

Project Report

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

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Course: Fundamentals of Distributed Systems

Date: 18 June 2025

GIT HUB LINK :-

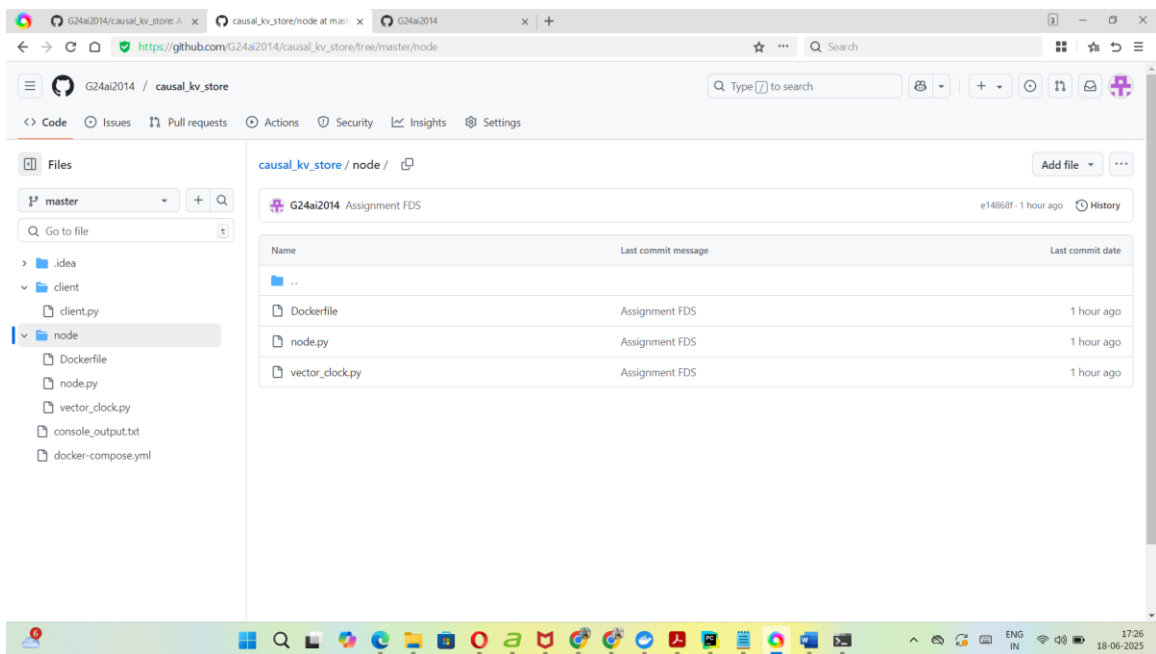
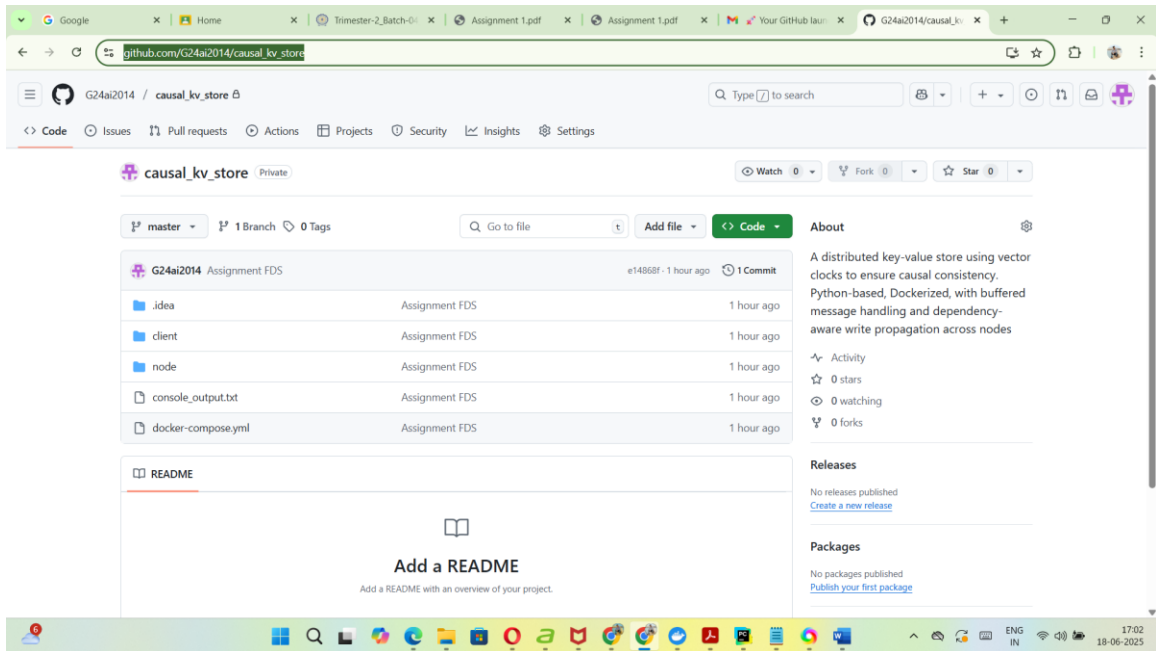
https://github.com/G24ai2014/causal_kv_store.git

ZIP FILE OF PROJECT :



causal_kv_store.zip

Screenshots:



1. 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.

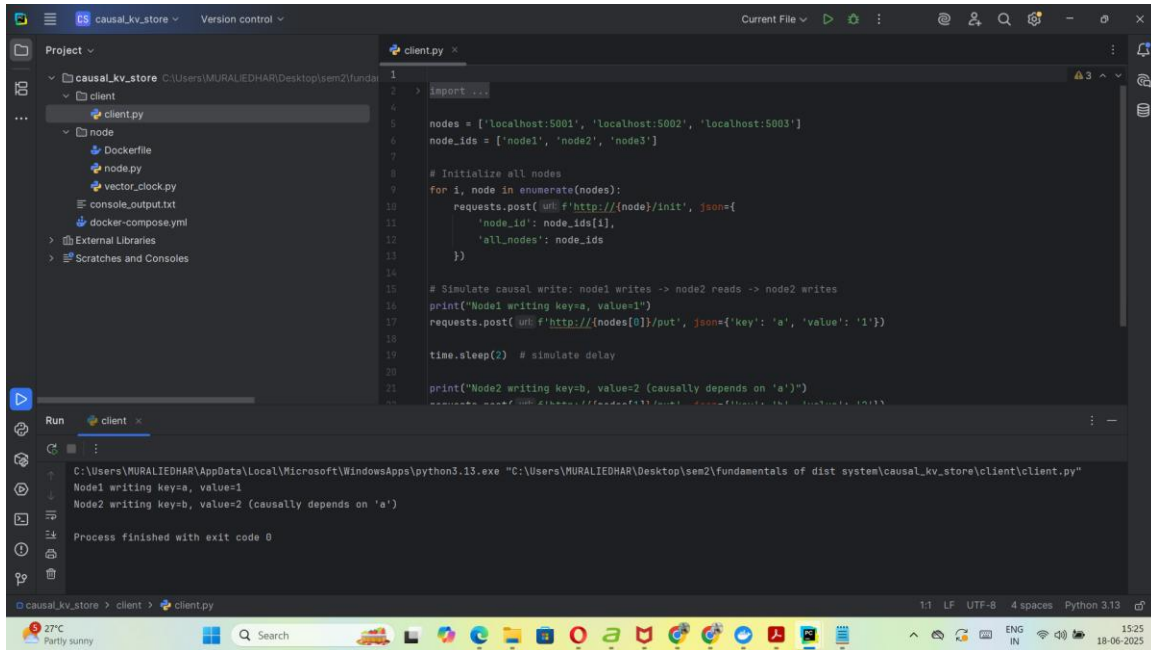
3. Implementation Details

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.

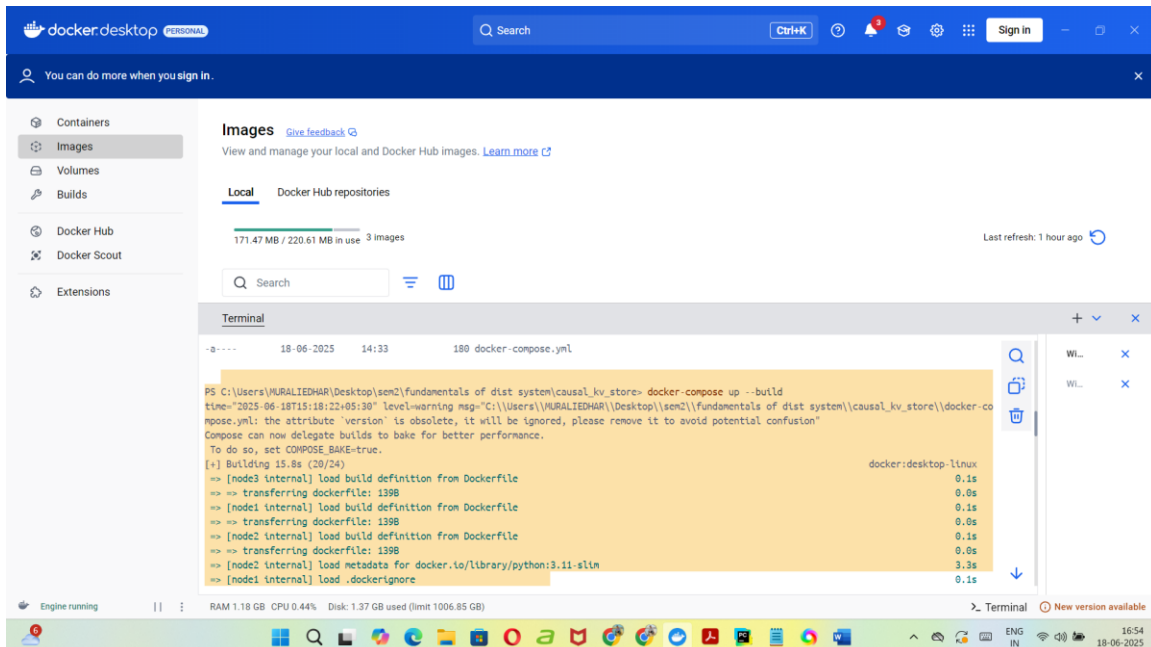
4. Test Scenario and Verification

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 interface. 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 'Terminal' tab. The terminal displays 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 interface. 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 'Terminal' tab. The terminal displays 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:

Images [Give feedback](#)

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

Local Docker Hub repositories

171.47 MB / 220.61 MB in use 3 Images Last refresh: 1 hour ago

Search

Terminal

```
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\sen2\fundamentals of dist system\causal_kv_store> docker-compose logs node1
time="2025-06-18T15:23:22+05:30" level=warning msg="C:\Users\HURALIEDHAR\Desktop\sen2\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"
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 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\sen2\fundamentals of dist system\causal_kv_store>
```

ALL IMAGES CREATED THROUGH YAML :

Images [Give feedback](#)

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

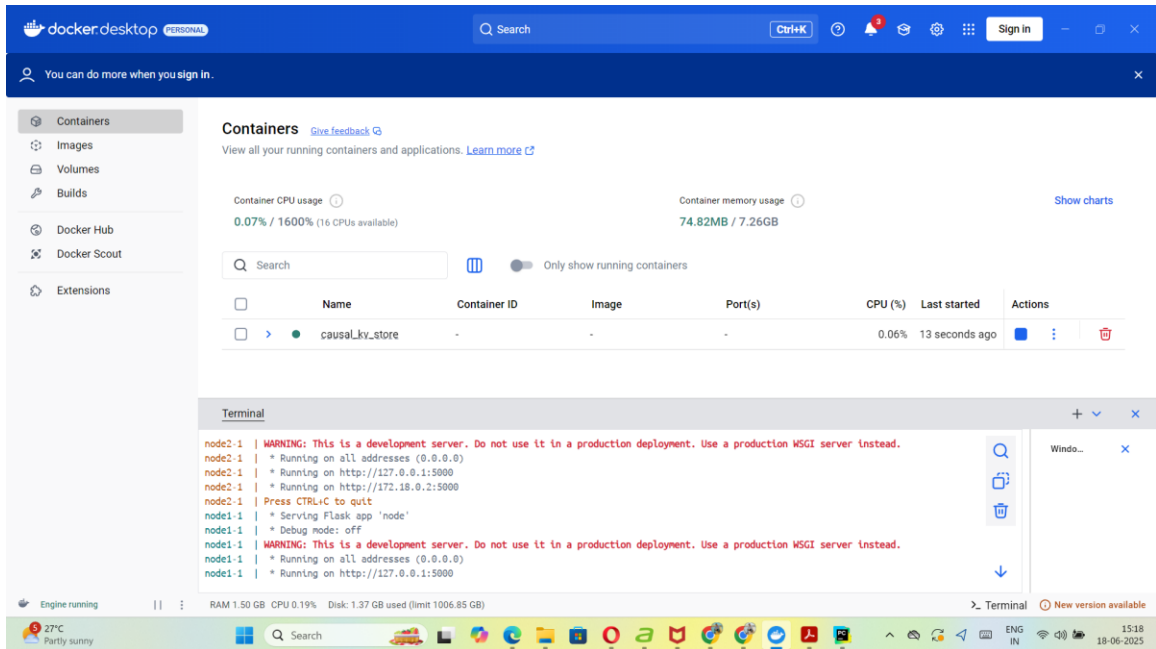
171.47 MB / 220.61 MB in use 3 Images Last refresh: 1 hour ago

Search

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

Terminal

```
=> [node2] resolving provenance for metadata file 0.1s
=> [node3] resolving provenance for metadata file 0.0s
[+] Running 7/7
✓ node1 Built 0.0s
✓ node2 Built 0.0s
✓ node3 Built 0.0s
✓ Network causal_kv_store_default Created 0.1s
✓ Container causal_kv_store-node3-1 Created 0.5s
✓ Container causal_kv_store-node1-1 Created 0.5s
✓ Container causal_kv_store-node2-1 Created 0.5s
```

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.