Project Report

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

Name: Muraliedhar / G24AI2014

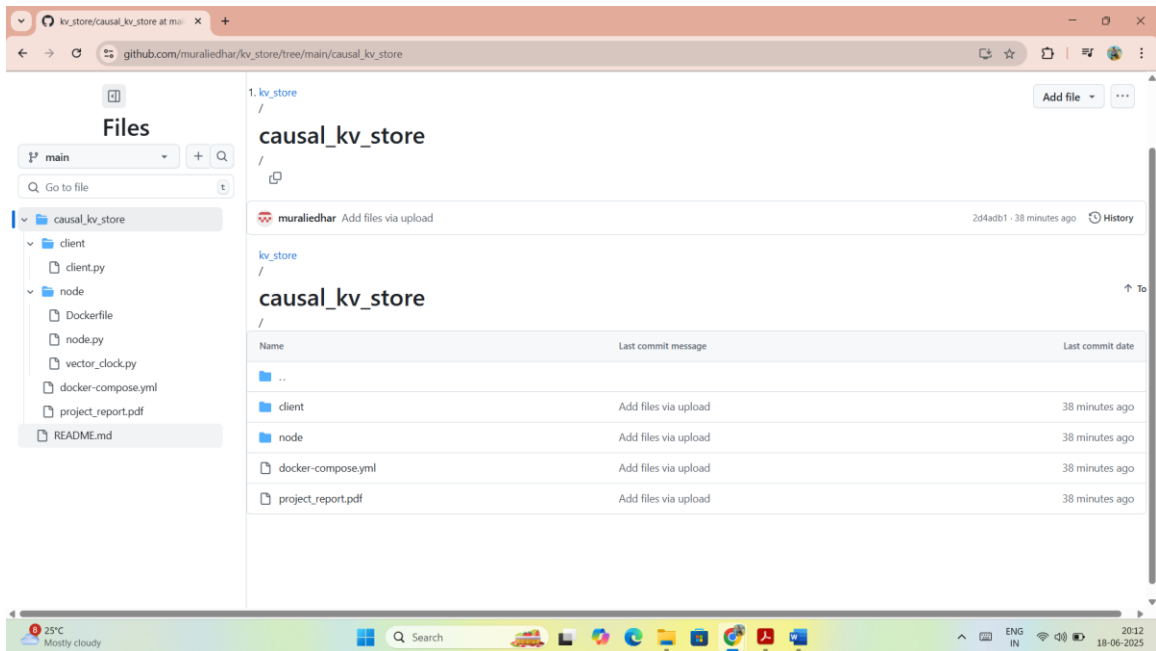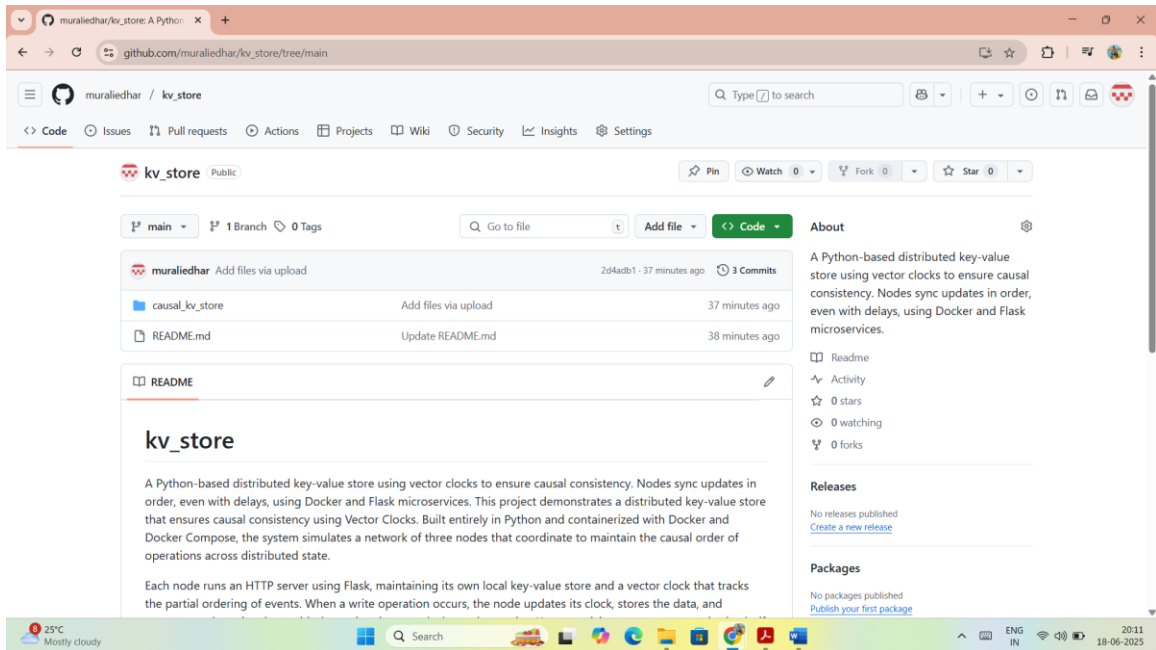Course: Fundamentals of Distributed Systems

Date: 18 June 2025

GIT HUB LINK :-

https://github.com/muraliedhar/kv_store.git

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.
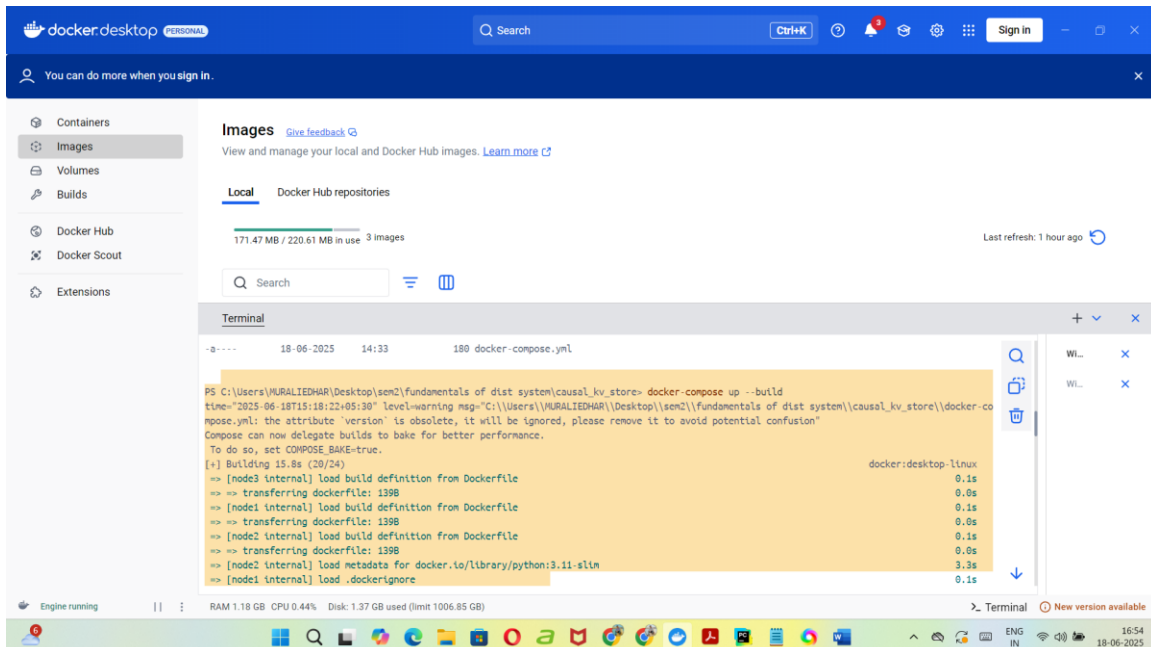
4. Test Scenario and Verification

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
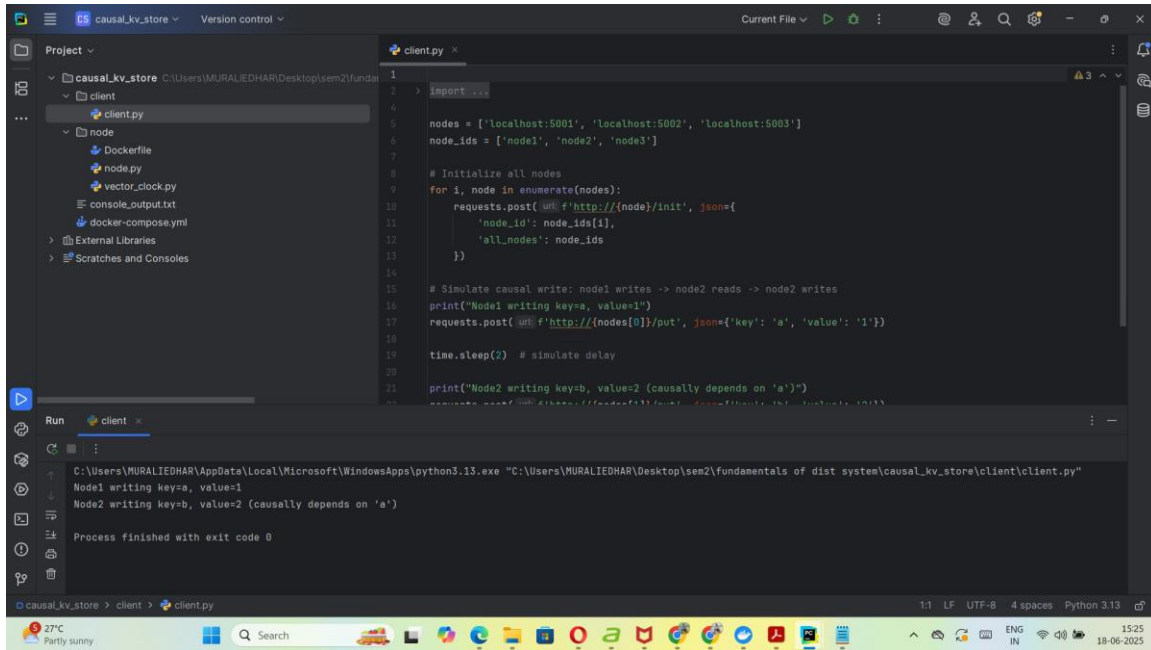
6. Docker compose yaml execution

Node 3;

Node 2:

Node 1:

ALL IMAGES CREATED THROUGH YAML :

Containers :
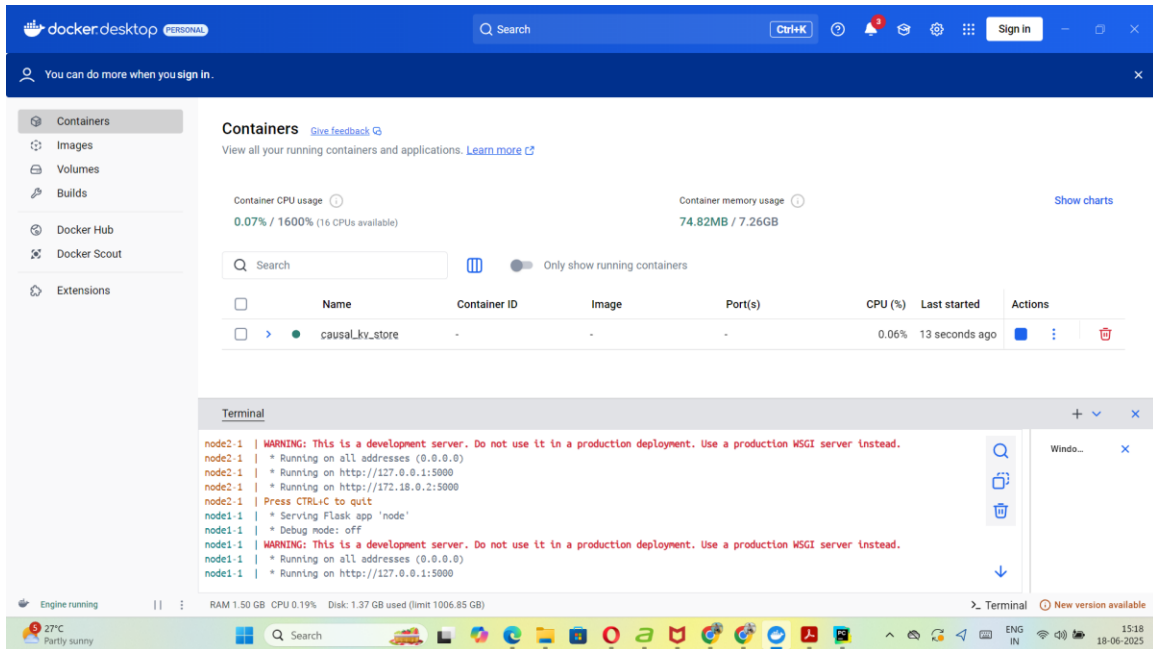
6. Conclusion

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.