

# Project Report

---

Title: Causally Consistent Distributed Key-Value Store using Vector Clocks

Name: Muraliedhar / G24AI2014

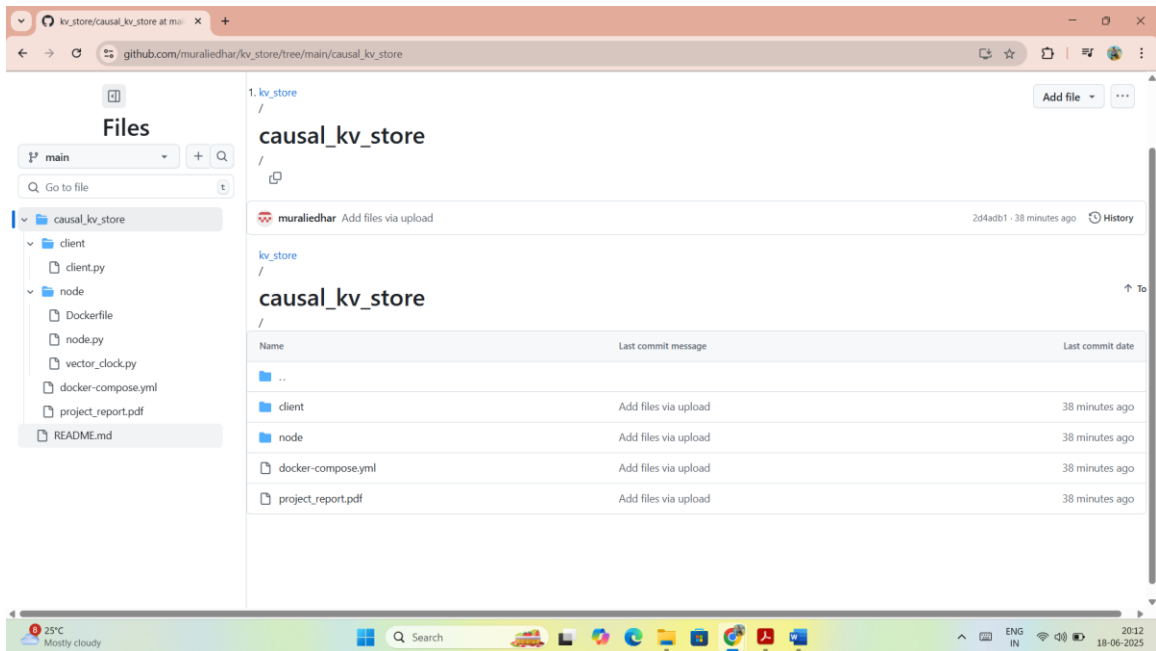
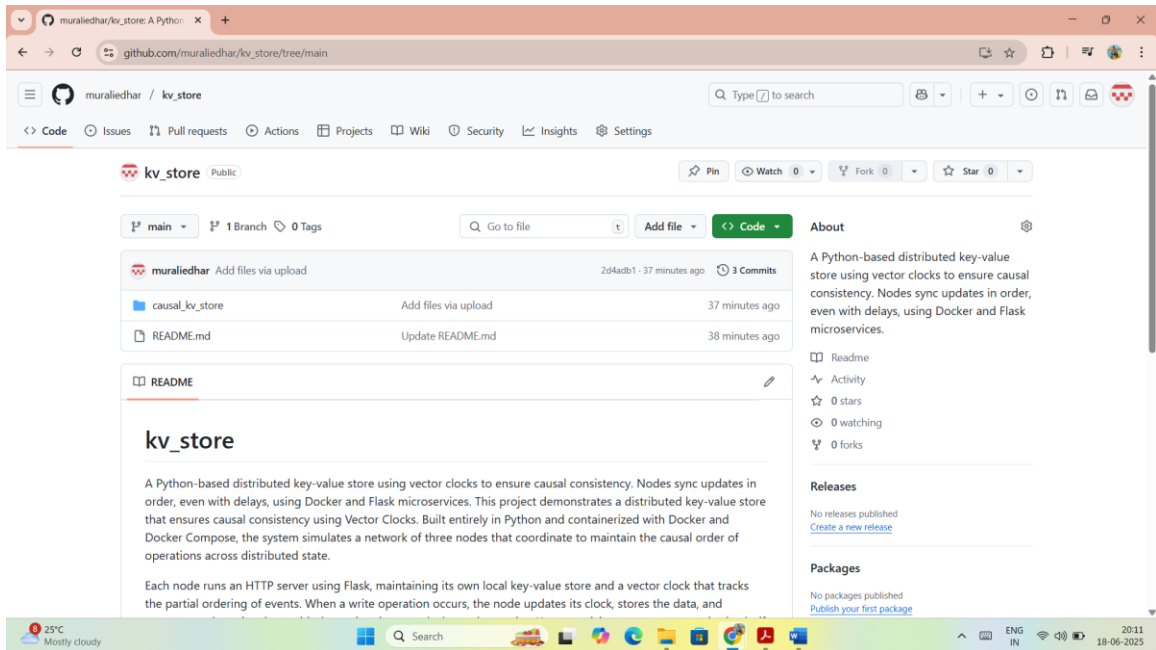
Course: Fundamentals of Distributed Systems

Date: 18 June 2025

**GIT HUB LINK :-**

**[https://github.com/muraliedhar/kv\\_store.git](https://github.com/muraliedhar/kv_store.git)**

## Screenshots:



## **. Introduction**

This project demonstrates a distributed key-value store that guarantees causal consistency using Vector Clocks. Each node in the system maintains its local key-value store and a vector clock to track causality across events. The goal is to ensure that write operations are processed in the correct causal order on all nodes.

## **2. System Architecture**

The system consists of three nodes implemented using Python and Flask, with each node maintaining a vector clock. All nodes are containerized using Docker and managed via Docker Compose. A client script coordinates the test scenario to demonstrate causal consistency.

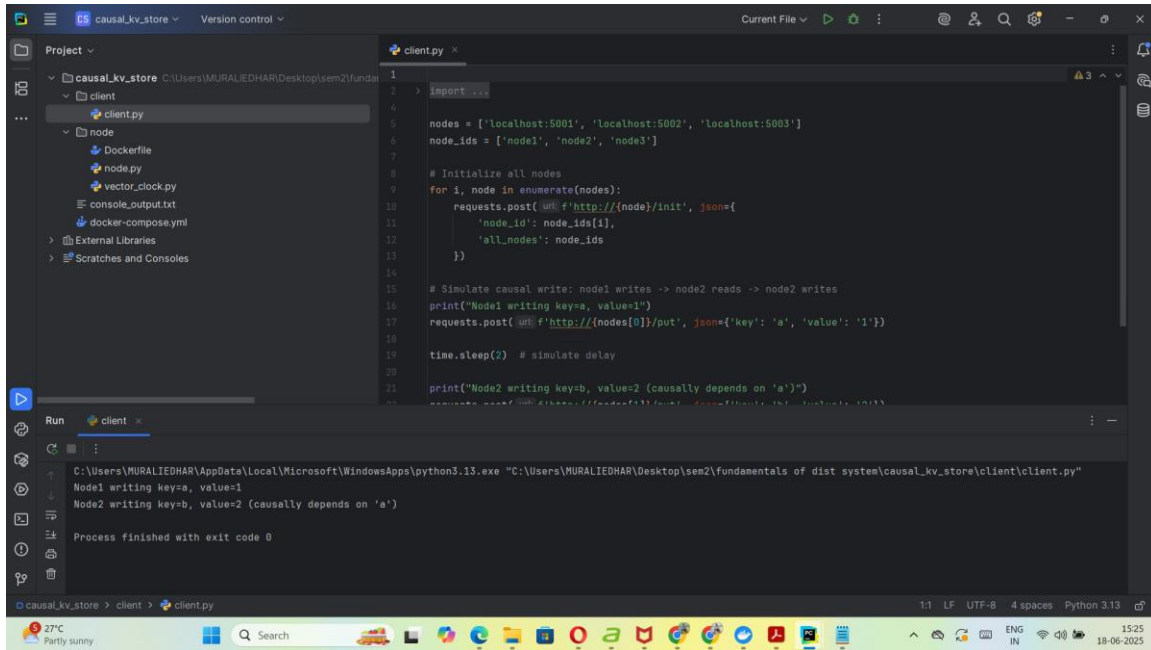
## **3. Implementation Details**

Each node has a REST API to handle writes and replication. Vector Clocks are updated on local events and merged when receiving messages. If causal dependencies are unmet, messages are buffered until all prior dependencies are fulfilled. Docker Compose orchestrates the deployment and networking between containers.

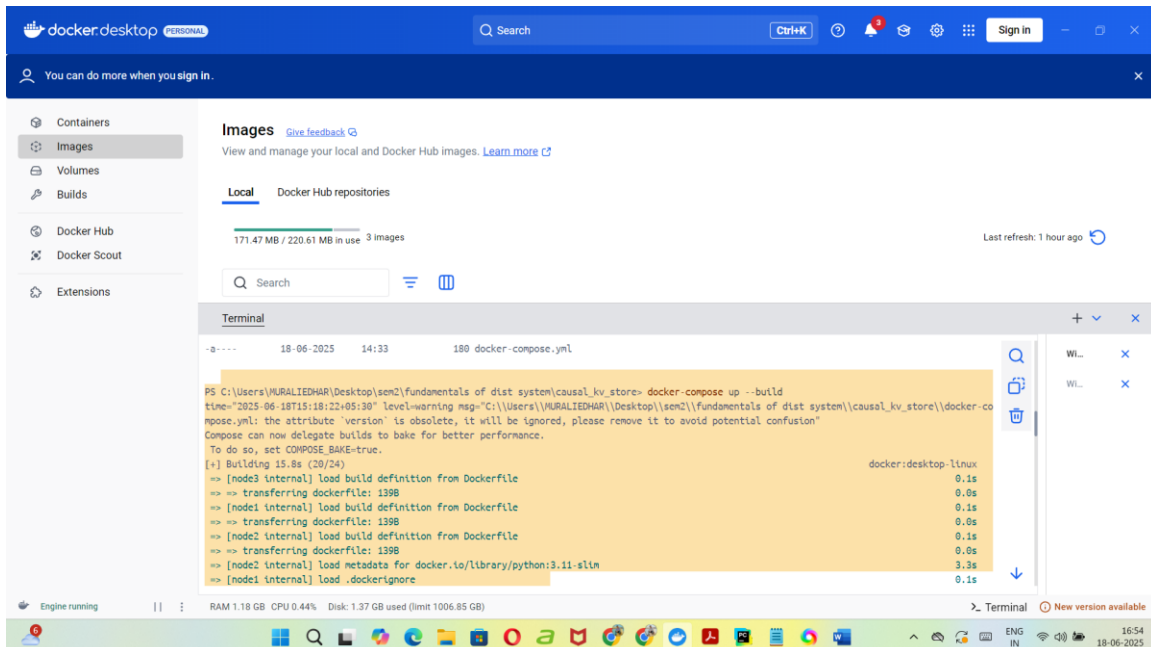
## **4. Test Scenario and Verification**

To test causal consistency, the client performs a write from node1 (key='a', value='1') and then initiates a dependent write from node2 (key='b', value='2'). This confirms that node2's operation is causally dependent on node1's write, and is applied only after node1's write is received.

## 5. PYCHARM – PROJECT STRUCTURE SCREENSHOT



## 6. Docker compose yaml execution



## Node 3;

The screenshot shows the Docker Desktop application window. The left sidebar contains navigation options: Containers, Images, Volumes, Builds, Docker Hub, Docker Scout, and Extensions. The main area is titled 'Images' and shows 'Local' Docker Hub repositories. A progress bar indicates 171.47 MB / 220.61 MB in use for 3 images. Below this is a search bar and a list of images. The 'Terminal' tab is active, displaying the logs for 'node3'. The logs show the following output:

```
node2-1 | * Debug mode: off
node2-1 | WARNING: This is a development server. Do not use it in a production deployment. Use a production MSGI server instead.
node2-1 | * Running on all addresses (0.0.0.0)
node2-1 | * Running on http://127.0.0.1:5000
node2-1 | * Running on http://172.18.0.2:5000
node2-1 | Press CTRL+C to quit
PS C:\Users\HURALIEDHAR\Desktop\sem2\fundamentals of dist system\causal_kv_store> docker-compose logs node3
time="2025-06-18T15:23:40+05:30" level=warning msg="C:\Users\HURALIEDHAR\Desktop\sem2\fundamentals of dist system\causal_kv_store\docker-co
mpose.yml: the attribute 'version' is obsolete, it will be ignored, please remove it to avoid potential confusion"
node3-1 | * Serving Flask app 'node'
node3-1 | * Debug mode: off
node3-1 | WARNING: This is a development server. Do not use it in a production deployment. Use a production MSGI server instead.
node3-1 | * Running on all addresses (0.0.0.0)
node3-1 | * Running on http://127.0.0.1:5000
node3-1 | * Running on http://172.18.0.4:5000
node3-1 | Press CTRL+C to quit
PS C:\Users\HURALIEDHAR\Desktop\sem2\fundamentals of dist system\causal_kv_store>
```

The bottom status bar shows 'Engine running', RAM 1.16 GB, CPU 0.06%, and Disk 1.37 GB used (limit 1006.85 GB). The system tray shows a temperature of 27°C, weather 'Partly sunny', and the date '18-06-2025'.

## Node 2:

The screenshot shows the Docker Desktop application window. The left sidebar contains navigation options: Containers, Images, Volumes, Builds, Docker Hub, Docker Scout, and Extensions. The main area is titled 'Images' and shows 'Local' Docker Hub repositories. A progress bar indicates 171.47 MB / 220.61 MB in use for 3 images. Below this is a search bar and a list of images. The 'Terminal' tab is active, displaying the logs for 'node2'. The logs show the following output:

```
node1-1 | * Debug mode: off
node1-1 | WARNING: This is a development server. Do not use it in a production deployment. Use a production MSGI server instead.
node1-1 | * Running on all addresses (0.0.0.0)
node1-1 | * Running on http://127.0.0.1:5000
node1-1 | * Running on http://172.18.0.3:5000
node1-1 | Press CTRL+C to quit
PS C:\Users\HURALIEDHAR\Desktop\sem2\fundamentals of dist system\causal_kv_store> docker-compose logs node2
time="2025-06-18T15:23:39+05:30" level=warning msg="C:\Users\HURALIEDHAR\Desktop\sem2\fundamentals of dist system\causal_kv_store\docker-co
mpose.yml: the attribute 'version' is obsolete, it will be ignored, please remove it to avoid potential confusion"
node2-1 | * Serving Flask app 'node'
node2-1 | * Debug mode: off
node2-1 | WARNING: This is a development server. Do not use it in a production deployment. Use a production MSGI server instead.
node2-1 | * Running on all addresses (0.0.0.0)
node2-1 | * Running on http://127.0.0.1:5000
node2-1 | * Running on http://172.18.0.2:5000
node2-1 | Press CTRL+C to quit
PS C:\Users\HURALIEDHAR\Desktop\sem2\fundamentals of dist system\causal_kv_store>
```

The bottom status bar shows 'Engine running', RAM 1.16 GB, CPU 0.06%, and Disk 1.37 GB used (limit 1006.85 GB). The system tray shows a temperature of 27°C, weather 'Partly sunny', and the date '18-06-2025'.

## Node 1:

The screenshot shows the Docker Desktop interface. The left sidebar contains navigation options: Containers, Images (selected), Volumes, Builds, Docker Hub, Docker Scout, and Extensions. The main area is titled 'Images' and shows 'Local' Docker Hub repositories. A search bar is present. Below the search bar, a terminal window is open, displaying the output of the command 'docker-compose logs node1'. The terminal output shows a warning message: 'WARNING: This is a development server. Do not use it in a production deployment. Use a production MSGI server instead.' and the application is running on http://127.0.0.1:5000. The bottom status bar indicates 'Engine running', 'RAM 1.16 GB', 'CPU 0.06%', and 'Disk: 1.37 GB used (limit 1006.85 GB)'. The system tray shows the date and time as 15:23 on 18-06-2025.

## ALL IMAGES CREATED THROUGH YAML :

The screenshot shows the Docker Desktop interface with the 'Images' tab selected. The main area displays a list of images created through YAML. The table below shows the details of these images:

Name	Tag	Image ID	Created	Size	Actions
causal_kv_store-node1	latest	ad0bdf270e76	33 seconds ago	227.72 MB	[Play] [More] [Delete]
causal_kv_store-node3	latest	8785821a1982	33 seconds ago	227.72 MB	[Play] [More] [Delete]
causal_kv_store-node2	latest	4b98b6aa7aa7	33 seconds ago	227.72 MB	[Play] [More] [Delete]

Below the table, a terminal window is open, showing the output of the command 'docker-compose logs node1'. The terminal output shows the application is running on http://127.0.0.1:5000. The bottom status bar indicates 'Engine running', 'RAM 1.11 GB', 'CPU 0.00%', and 'Disk: 1.37 GB used (limit 1006.85 GB)'. The system tray shows the date and time as 15:19 on 18-06-2025.

Containers

Images

Volumes

Builds

Docker Hub

Docker Scout

Extensions

docker desktopPERSONAL

Search

Ctrl+K

Sign in

You can do more when you sign in.

Images

Give feedback

View and manage your local and Docker Hub images. [Learn more](#)

171.47 MB / 220.61 MB in use 3 images

Last refresh: 1 hour ago

Search

	Name ↑	Tag	Image ID	Created	Size	Actions
<input type="checkbox"/>	causal_kv_store-node1	latest	ad0bdf270e76	33 seconds ago	227.72 MB	<div></div> <div></div> <div></div>
<input type="checkbox"/>	causal_kv_store-node3	latest	8785821a1982	33 seconds ago	227.72 MB	<div></div> <div></div> <div></div>
<input type="checkbox"/>	causal_kv_store-node2	latest	4b98b6aa7aa7	33 seconds ago	227.72 MB	<div></div> <div></div> <div></div>

Terminal

+ - x

node3-1 | \* Debug mode: off  
node1-1 | Press CTRL+C to quit  
node3-1 | WARNING: This is a development server. Do not use it in a production deployment. Use a production WSGI server instead.  
node3-1 | \* Running on all addresses (0.0.0.0)  
node3-1 | \* Running on http://127.0.0.1:5000  
node3-1 | \* Running on http://172.18.0.4:5000  
node3-1 | Press CTRL+C to quit

View in Docker Desktop

View Config

Enable Watch

Engine running

RAM: 1.56 GB CPU: 0.19% Disk: 1.37 GB used (limit 1006.85 GB)

Terminal

New version available

27°C

Partly sunny

Search

ENG IN

15:19

18-06-2025

## Containers :

Containers

Images

Volumes

Builds

Docker Hub

Docker Scout

Extensions

docker desktopPERSONAL

Search

Ctrl+K

Sign in

You can do more when you sign in.

Containers

Give feedback

View all your running containers and applications. [Learn more](#)

Search

Only show running containers

	Name	Container ID	Image	Port(s)	CPU (%)	Last started	Actions
<input type="checkbox"/>	causal_kv_store	-	-	-	0.06%	23 seconds ago	<div></div> <div></div> <div></div>
<input type="checkbox"/>	node1-1	e46c1714ca50	causal_kv_store-node1	5001:5000	0.02%	23 seconds ago	<div></div> <div></div> <div></div>
<input type="checkbox"/>	node3-1	6316fbb8a8d2	causal_kv_store-node3	5003:5000	0.02%	23 seconds ago	<div></div> <div></div> <div></div>
<input type="checkbox"/>	node2-1	5a369c44c632	causal_kv_store-node2	5002:5000	0.02%	23 seconds ago	<div></div> <div></div> <div></div>

Showing 4 items

Terminal

+ - x

node2-1 | WARNING: This is a development server. Do not use it in a production deployment. Use a production WSGI server instead.  
node2-1 | \* Running on all addresses (0.0.0.0)  
node2-1 | \* Running on http://127.0.0.1:5000  
node2-1 | \* Running on http://172.18.0.2:5000  
node2-1 | Press CTRL+C to quit  
node1-1 | \* Serving Flask app 'node'  
node1-1 | \* Debug mode: off  
node1-1 | WARNING: This is a development server. Do not use it in a production deployment. Use a production WSGI server instead.  
node1-1 | \* Running on all addresses (0.0.0.0)  
node1-1 | \* Running on http://127.0.0.1:5000

View in Docker Desktop

View Config

Enable Watch

Engine running

RAM: 1.56 GB CPU: 0.13% Disk: 1.37 GB used (limit 1006.85 GB)

Terminal

New version available

27°C

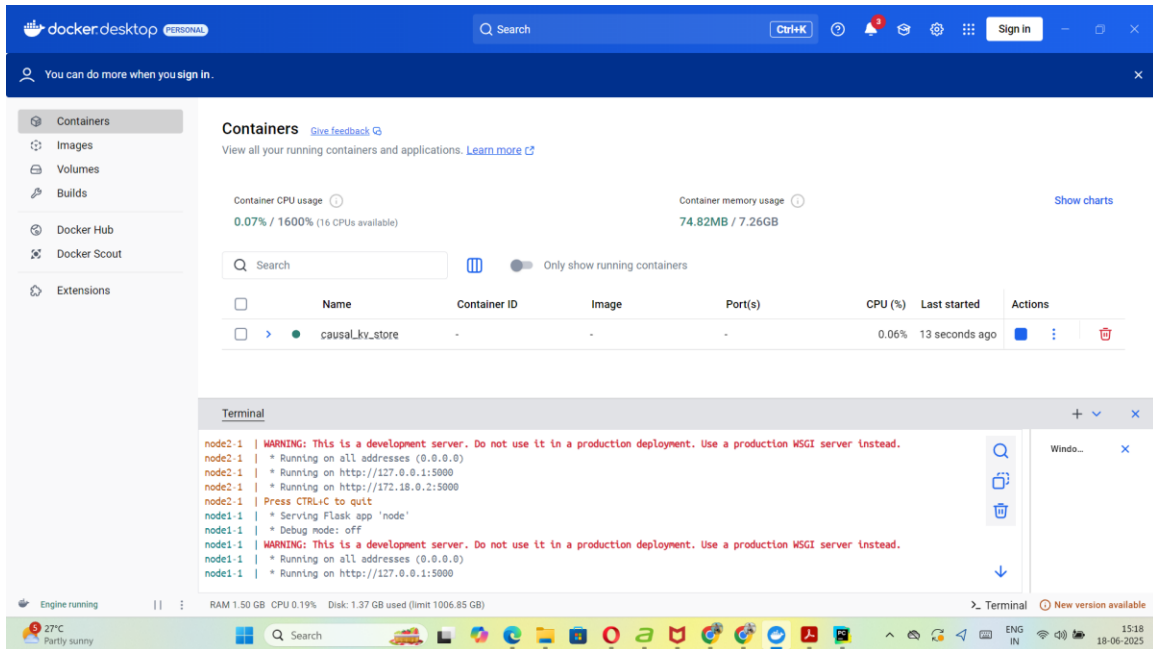
Partly sunny

Search

ENG IN

15:19

18-06-2025



## 6. Conclusion

This project successfully demonstrates causal consistency in a distributed system using vector clocks. The buffer mechanism ensures that operations are only applied once all causal dependencies are met. Further improvements could include UI visualization, adding fault tolerance, or scaling the system to more nodes.