Lecture 4: Containers II

AC215

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Outline

1. Recap: Review of Previous Material
2. Containers in Architecture: Microservices vs. Monolithic
3. Implementing Containers as Microservices

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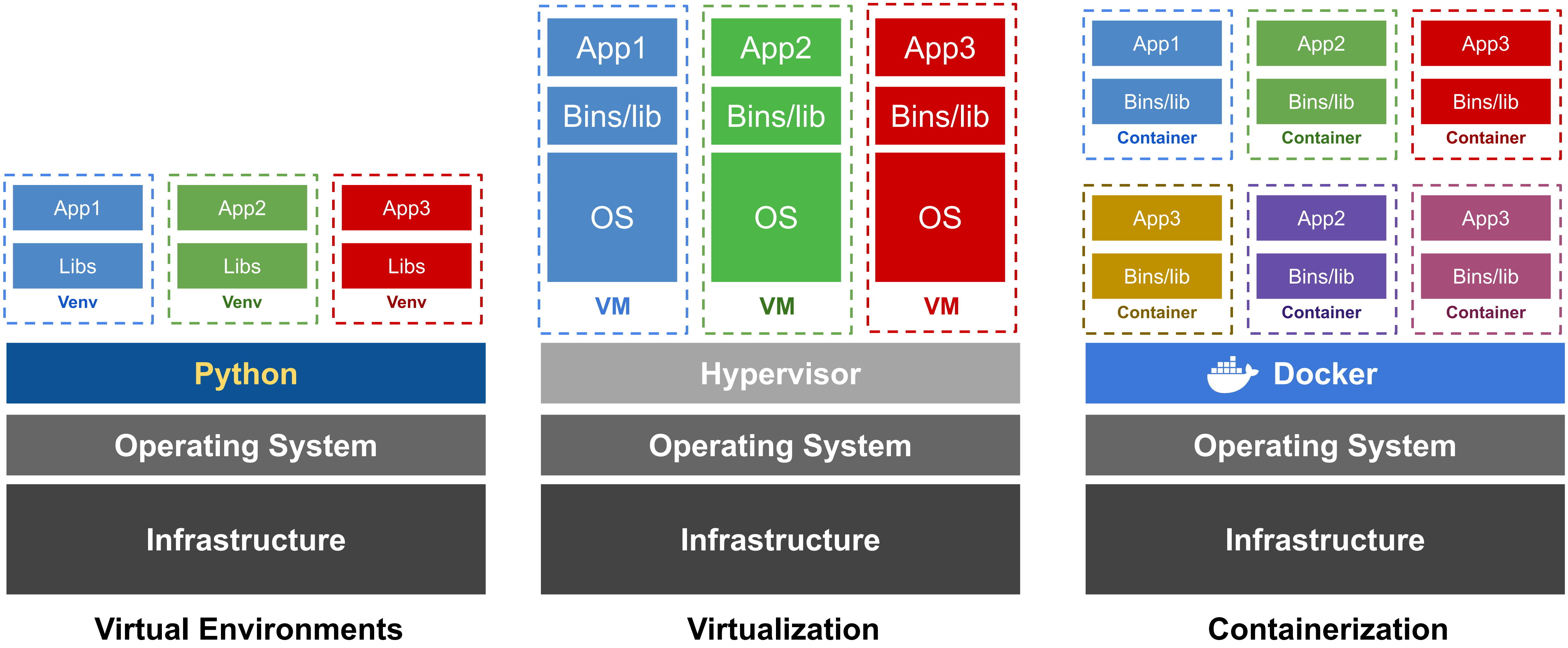
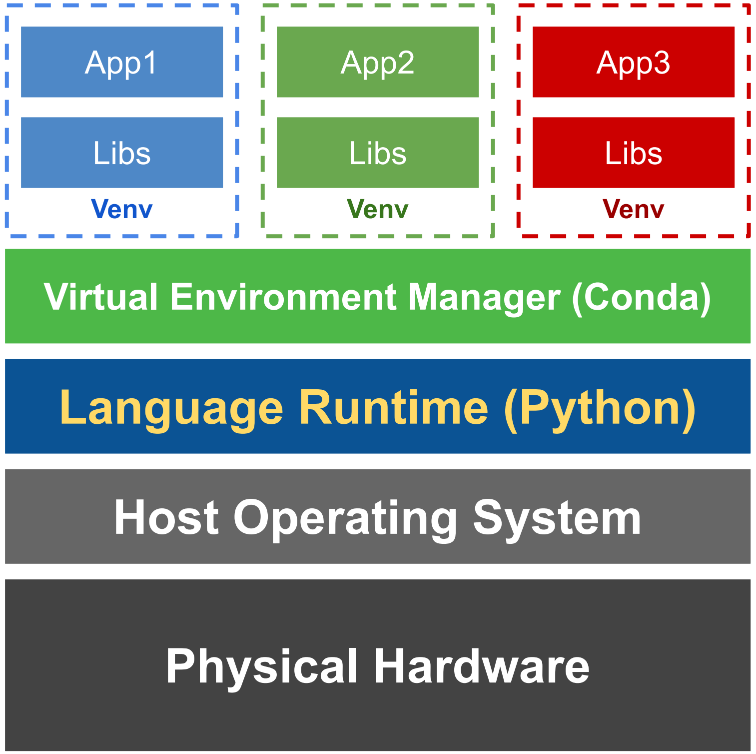
Recap: Environments vs Virtualization vs Containerization



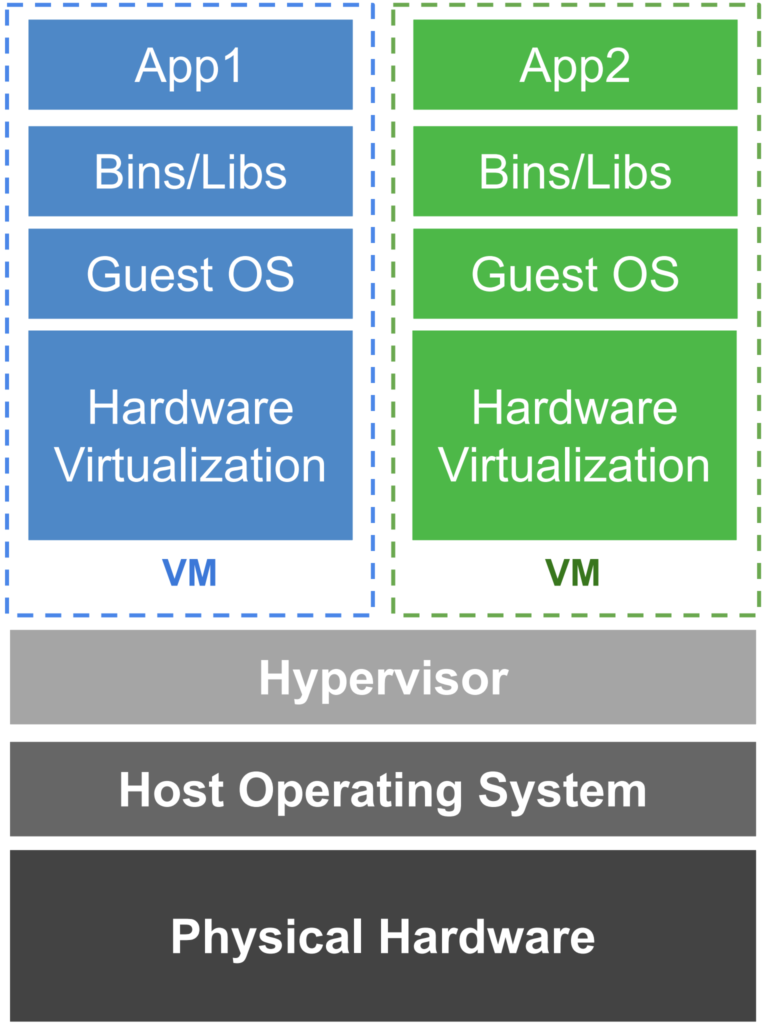
Environments



Virtual Environments

- **Dependency Isolation**: Virtual environments modify the PATH and other environment variables so that the dependencies are loaded from the environment's directory, rather than system-wide directories
- **No Kernel Isolation**: Unlike VMs and containers, virtual environments don't provide any kernel level isolation.
- **Resource Utilization**: Since virtual environments don't have any additional OS or kernel, they are the most efficient in terms of resource utilization among the three.
- **Filesystem Boundaries**: Virtual environments usually don't provide isolation at the filesystem level; files written in one environment are accessible from others.

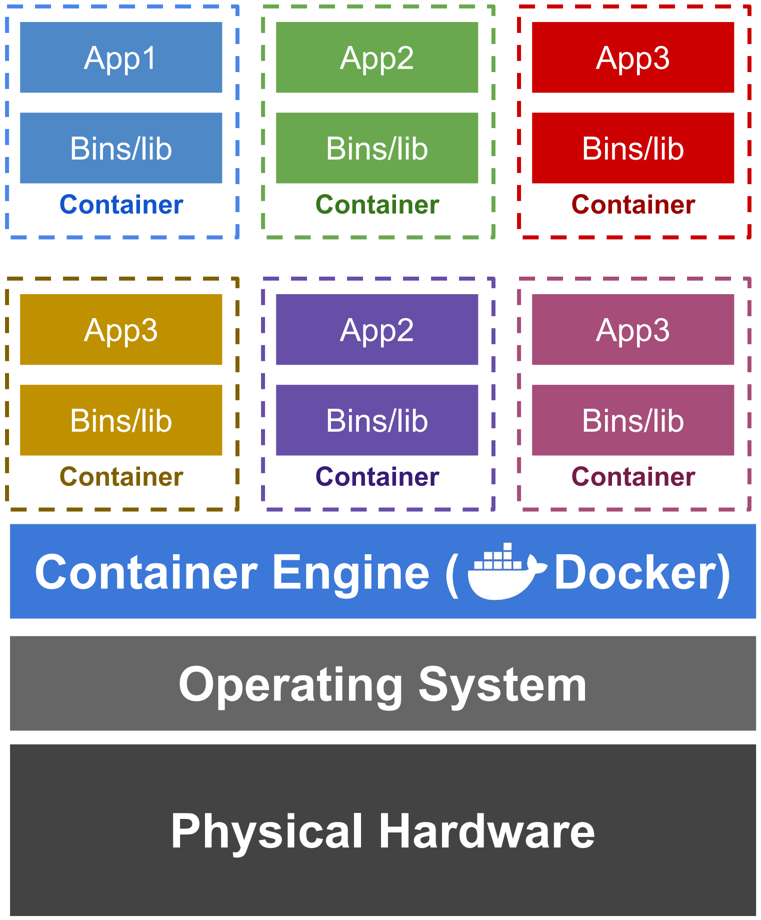
Virtualization (Virtual Machines)



Virtualization

- **CPU Virtualization**: VMs usually have a set number of virtual CPU cores allocated by the hypervisor. These virtual CPUs map to physical CPU cores, but the hypervisor adds a layer of management and overhead, which can lead to inefficiencies.
- **Emulated Devices**: VMs have emulated hardware devices, meaning the VM sees virtual CPUs, virtual network adapters, and virtual disks that the hypervisor translates to real hardware resources.
- **Full OS**: Each VM runs its full guest OS. This means that each VM has its own separate kernel space and user space, making resource management fully independent but less efficient.
- **Resource Allocation:** RAM and CPU are often (not always) allocated in blocks, and disk space is generally pre-allocated, making VMs less flexible in terms of resource utilization.

Containerization



Containerization

- **Namespaces**: Containers use kernel features like namespaces to provide isolation of processes and resources. This allows each container to operate as if it is the only application running on the system. Example namespaces include:
  - PID Namespace: Isolates the process ID number space. In other words, processes in different PID namespaces can have the same PID.
  - Mount Names: Isolates the file system tree so that each namespace can have its own file system layout.
- **Control Groups (cgroups)**: Complementary to namespaces, cgroups limit resource usage, like CPU, memory, and IO, allowing for better resource utilization compared to VMs.
- **Process Virtualization:** Namespaces and cgroups together enable process virtualization by allowing processes to run in isolated environments with controlled access to system resources.
- **Shared Kernel**: Containers share the host's OS kernel but have their own filesystem, libraries, and bins, making them lightweight yet isolated.
- **Direct Access**: Containers can access host resources more directly, avoiding much of the overhead introduced by hypervisors in VMs.

Pro Tips 1: **multi-stage builds**

Multi-stage builds in Docker allow for the use of multiple FROM statements in a single Dockerfile

- decreases container size
- improves security (e.g. avoid sharing private keys from GitHub)
- leveraging different base images for each stage while preserving only the final image.
-

`dockerfile` command:

Name of previous image you want to get file(s) from

Dockerfile command

```
COPY --from=builder /bin/hello /bin/hello
```

Location of file(s) from previous image

Location where file(s) from previous image should live on new image

[multi-stage builds]()

Pro Tips 1: **multi-stage builds: example**

```
# First Stage: Building the Python application
FROM python:3.8 AS build-env
WORKDIR /app
COPY BLAH BLAH
RUN  BLAH BLAH

# Second Stage: Copy the dependencies and run the application
FROM python:3.8-slim
COPY --from=build-env /usr/local/lib/python3.8/site-packages
/usr/local/lib/python3.8/site-packages
WORKDIR /app
COPY BLAH BLAH
CMD BLAH BLAH
```

Pro Tips 2: **multi-platform images**

When building a more complicated Docker image, there is a small chance the specific platform (OS and CPU architecture) on your machine causes issues when sharing the Docker image with someone on a different machine

Example: Building a complex image on M1 Mac (linux/arm64) and trying to run the image on an older Macbook (linux/amd64)

Error message to look out for

```
The requested image's platform (linux/arm64) does not match the detected host platform (linux/amd64) and nospecific platform was requested
```

Solution:

- Use the `--platform` flag within the FROM command in your Dockerfile to specify the target OS and CPU architecture for the build output

Multi-platform images

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Why use Containers?

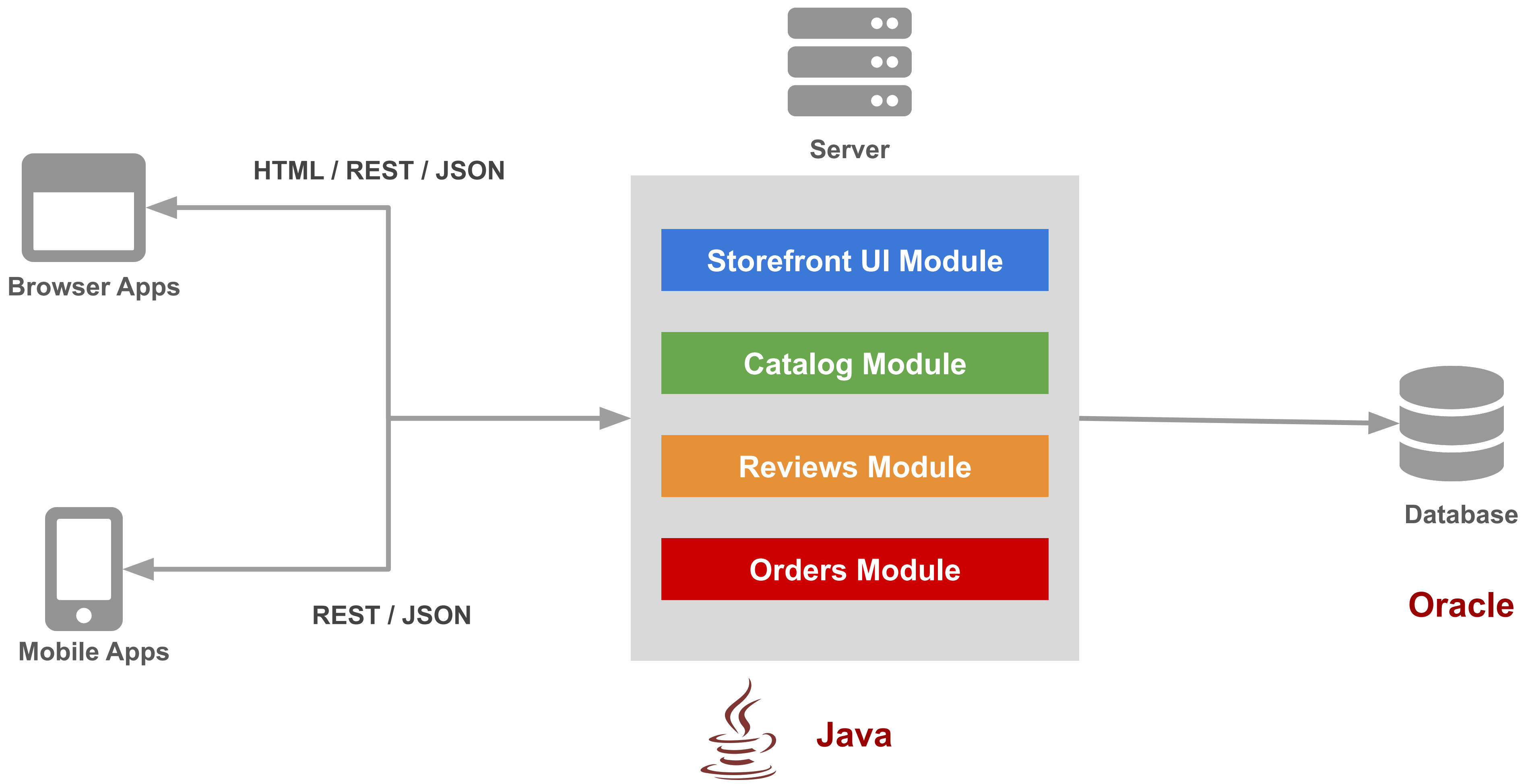
Conceptual Scenario

- Picture building a comprehensive application, such as an online store.

Traditional Approach

- Traditionality you would build this using a Monolithic Architecture

Monolithic Architecture



Monolithic Architecture - **Advantages**

Simplicity in Development:

Streamlined development process as most tools and IDEs natively support monolithic applications.

Ease of Deployment:

Hassle-free deployment with all components bundled into a single, unified package.

Scalability:

Easier to scale horizontally by replicating the entire application as a whole.

Monolithic Architecture - **Disadvantages**

Maintenance Challenges:

Complexity increases over time, making it harder to implement changes or find issues.

System Vulnerability:

A failure in a single component can lead to the collapse of the entire system.

Patching Difficulties:

Patching or updating specific modules can be cumbersome due to tightly-coupled components.

Monolithic Architecture - **Disadvantages**

Technology Lock-in:

Adopting new technologies or updating existing ones can be problematic due to interdependencies.

Slow Startup:

Increased startup time as all components must be initialized simultaneously.

Applications have changed dramatically

A decade ago

Apps were monolithic
Built on a single stack (e.g. .Net or Java)
Long lived
Deployed to a single server

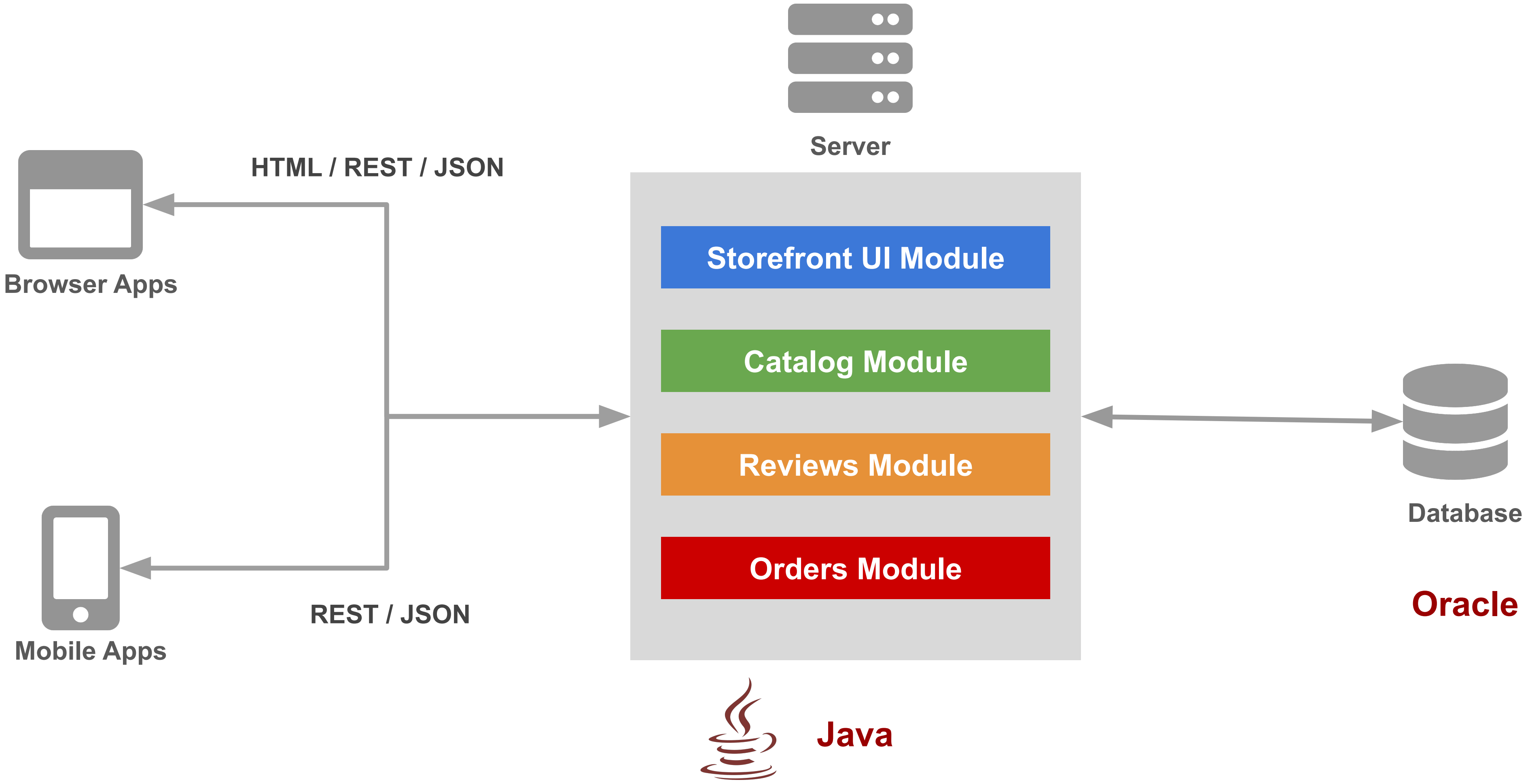
Today

Apps are constantly being developed
Build from loosely coupled components
Newer version are deployed often
Deployed to a multitude of servers

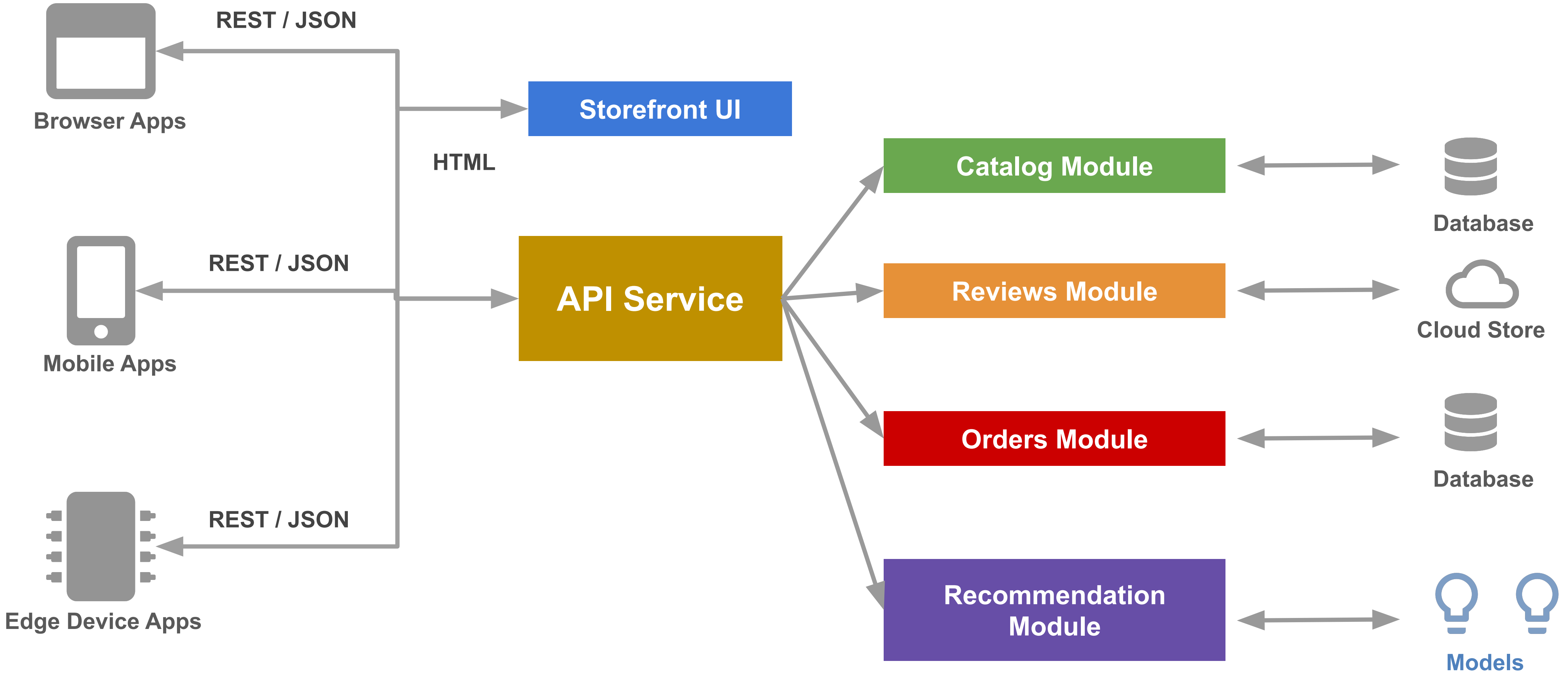
Data Science

Apps are being integrated with various data types/sources and models

Monolithic Architecture



Today: Microservice Architecture



Microservice Architecture - **Advantages**

Simplified Maintenance:

Modular design makes it easier to manage, update, and debug individual services.

Fault Isolation:

Independent components ensure that failure in one service doesn't bring down the entire application.

Streamlined Patching:

Easier to patch or update specific services without affecting the entire system.

Technological Flexibility:

Adapting to or adopting new technologies becomes seamless due to service independence.

Quick Startup:

Reduced startup time as all components can be initialized in parallel.

Microservice Architecture - **Disadvantages**

Development Complexity:

Varied technologies across components can complicate the development process.

Deployment Hurdles:

Multiple technologies and dependencies require a complex setup for deployment.

Scaling Concerns:

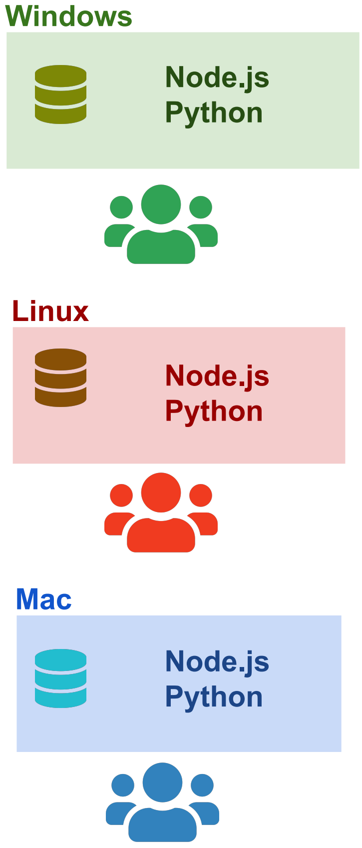
Scaling the entire application can be intricate due to disparate components.

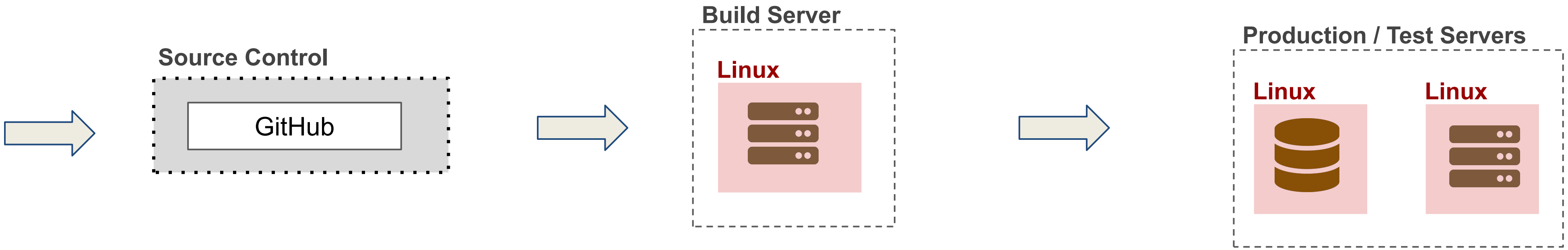
Docker + Kubernetes

Why use Containers?

- Consider a software development team workflow for developing an App
- Traditionality you would develop/build this independently in various machines (dev, test, qa, prod)

Software Development Workflow (no Docker)





Every team member moves code to source control

Build server needs to be **installed** with all required softwares/frameworks

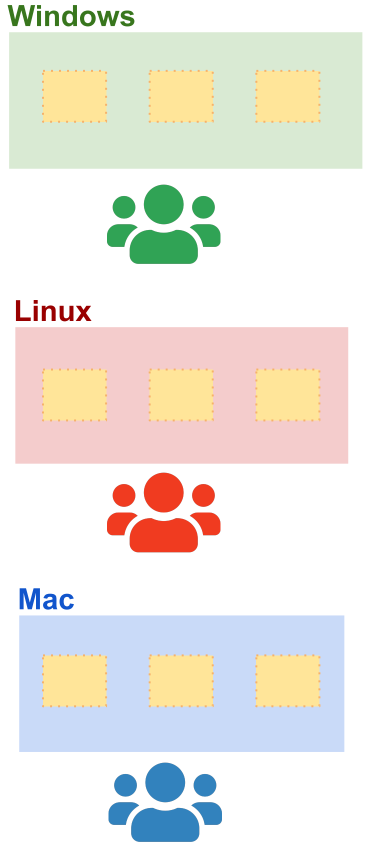
Production build is performed by pulling code from source control

Production server needs to be **installed** with all required softwares/frameworks

Production server will be different OS version than development machines

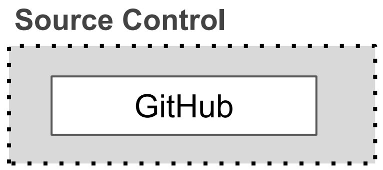
OS Specific **installation** in every developer machine

Software Development Workflow (with Docker)

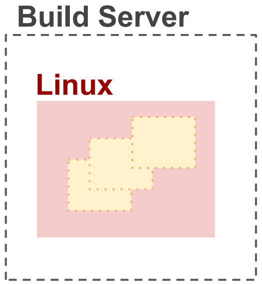


Development machines only needs **Docker installed**

Containers need to be setup only once

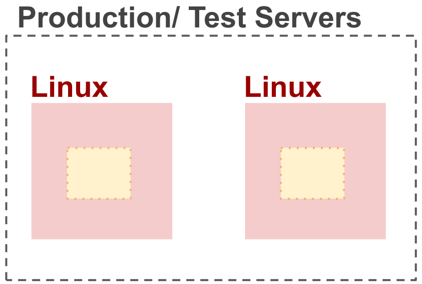


Every team member moves code to source control



Build server only needs **Docker installed**

Docker **images** are built for a release and pushed to **container registry**



Production server only needs **Docker installed**

Production server pulls Docker **images** from **container registry** and runs them

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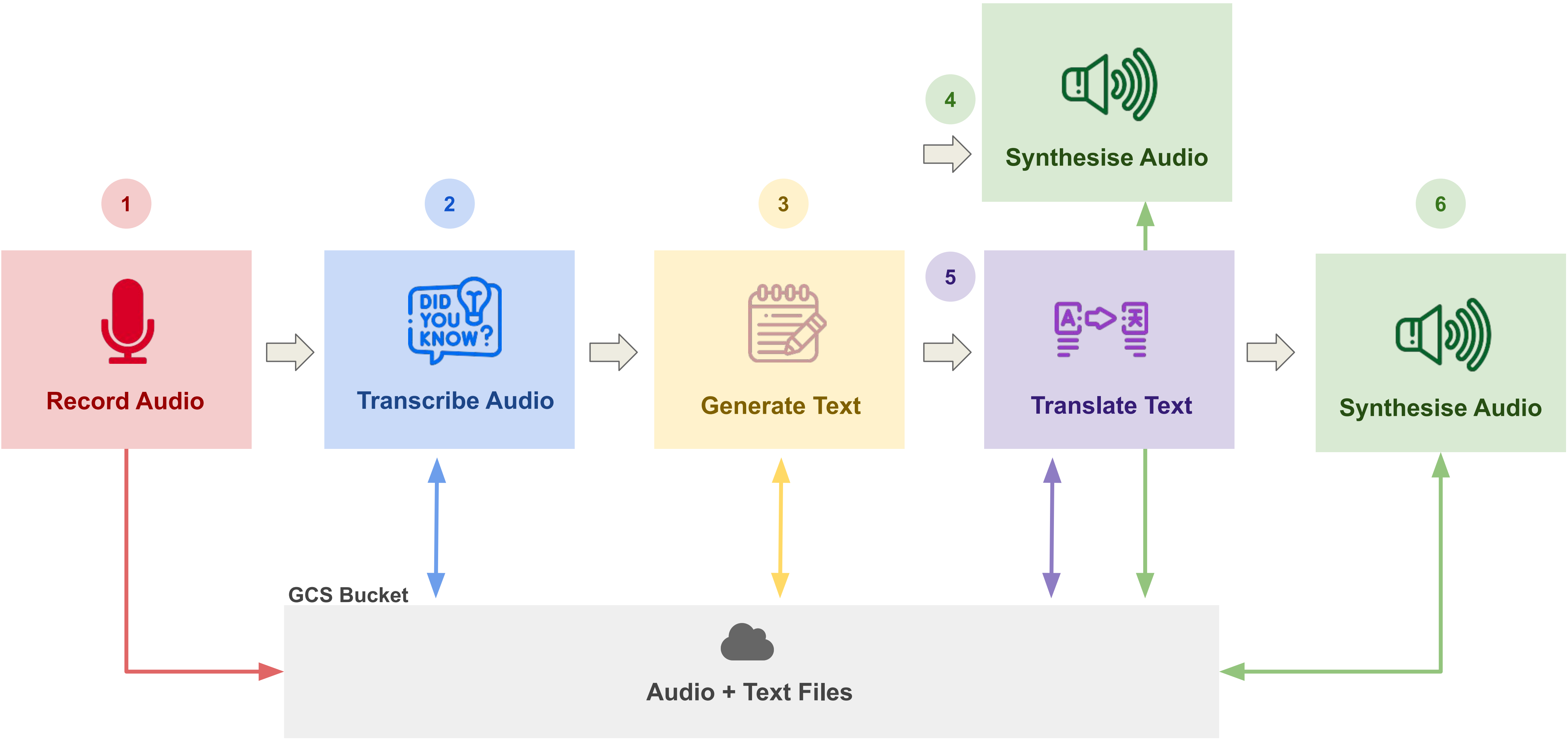
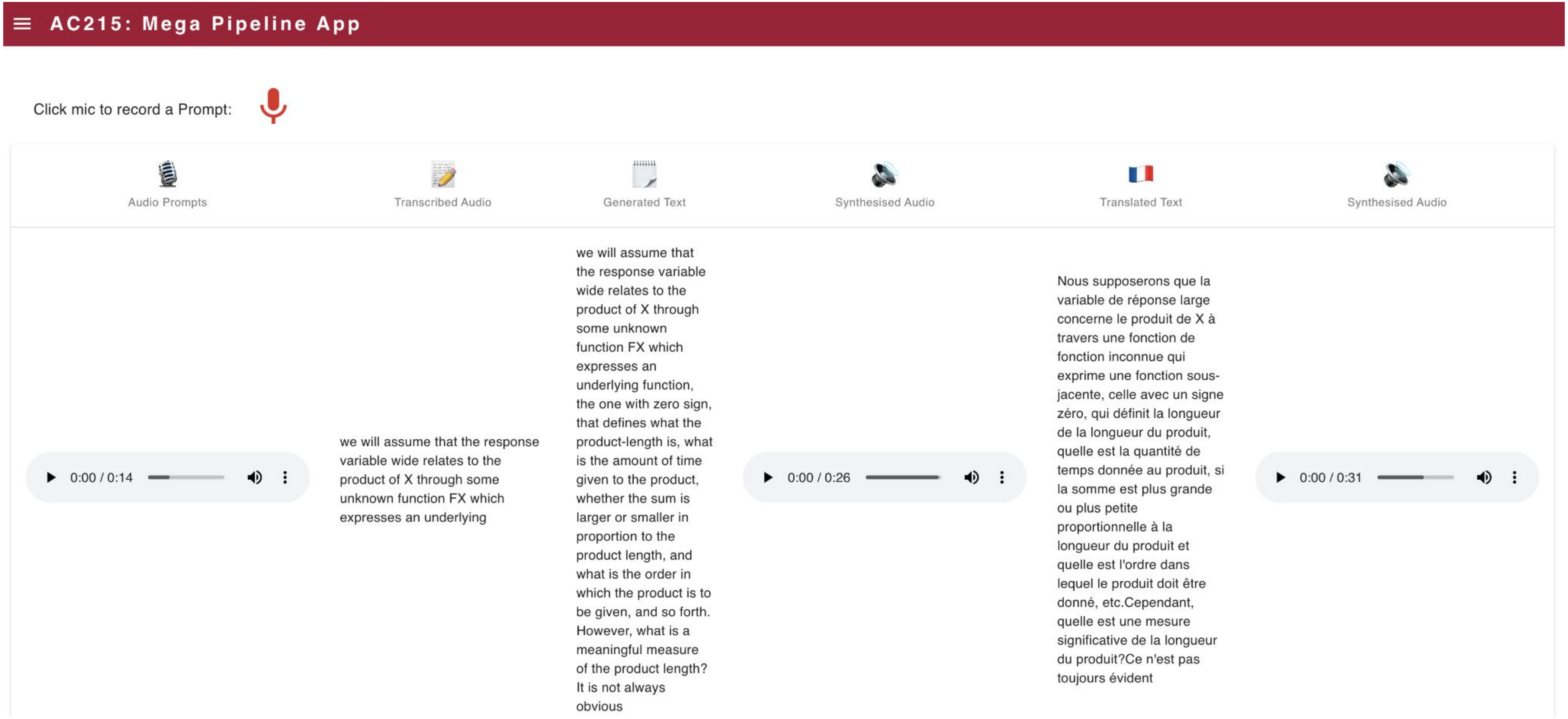
Tutorial - Building the Mega Pipeline App



Tutorial - Building the Mega Pipeline App



Tutorial - Building the Mega Pipeline App

- App: https://ac215-mega-pipeline.dlops.io/
- Teams
  - 📝Team A transcribe_audio:
  - 🗒️Team B generate_text:
  - 🔊Team C synthesis_audio_en:
  - 🇫🇷Team D translate_text:
  - 🔊Team E synthesis_audio:
- Instructions: https://github.com/dlops-io/mega-pipeline

THANK YOU