes, and hundreds of processes can run independently in containers in the same host. This isolation restricts the effects of application failure and enhances security through minimised attack surface [7]. Even though the containers can be used with a similar kernel, other security measures like namespaces and groups are used to place limitations. Isolation is additionally facilitated in modern orchestration systems by policy and controlled communication [11].

Document interchange Documents and Containers

Docker relies on the filesystem which is layered to save images in form of stackable layers. This design has reuse features since base layers can be shared to many images thus minimising disc space and build time [6]. In case of changes, the only thing added is new layers, which build effective versioning and rollback. This modularity will ease the image customisation and enhance maintainability when deploying the application at the scale [3].

Docker hubs

Docker Hubs or private cloud registries are registries that serve as points of storage and distribution of container images. Users can either retrieve ready images or upload personal images to be shared by developers [6]. The registries help in versioning, automated scanning and controlled access policy, which renders image distribution secure and transparent. The combination with CI/CD pipelines helps advance the deployment processes, and this takes place through the support of enterprise-wide automation strategies [7].

Building an Image with a Docker file

A Docker file contains commands on how to create a container image, typically beginning with a base image like Ubuntu or Alpine. It contains commands on copying files that are applications, installing dependencies and exposing ports in the network. Once the file has been written, docker build command generates the final image [3]. This is a repeatable exercise, which ensures that a production is deterministic, allowing teams to have the same application environment when going through a production cycle [6].

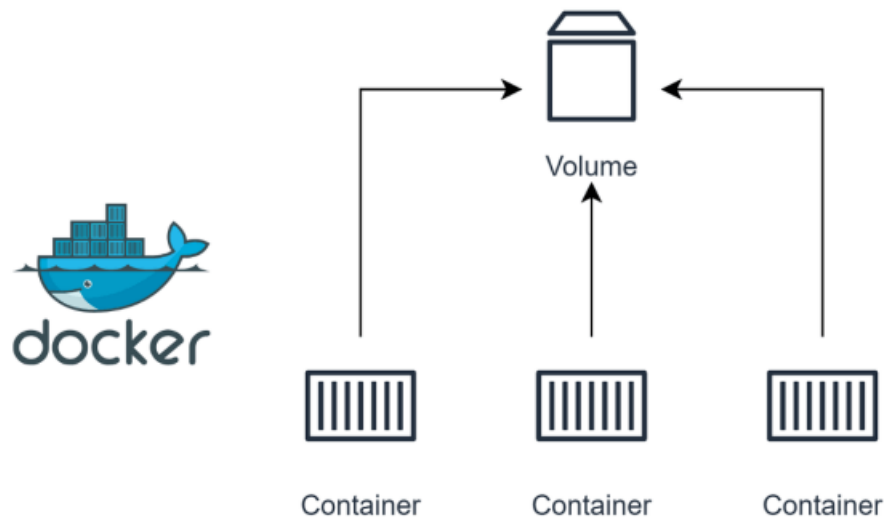


Figure: Types of docker volume [17].

Practical Example: Constructing a Dockerfile

A basic Dockerfile was developed as part of the practical activity that was done in the course of the lesson to illustrate how an application can be containerised. The webserver application presented here is an Nginx which shows a personalised page in HTML.

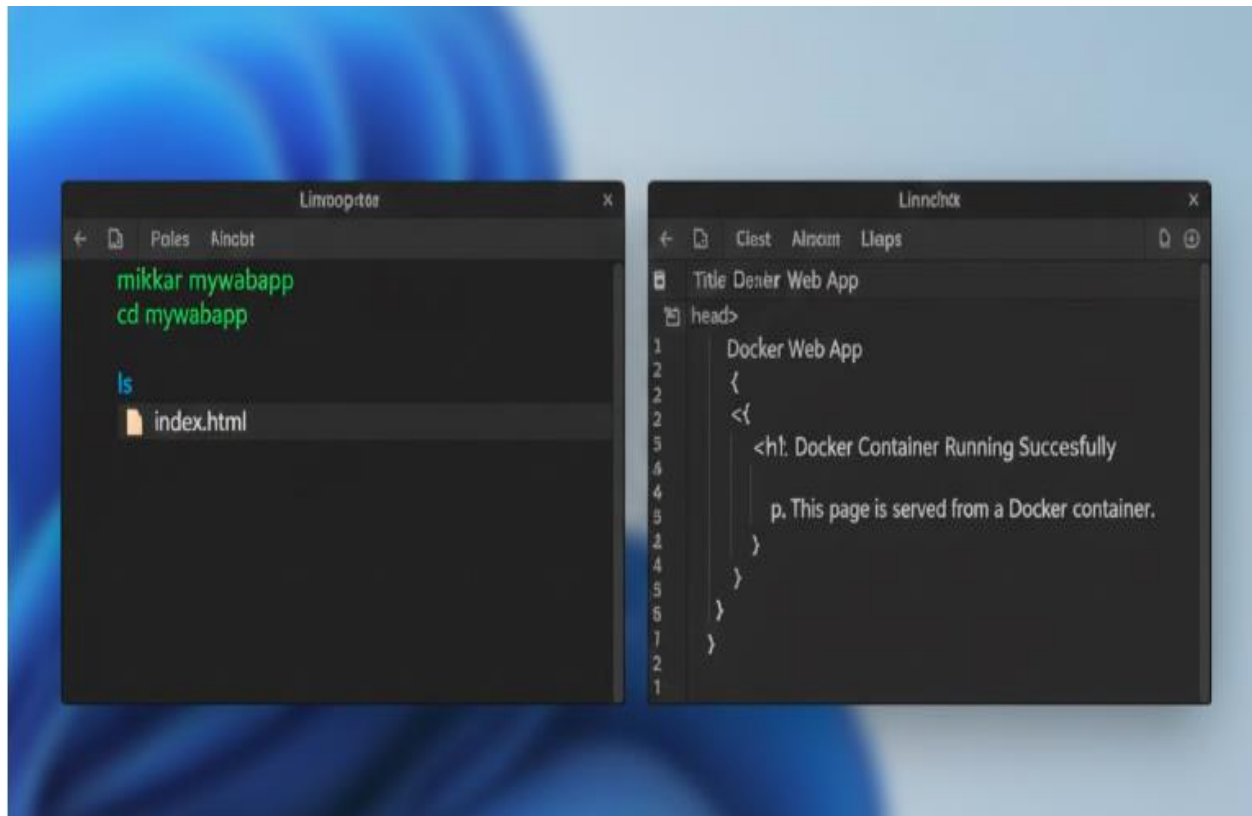


Figure: Project directory containing the Dockerfile and HTML application [8].

Dockerfile Example:

```
FROM nginx:alpine
COPY index.html /usr/share/nginx/html/index.html
EXPOSE 80
```

In this Dockerfile:

- The FROM instruction indicates a lean base image (Nginx Alpine).
- COPY command is used to duplicate a personalised HTML file in the container.
- Port 80 is opened to outside access courtesy of the EXPOSE direction.

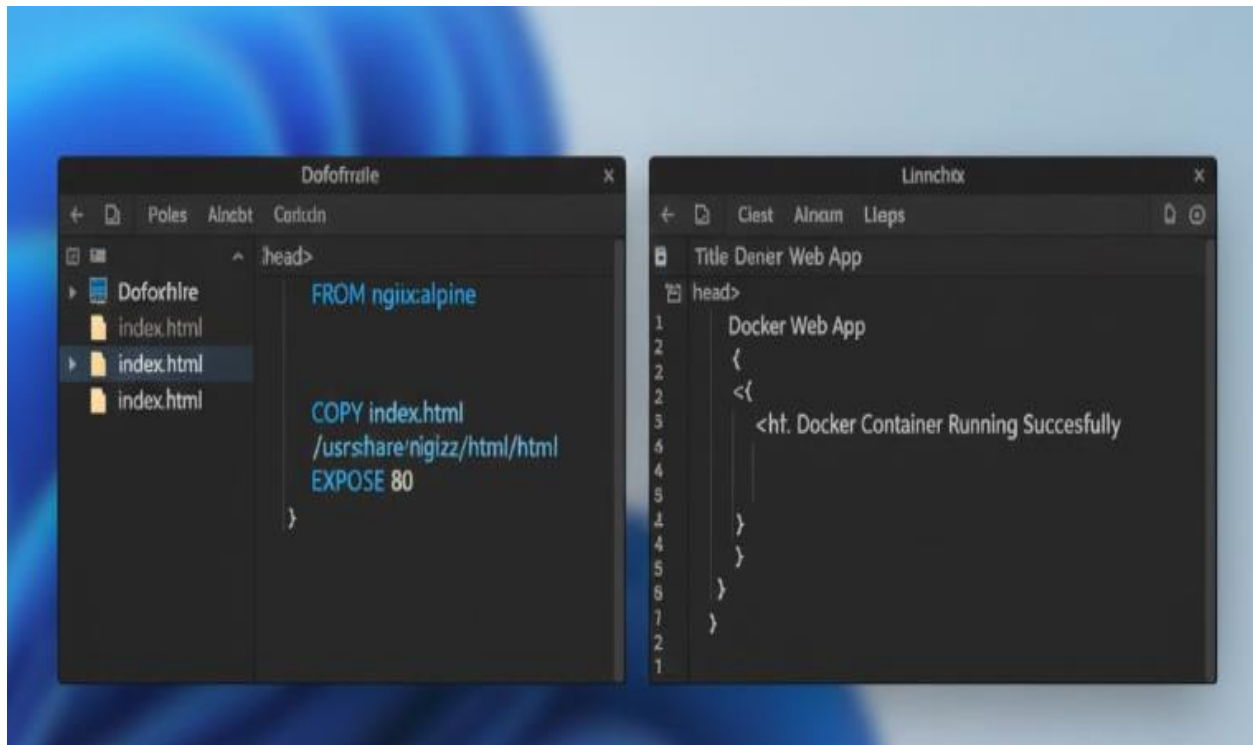


Figure: Dockerfile used to build the Nginx-based container image [4].

Efficiency and Cloud Cost Optimisation

Containers use much less system resources than virtual machine since they share the host operating system kernel. This performance enables the cloud platforms to utilise more workloads per physical server, reducing operation and energy expenses [5]. These savings are huge as the organisations expand their applications. Container scheduling systems also make efficient use of resources by means of smart placement algorithms [9].

Containerisation and its application in Microservices Architecture

More modern applications now use microservices, in which the functionality is broken into small services that can be deployed separately. Containers are complementary to this architecture because they offer isolated environments to each service, allowing scaling and updating them independently [4], [11]. The isolation reduces the effect of malfunction and eases the handling of versions. This modules architecture enhances system agility and provides swift innovation in very dynamic development endeavours.

4. Docker Images and Publishing Images

Introduction to Docker Images

Docker images are templates that are light and read-only and they are used to create containers. They have the code to run, libraries and configuration required to run. Images provide uniformity within any setting since any container created out of an image will act of the same manner. Such reproducibility is beneficial to reliability when used during development and production deployments [3]. Images are at the heart of containerisation operation and affect the results of storage, security and performance.

Structure and Multifaceted Filesystem Structure

The layers of the filesystem are layered and every single instruction of the Dockerfile creates a new layer. All the layers are added one over the other generating a coherent image that removes duplication and enhances efficiency [6]. Base layers can be used to share disc space across the images since they are common components of the operating system. This architecture also speed ups rebuilds since identical layers are used when updating and this also increases the productivity of the developer [3].

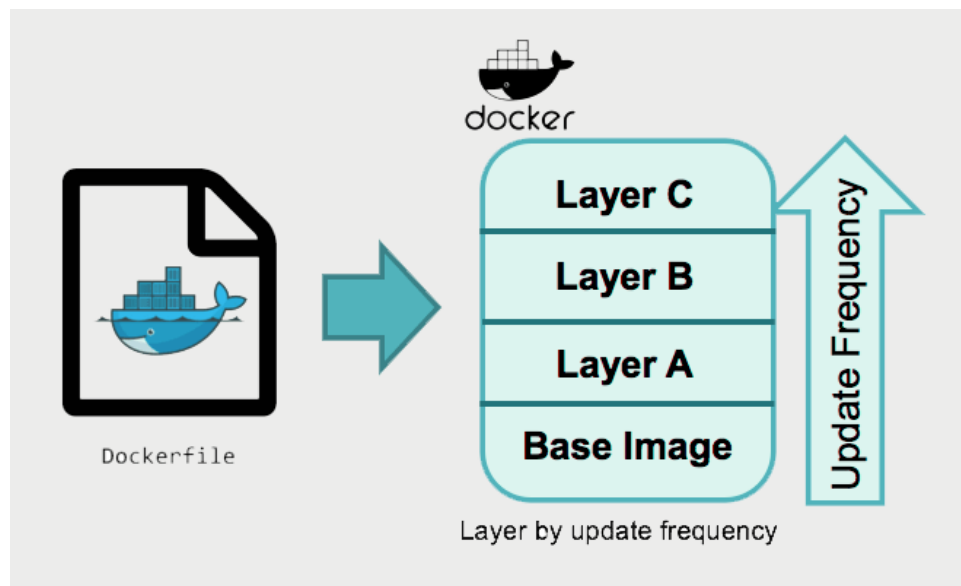


Figure: Image inheritance [14].

Base Advertising and Image Inheritance

Docker images are usually built on top of some underlying image such as ubuntu, alpine or python. These basic images provide the basic environment upon which the application is to be executed. The developers add dependencies to these images, configuration files or other software subunits [6]. So as to facilitate modularity, image inheritance works towards having a centralised base image ensures that teams have a consistent base image without varying amongst teams. It is a structure that facilitates the version control and simplifies the governance between containerised applications [7].

Dishonest Methods

Docker files are small instructions in lines on the way to build an image. From, copy, run and expose are some commands used to define the layers and behaviours in the execution of the containers. When the Docker file is complete, the command of docker build will create the entire image [3]. Commonsensical Deterministic builds based on Docker files allow consistent performance in both inter/intra-environment and simplify the automation of CI/CD pipelines [6].

Image Tagging and Version Management

Tagging assists in the differentiation of varying images of an image, such as v1.0, latest or release particulars. With tags, developers can monitor updates, roll back as well as workflows in deployment in a more efficient manner. Ethical tagging practises also minimise confusion in collaborative settings whereby the state and purpose of the image is clearly indicated [7]. Large scale, distributed systems require versioning as a means to keep large system integrity [11].

Image Storage and Local Registry

Once an image is created developers are able to store locally in their machine or in an owned registry. Local storage gives the opportunity to perform tests within a highly brief time without any outside requirements, whereas private registries offer improved access and governance [6]. Air-gapped environments with limited means of external network access are also supported by local registries [3].

Publishing to Docker Hub

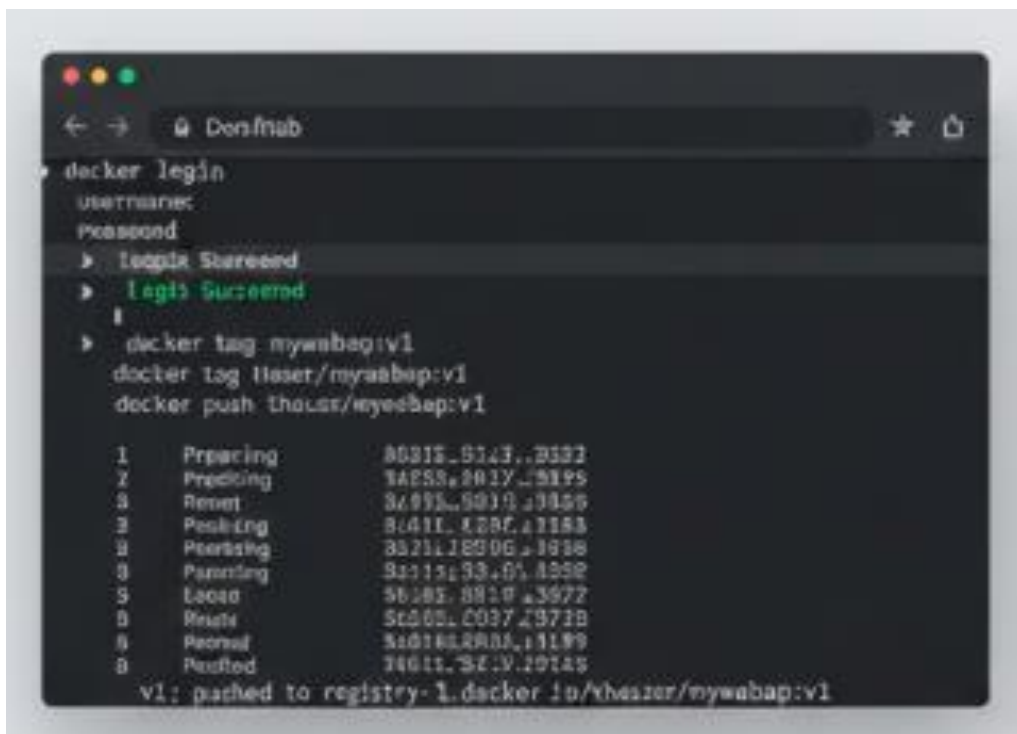
The most common widespread is the Docker Hub used in the distribution of container images as a public registry. The developers identify themselves with Docker CLI and push images using the docker push command. After it is published, images can be deployed or allowed to work by multiple teams [6]. Docker Hub has tags, automated construction, and inbuilt scanning applications and assists the individual in maintaining high quality and secure image repositories [7].

Practical Example: Pushing an Image to Docker Hub

```
docker tag mywebapp:v1 username/mywebapp:v1
```

```
docker login
```

```
docker push username/mywebapp:v1
```



```
docker login
username:
Password:
> Login Succeeded
> Login Succeeded
>
> docker tag mywebapp:v1
docker tag theuser/mywebapp:v1
docker push theuser/mywebapp:v1

1  Preparing      80315_8143..B532
2  Preparing      1A258_801Y..J9195
3  Reset          34995_801Q..J9156
3  Pushing        8:41L_428F..J1163
3  Pushing        3521L1890G..J9168
3  Pushing        34115L934G..J9582
3  Load         36181_8810..J3672
3  Reset         5c065L0037..J9718
3  Reset         34016L8883..J1189
3  Pushed        74611_341V..J9145

v1: pushed to registry-1.docker.io/theuser/mywebapp:v1
```

Figure X: Docker image successfully pushed to DockerHub [4].

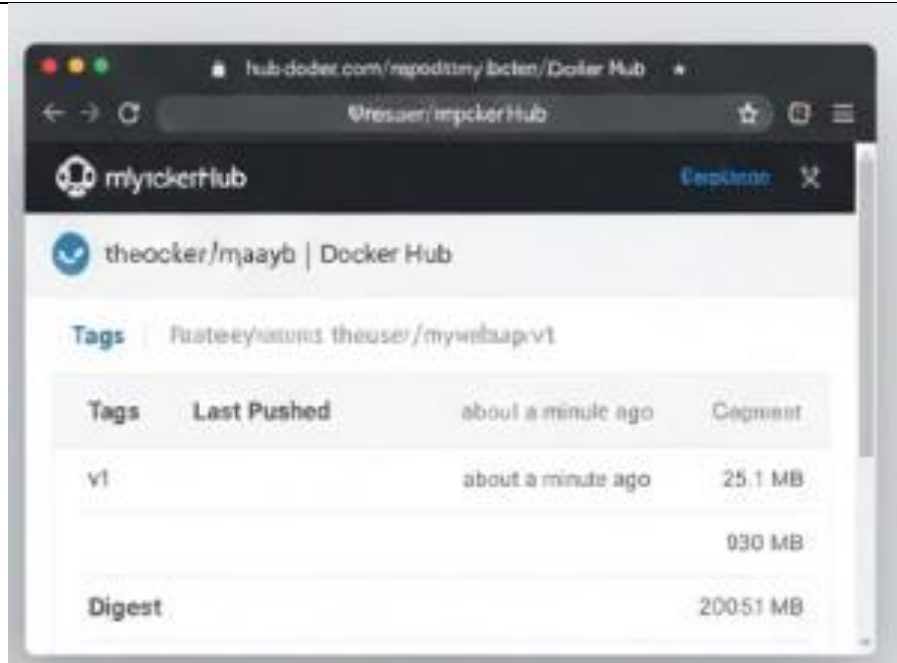


Figure: DockerHub repository page [14].

Transferring Pictures to Cloud Storage

In cloud environments used by an enterprise, the pictures may be sent to registry retention accessible to the provider, e.g. AWS ECR or Azure ACR or Google Container Registry. These registries have sophisticated access controls, scale and compatibility with orchestration services [12]. Hosted registries improve the performance by minimising the delay between storage and processing. They also assist in encryption transmission and automatic vulnerability screenings which enhance security of the operation [14].

5. Container Volume

Definitions of Docker Volumes

Introduction to Docker Volumes Introduction to Volumes Although volumes appear to be straightforward and easy to understand, grasping their complete functionality takes a bit of time before they become understandable. Introduction to Docker Volumes Introduction to Volumes Unlike volumes seem like simple things to learn, it requires a little time to figure out the scope of volume functionality before it becomes simple to understand [3], [6].

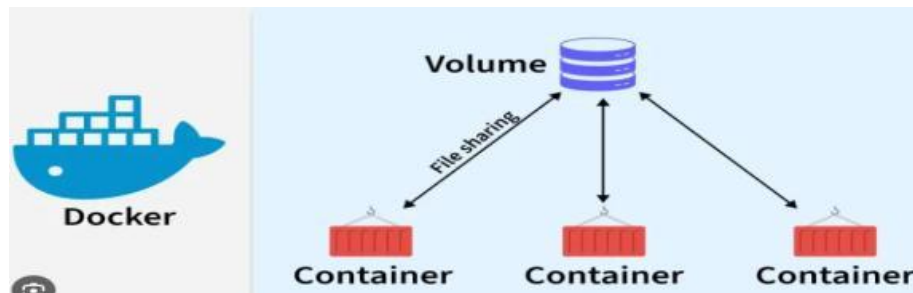


Figure: Docker volume [8].

The necessity of Continuous storage

The default is that Docker containers are actually stateless, i.e.: all information written into the container is dissipated when the container is washed away. The design is effective in application which are stateless, however in most applications like databases and file storage systems, persistent data is needed. Volumes overcome this weakness by offering storage that is not dependent on the lifecycle of the container [6], [9]. This renders volumes necessary in the operation of stateful applications in the cloud.

Types of Docker Volumes

There are multiple types of volumes that are offered by Docker and aimed at various purposes. Host-mounted volumes contain information in host filesystem and named volumes enable the containers to make use of storage that has been controlled by Docker. Cloud-backed volumes are also there and allow the storage of high-availability in the cloud environment [6]. These kinds are flexible concerning the performance, backup and scalability based on the requirements of the workload [7].

Managing Docker Volumes

Docker also contains a number of volume commands including `docker volume create`, `docker volume ls`, and `docker volume inspect`. Sharing data between containers is achievable solely within the scope of the Open Alex architecture. The exchange of data between containers is only possible in the context of the Open Alex architecture [9], [6].

Practical Example: Creating a Docker Volume

```
docker volume create webdata
```

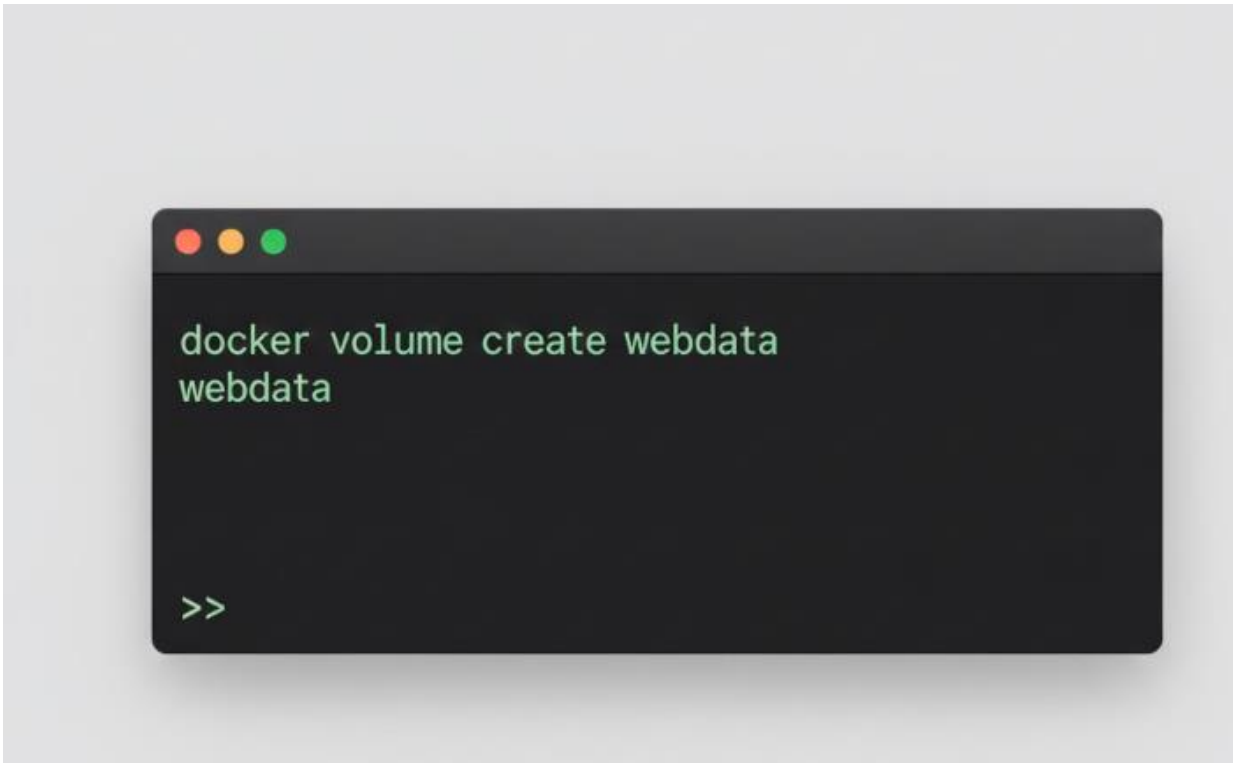


Figure: `docker volume create webdata` [3],

```
docker run -d -p 8081:80 \  
-v webdata:/usr/share/nginx/html \  
--name webcontainer2 nginx
```

```
[root@feb2j-2 ~]# docker run -d -p 8081:80 -v  
webdata:/usr/share/nginx/html --name webcontain  
er2 nginx  
64p7624960790b448101c001552d2423a5d6ad805772387
```

Figure: Container using volume [3]

Data Exchange between Containers

Among the essential advantages of Docker volumes, one can distinguish the possibility to share information between containers. This is also especially handy in microservices architectures, where various containers might have to share a configuration file, logs or databases [6]. Forced migration lowers redundancy and guarantees consistency of services.

Video Link: <https://www.youtube.com/watch?v=A8-CnsNbXhI>

6. Container Networking

The History of Networking

Container networking allows communication between containers of the same host, communication between containers of different hosts. Docker offers various networking designs in order to support communications between containers, such as bridge, host, and overlay network. Networking is a fundamental part of providing means through which containers may communicate with one another and with other resources and it forms a crucial part of containerised application deployment [6], [7].

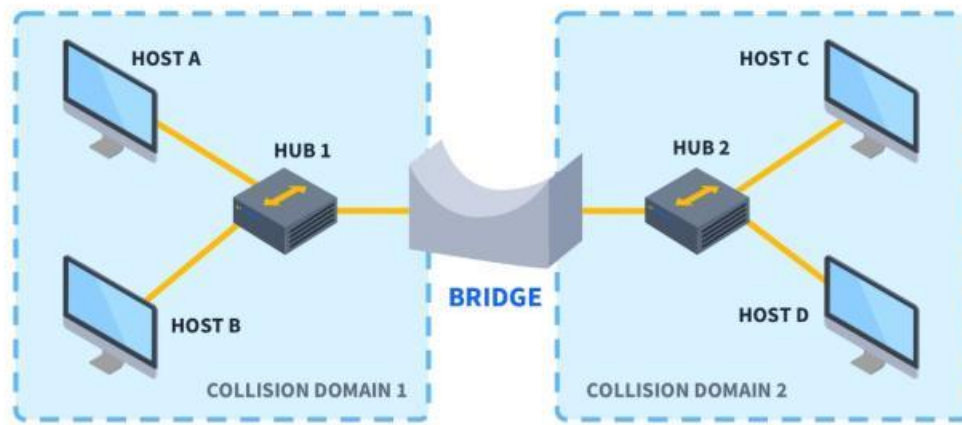


Figure: Bridge network [9].

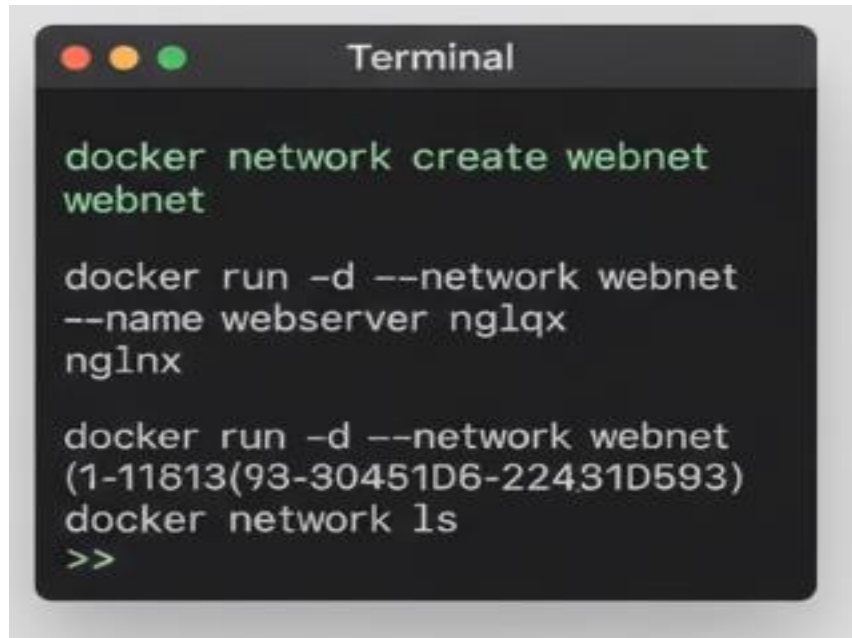
Types of Docker Networks

Docker provides various networks such as bridge network, host network and overlay network. The host network does not utilise the networking stack of Docker and instead presents container ports directly to the host. The overlay network allows containers to exchange communication between several Docker hosts, an important part of deploying containers on many hosts and clustering based on orchestrators, such as Kubernetes [6], [9].

Practical Example: Creating a Docker Network

```
docker network create webnet
```

```
docker run -d --network webnet --name webserver nginx
```

A terminal window titled "Terminal" with a dark background and light green text. It shows the following commands and their outputs:

```
docker network create webnet
webnet

docker run -d --network webnet
--name webserver nginx
nginx

docker run -d --network webnet
(1-11613(93-30451D6-22431D593)
docker network ls
>>
```

Figure: Custom Docker network created for container communication [4].

A terminal window titled "Terminal" with a dark background and light green text. It shows the output of the 'docker network ls' command as a table with four columns: NETWORK ID, NAME, DRIVER, and SCOPE.

NETWORK ID	NAME	DRIVER	SCOPE
webnet			
bridge		bridge	
host		bridge	
none		local	
webnet			
		local	

```
>>
```

Figure: Docker container connected to a custom network. [6]

Bridge Network

Docker containers use default network mode by default, which is a bridge network that does not utilise a specific network. It establishes a local internal network on the host system and every single container receives an IP address on the network. Containers are able to communicate with one another over the bridge and the host is in charge of routing traffic. This model can be used in small applications or testing environments in which containers have to communicate locally [6], [3].

Host Network

In the host network mode, containers share a network stack of the host, i.e., they utilise the IP address directly on a host and make their ports visible on the host. This arrangement is attained at a very high performance than bridge networking, since network address translation (NAT) is not required in this context [7]. Nonetheless, it is not segregated between containers and this may be a security risk in a multi-tenant setup. This is a mode that is frequently utilised in high-performance applications [6].

Overlay Network

The containers on the different Docker hosts are connected with the help of the overlay network to communicate with one another, and this is what can be called multi-host. It is applied together with the container orchestration software such as Docker Swarm or Kubernetes to facilitate communication between containers deployed on many hosts. Overlay networks prefer VXLAN (Virtual Extensible LAN) tunnelling to wrap up and forward network packets on the physical hosts [9], [12]. This form of network is necessary where we have a large-scale and distributed application.

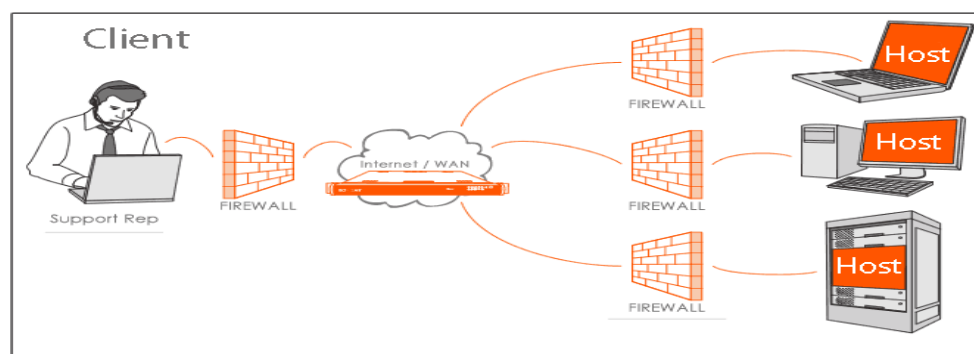


Figure: Host network [6].

7. Full Demonstration Workflow

Overview of the Workflow

This demonstration identifies the overall life cycle of developing, executing and publication of a Docker image. It consists of defining the environment where the application is going to be run, creating the Docker image, launching the image as a container and pushing the image to a repository such as Docker Hub. These measures demonstrate the ease with which Docker deploys applications, performs testing, and distributes them in different environments [6], [7].

Step 1: Defining of the Docker Image

The initial picture in the workflow is the definition of the environment of the application. This is achieved with the help of a Docker file, which is a text file stipulating the building instructions of Docker image. Such instructions will define what base image to apply as well as dependencies to instal, and files or configurations to be added. The Docker file is basically the map of the application that can guarantee the application to be consistent when used with different systems [3], [7].

Step 2: There is the creation of the Docker Image

When the Docker file is set, building Docker image should be the next thing to do. The image includes all the files required to execute the application, including; operating system libraries, application code, and configuration files. The image is put locally and may be utilised to develop containers on any system utilising Docker [6]

```
$ docker build -t mywebapp:v1 .
Step 1/3 : FROM nginx:alpine
----> 804054c900a1
Step 2/3 : COPY index.html /usr/share/nginx/html/index.html
----> 5d29f8a00c8d
Step 3/3 : EXPOSE 80
----> 0e3f1a00c6c1
Successfully built 0e3f1a00c6c1
Successfully tagged mywebapp:v1
> 
```

Building the Docker image using the Dockerfile.

Figure X: Successful execution of the Docker image build process [9].

```
docker images
```

REPORITORY	IMAGE ID	IMAGE ID	CREATED	SIZE
mywababb	800056c000a1		about a minute ago	25.1MB
v1	5d2788a00ccd			
mywabapb	50756ac005n			25.1MB
nginx:alpine	801912c28cn			

```
> 
```

Docker image succesisully created and stored locally.

Figure: Locally available Docker images after build completion [6],

Practical Example: Building and Running a Container

The Docker image was created with the help of the following command:

```
docker build -t mywebapp:v1 .
```

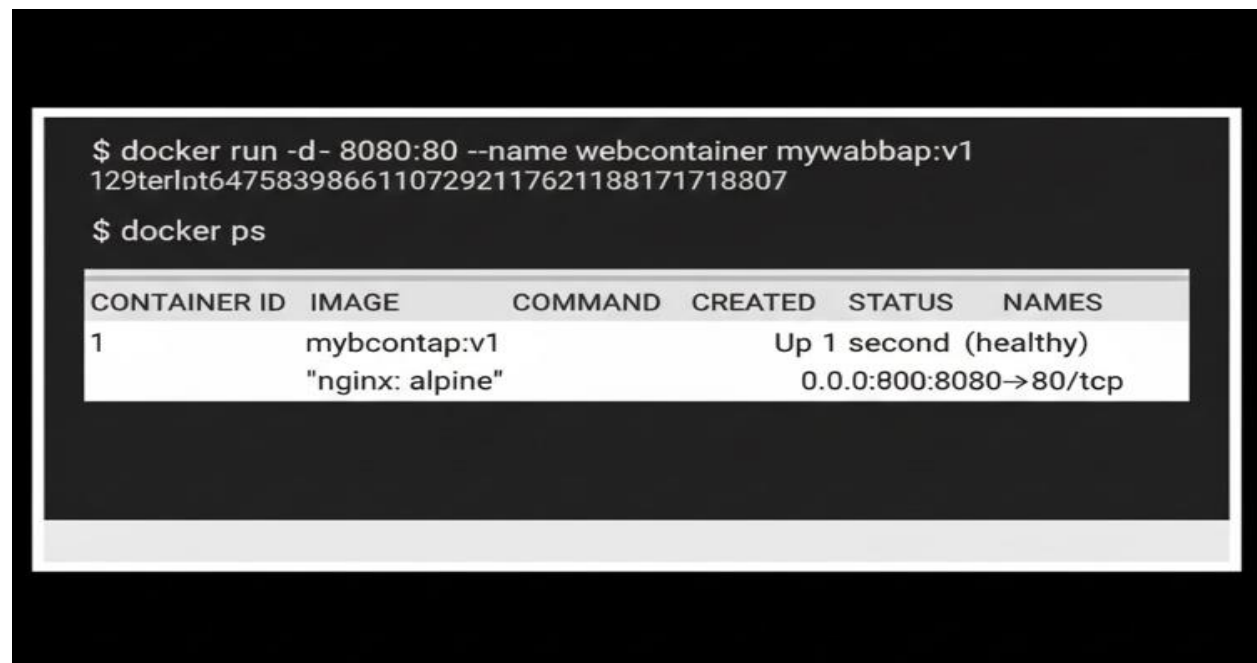
When the picture was made successfully, it was performed as a container:

```
docker run -d -p 8080:80 --name webcontainer mywebapp:v1
```

The following command brings the container to a detached mode and opens port 80 within the container to port 8080 on the host machine. By opening up a web browser and typing in the URL of localhost:8080, the HTML page will be hosted, thus it is now known that the container is operating properly.

Step 3: Running the Container

Once the Docker image has been made, the following step is to execute the application in the form of a container. A container is a closed system which executes the application, as a blueprint to which the image is used as input. Containers offer predictable performance and behaviour on a variety of environments and every time an application needs to run somewhere it should run in the same manner, be that on a laptop development or in a production environment [6]



```
$ docker run -d -p 8080:80 --name webcontainer mywabbap:v1
129terInt64758398661107292117621188171718807

$ docker ps
```

CONTAINER ID	IMAGE	COMMAND	CREATED	STATUS	NAMES
1	mybcontap:v1			Up 1 second (healthy)	
	"nginx: alpine"			0.0.0:800:8080→80/tcp	

Figure X: Docker container running in detached mode [7]

End to end-demonstration: Web Server Deployment.-The following demonstration shows the process of full containerisation that will occur during classes:

1. Relevant web page is created in simple HTML.
2. A Dockerfile was created to package the web page with the usage of Nginx.
3. The Dockerfile was then used to create a Docker image.
4. The image was carried out as a vessel.
5. Persistent storage was accorded by connecting a Docker volume.
6. The container was attached to a custom Docker network.
7. The image was uploaded on Docker Hub.

This is an end to end workflow illustrating how Docker is used to businesses to efficiently deliver applications, make them portable, scalable and cloud ready.

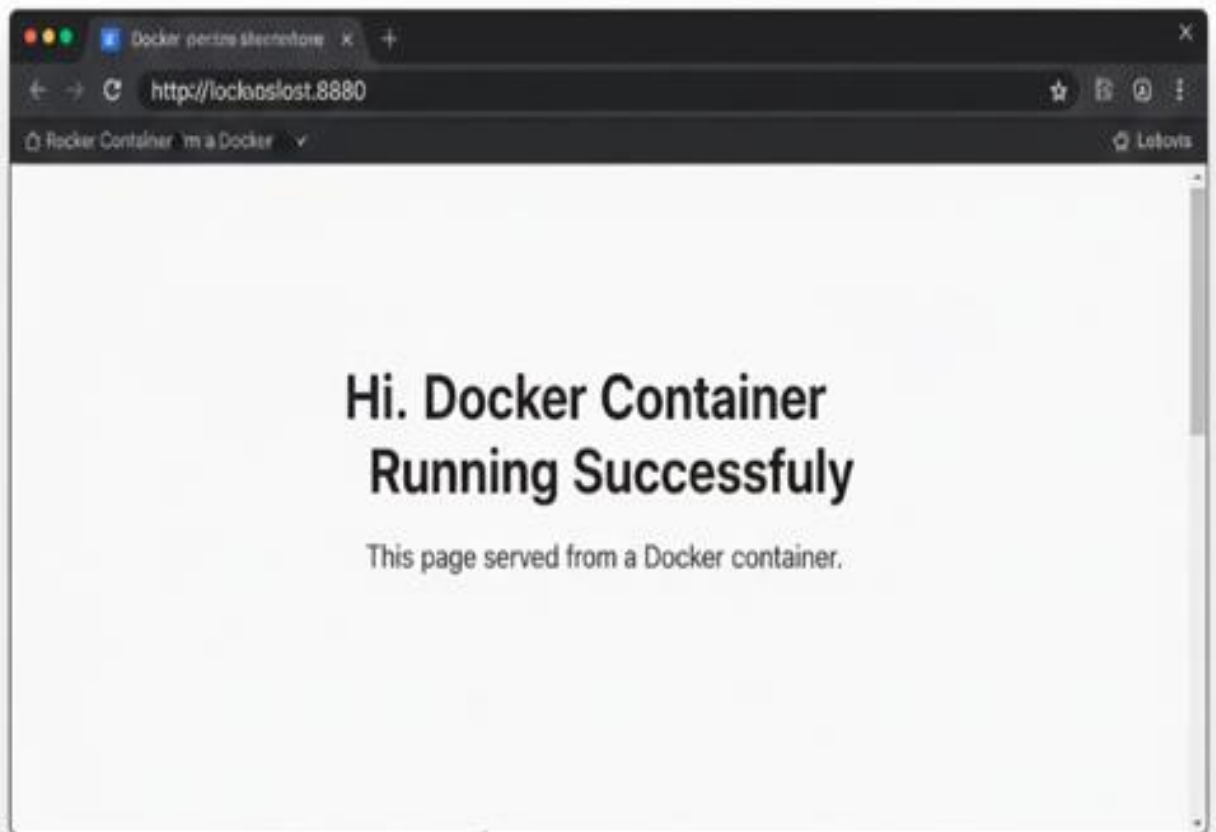


Figure: Web server running inside a Docker container displaying the HTML page [7]

8. Cloud Concepts: Load Balancing, Scalability & Application Gateways

A brief description of a cloud provider's approach to implementing each of these concepts.

Three main concepts are crucial in the current cloud conditions which are load balancing, scalability and application gateways to maintain that applications run smoothly and respond to the fluctuation of the workload. These two ideas combine to implement high availability, resource efficiency, and end user functionality. Combined they are the basis of the foundation of trustworthy, economical, and expandable cloud services [6], [9].



Figure: Cloud concepts [6].

Why Load Balancing and Scalability Are Complementary

Scalability and load balancing serve a mutual purpose of application availability and performance. Load balancing will evenly distribute incoming traffic to multiple instances, whereas scalability will make sure that adequate instances will be used to serve the traffic. Load balancing would be nothing but redistribution of load without scalability. Scaling would leave more instances on the server unutilised without load balancing. The combination of them allows efficient use of resources, fault tolerance, and uninterrupted user experience.

Cloud Environment Load Balancing

Load balancing is done to allocate incoming traffic to more than one server, so that a single server is not overloaded. Load balancing is used in cloud computing to attain high availability and fault tolerance by automatically redirecting the traffic to the healthy examples when one is unavailable. managed load balancers the load balancers that are provided by cloud providers, like AWS, Azure, and Google Cloud, can be integrated into the computer services and guarantee a seamless scaling of applications, when subjected to different workloads [7], [9].

Load Balancing by Cloud Providers

There are various ways of load balancing that cloud service providers provide. An example of such is called AWS Elastic Load Balancer (ELB) which uses a dynamic distribution of requests to multiple EC2 instances depending on the burst of traffic. Azure Load Balancer can be used to offer global load balancing across regions whereas Google Cloud Load Balancing can offer automatic scaling depending on real-time analysis of traffic. The services make sure resources are distributed efficiently and minimise response times and enhances resilience of applications [12], [6].

Benefits of Combining Load Balancing, Scalability and Application Gateways

The Advantages of Load balancing, scalability and application gateway combination. A combination of those three technologies will result in a reliable cloud service. The integration gives it security, performance, and high availability besides maximising operational cost.

In a case of e-commerce application:

- Application gateways are used to control secure traffic routing and termination of the SSL
- Load balancers distribute requests of customers uniformly.
- Auto-scaling scales up and down automatically when resources are required during high activities of purchasing [9].

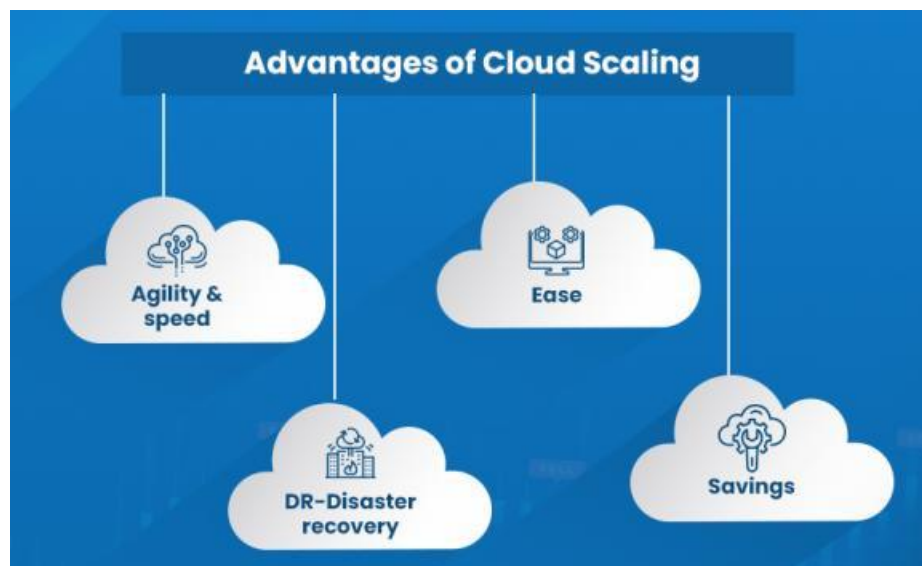


Figure: Cloud scaling [12].

Scalability in Cloud Systems

Scalability refers to how a cloud application is capable of dealing with emerging or dwindling workloads successfully. In vertical scaling (scaling up), an increase in number of resources (CPU, memory) is added to the single server whereas horizontal scaling (scaling out) is the addition of more servers to share the load. Clouds allow auto-scaling, which is a process that changes the resources assignment accordingly to the existing demand and thus applications can be performant in times of peak usage [7]

Auto-Scaling and Elastic Scalability

Another major aspect in cloud computing is known as auto-scaling where applications automatically scale their resources based on the changing demand. As the traffic grows, the system deploys more instances to support the traffic. This is essential where businesses have fluctuating traffic patterns because the ability to manage the costs of its resources is cost effective besides the desired high performance [7], [12].

Application gateways Role

An application gateway serves as a reverse proxy that is used between the end user and the end servers and includes functionality like the termination of the SSL, traffic blocking, and routing of requests. The gateways process traffic on the topmost layer thus allowing a greater control over the traffic entering and entering the service, offering a higher level of security and performance optimization [9].

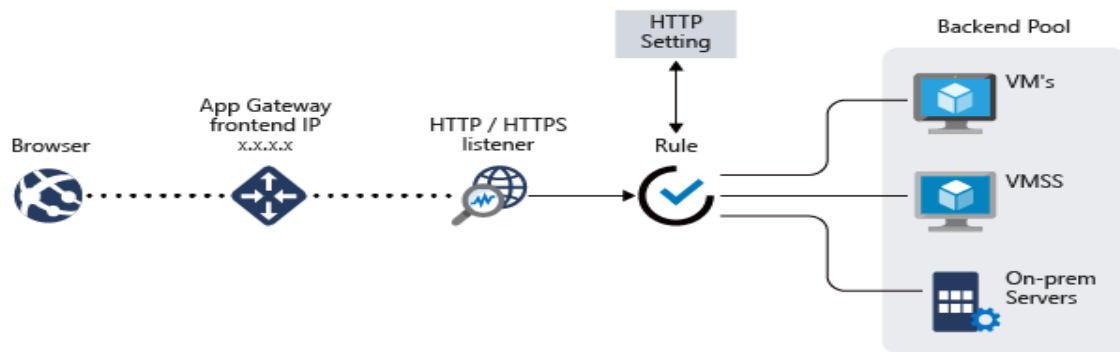


Figure: Application gateway [17].

9. Driving Forces in Cloud Expansion

Cost Efficiency

Cost efficiency is one of the major cloud growth factors. Cloud systems come with a pay-as-you-go, i.e., it charges the companies per consumption. This removes the ability to have large capital expenditure upfront that occurs when using on premise hardware. Cloud services enable businesses to use their funds on more productive activities such as innovation and development since they minimise the cost of infrastructure, hence adoption of the cloud option is a cost-effective choice [7], [9].

Scalability and Flexibility

Cloud conditions offer unrivalled flexibility and scalability. Organisations are also able to add and remove resources depending on the demand that only makes them pay as they consume. This scalability is crucial to the enterprises whose need has varying workload, since it enables them to scale up or down their resources without necessarily going out into the market and investing in hardware. Cloud based platforms are also provided with global distribution, where companies can operate applications in various parts to enhance performance and availability [6]

Availability of State-of-the-art Technologies

Cloud platforms provide entrepreneurs with the opportunity to use numerous innovative technologies, including artificial intelligence (AI), machine learning (ML), or big data analytics. Cloud computing companies, such as AWS, Google Cloud, and Microsoft Azure, keep innovating and introducing new services that enable companies to enjoy being on the cutting edge of using advanced technologies without significant investments [7], [12].

10. Serverless Computing and Driving Forces of Cloud Expansion

Serverless Computing

Service-free computing is the novel model of cloud computing; developers are allowed to write and deploy code, without taking care of the infrastructure. Serverless systems, e.g., AWS Lambda and Azure Functions, manage the infrastructure without the need to make life more complex by doing this, which enables agility in the development process [6], [9].

Function as a Service (FaaS), or serverless computing, is a recent technology that introduces a different implementation of cloud-based web services. This model is developed by programmers creating small, event-driven units of codes and the cloud provider scaling, provisioning, and availability. Serverless computing is very economical, like AWS Lambda and Azure Functions will automatically scale resources and charge only based on the run time, which is why serverless computing is a perfect solution to workload of a variable or unpredictable demand.

Benefits of Serverless Computing

The benefits of serverless computing include: high-cost efficiency, elasticity, and operation overhead. In serverless, companies are only charged the amount of time their code runs, and not the idle server time. Besides, the serverless functions get automatically scaled as per demand, which provides performance without human effort [12], [6].

Cost efficiency and flexibility are the major factors that have led to the blistering growth of cloud computing. Conventional on premise Solutions are costly to acquire and maintain in addition, however cloud services follow a pay-on-use approach that lowers capital costs and enables organisations to become resourceful by dynamically scaling.



Figure: Docker pragmatics [19].

11. Personal Reflection

Cloud Engineering Concept

In the process of this report, I have learned a better idea of the main concepts of cloud engineering such as virtualisation, containerisation, and serverless computing. Scalable cloud infrastructure has been found to depend on virtualisation, where physical resources are abstracted into a virtual environment. I also understood isolation workloads, therefore making it efficient in utilising resources which is crucial in cloud environments that demand efficiency and flexibility.

Investigating the Pragmatics of Docker

I understand the illustration of Docker, its development, and management of containerisation greatly helped me to realise what containerisation involves. I ease with which Docker can be used to build and deploy applications in various environments has demonstrated the relevance of containers in the contemporary DevOps concepts. I will use containerisation methods in my practise especially in the process of experimenting with the microgrids systems I am creating in my study.

11. Conclusion

Conclusively, cloud engineering concepts such as virtualisation, containerisation and serverless computing have radically transformed the application development, deployment and management processes. Virtualisation also allow resource allocation and isolation to be effectively performed, and containerisation is a lightweight and portable method to package the applications so that they have a uniform deployment in any environment. Serverless computing has offered an efficient and cost-effective approach to executing applications through its pay-per-use model, and infrastructure management is no longer of concern, which particularly proves convenient in event-driven workloads.

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