COMPSCI 677 : Distributed And Operating Systems
Lab 3 : Asterix and Multi-Trader Trouble

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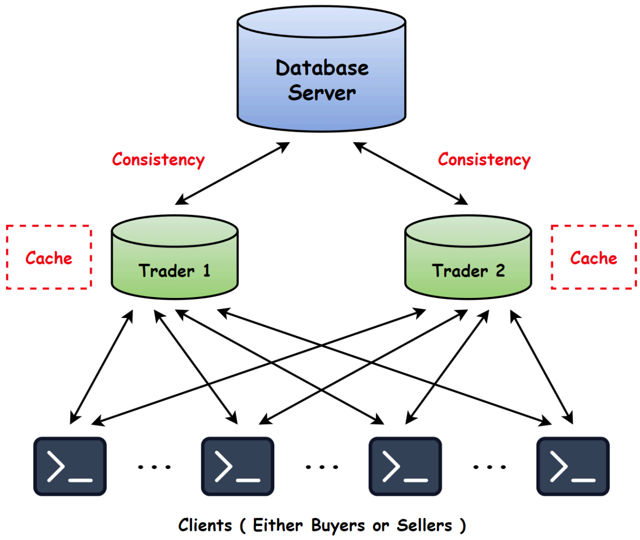
1. DESIGN DESCRIPTION



1.1. Peer Structure And Communication :

Peers run as isolated processes using Python's Multiprocessing module, ensuring no shared memory. Communication between peers occurs via interprocess messaging, simulating a distributed environment where peers interact as if they are running on separate machines.

1.2. Database Server Process :

The warehouse is implemented as a separate database server process, using a .json file to store inventory data (item names and quantities). Traders communicate with the warehouse to process buy and sell requests. Synchronous updates ensure consistency, and locks manage concurrent access to avoid race conditions.

1.3. Traders Electing Procedure :

Two traders are elected using the Bully algorithm as implemented in Lab 2. The first election determines the primary trader. The second election is triggered with the primary trader excluded, allowing the next highest-priority peer to be elected as the secondary trader. Both traders operate independently after elections.

1.4. Trading Process :

Buyers and sellers interact with traders based on their assigned roles :

- **Buy Requests :** Traders first check their local cache to determine availability and approve or deny the request. Transactions are logged in trader-specific .txt files.
- **Sell Requests :** Sellers deposit goods via traders, updating the local cache. Synchronization with the warehouse occurs to reflect updates in global inventory.

1.5. Cache Consistency Model :

A push and stateless model is implemented, where sell requests are cached by the trader and used to respond to subsequent buy requests. Both buy and sell requests are forwarded to the warehouse, which updates the inventory state and pushes the new state to active traders whenever a product is registered or sold. This approach ensures cache consistency between the warehouse and traders. Each product is managed with a priority queue ordered by Lamport clocks, allowing traders to handle buy and sell requests sequentially and in a globally consistent order.

1.6. Heartbeat Protocol :

Traders monitor each other's availability using a heartbeat protocol :

- Heartbeat messages are exchanged every 5 seconds.
- If no response is received within 5 seconds, the trader is marked as down, and peers update the failed trader's status to inactive. Active traders broadcast the failure status to ensure consistency.

1.7. Fault Tolerance :

When a trader fails, pending requests are reassigned to the active trader. The heartbeat protocol ensures quick detection and failover. When a trader fails, the remaining trader reads the queue of the failed trader and merges it with its own and starts serving the requests from the merged queue.

2. DESIGN TRADE-OFFS

- **Periodic (vs) On-Demand Synchronization :** Periodic synchronization reduces communication overhead but may lead to cache inconsistencies. On-demand synchronization would offer better accuracy but increase latency.

- **Two Elections For Two Leaders :** Using two elections simplifies implementation but increases message exchanges and election time. A single election could reduce time but would add significant complexity to handle dual leader selection.
- **Bully Algorithm For Elections :** The Bully algorithm is simple to implement but assumes reliable message delivery. More robust algorithms like the Ring algorithm may handle network failures more effectively in larger systems.

3. HOW TO EXECUTE MY SUBMISSION (also please go through README.md)

- Download and extract the provided zip file. Navigate to the project directory
- Ensure Python version >= 3.5 is installed on your system using `python --version`
- Run `pip install -r requirements.txt` to install the required dependencies
- For Windows users : Execute `python windows_run.py` and specify number of nodes: <value>
  For Mac or Linux users : Execute `python run_nodes.py` and specify number of nodes: <value>
- Note: For Mac users, Set up a virtual environment in the code directory, install dependencies from requirements.txt, and create directories named peer{i} (e.g., peer1, peer2, ...) for the number of peers, typically 6 and peer51 for the warehouse reflective of its port number.

4. POSSIBLE IMPROVEMENTS

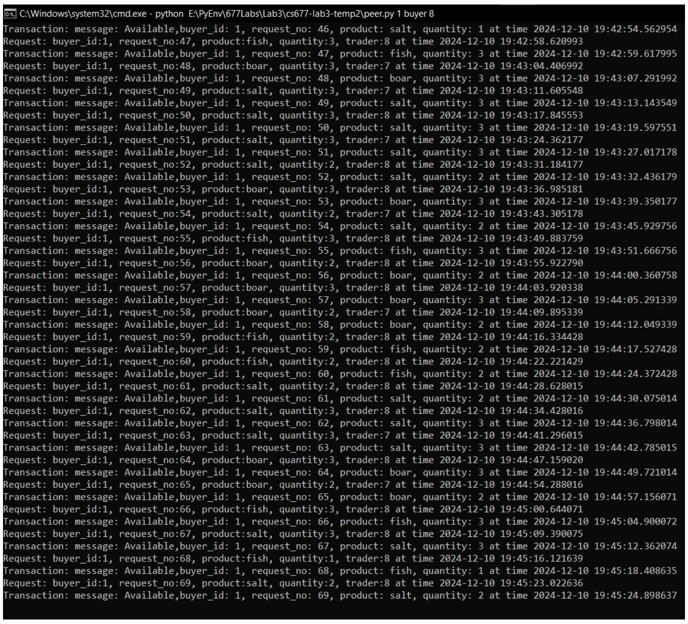
- Implementing dynamic trader replication based on workload (e.g., auto-scaling with cloud instances) to handle increased buyer or seller activity efficiently.
- Incorporating stronger consistency models, such as linearizability or quorum-based protocols, to further reduce overselling while maintaining performance.
- Adding mechanisms to replay or recover partially completed requests during trader failures to ensure no data or transaction is lost.

5. TESTS AND OUTPUTS

5.1. Tests : We conducted several tests to verify the implementation's correctness. The codebase meets the following key requirements (most of the edge cases and error handling are covered) :

- Handling overselling when multiple buyers request the same product with outdated cache data.
- Detecting false-positive trader failures due to network latency in the heartbeat protocol.
- Reprocessing unhandled requests perfectly during trader failover without duplicates or data loss.
- Preventing deadlocks in warehouse request queues under high-concurrency conditions.
- Managing partial inventory fulfillment when only part of a buyer's requested quantity is available.

5.2. Output :



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C:\Windows\system32\cmd.exe - python  E:\PyEnv\677Labs\Lab3\cs677-lab3-temp2\peer.py 1 buyer 8
Transaction: message: Available,buyer_id: 1, request_no: 46, product: salt, quantity: 1 at time 2024-12-10 19:42:54.562954
Request: buyer_id:1, request_no:47, product:fish, quantity:3, trader:8 at time 2024-12-10 19:42:58.620993
Transaction: message: Available,buyer_id: 1, request_no: 47, product: fish, quantity: 3 at time 2024-12-10 19:42:59.617995
Request: buyer_id:1, request_no:48, product:boar, quantity:3, trader:7 at time 2024-12-10 19:43:04.406992
Transaction: message: Available,buyer_id: 1, request_no: 48, product: boar, quantity: 3 at time 2024-12-10 19:43:07.291992
Request: buyer_id:1, request_no:49, product:salt, quantity:3, trader:7 at time 2024-12-10 19:43:11.605548
Transaction: message: Available,buyer_id: 1, request_no: 49, product: salt, quantity: 3 at time 2024-12-10 19:43:13.143549
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Transaction: message: Available,buyer_id: 1, request_no: 50, product: salt, quantity: 3 at time 2024-12-10 19:43:19.597551
Request: buyer_id:1, request_no:51, product:salt, quantity:3, trader:7 at time 2024-12-10 19:43:24.362177
Transaction: message: Available,buyer_id: 1, request_no: 51, product: salt, quantity: 3 at time 2024-12-10 19:43:27.017178
Request: buyer_id:1, request_no:52, product:salt, quantity:2, trader:8 at time 2024-12-10 19:43:31.184177
Transaction: message: Available,buyer_id: 1, request_no: 52, product: salt, quantity: 2 at time 2024-12-10 19:43:32.436179
Request: buyer_id:1, request_no:53, product:boar, quantity:3, trader:8 at time 2024-12-10 19:43:36.985181
Transaction: message: Available,buyer_id: 1, request_no: 53, product: boar, quantity: 3 at time 2024-12-10 19:43:39.350177
Request: buyer_id:1, request_no:54, product:salt, quantity:2, trader:7 at time 2024-12-10 19:43:43.305178
Transaction: message: Available,buyer_id: 1, request_no: 54, product: salt, quantity: 2 at time 2024-12-10 19:43:45.929756
Request: buyer_id:1, request_no:55, product:fish, quantity:3, trader:8 at time 2024-12-10 19:43:49.883759
Transaction: message: Available,buyer_id: 1, request_no: 55, product: fish, quantity: 3 at time 2024-12-10 19:43:51.666756
Request: buyer_id:1, request_no:56, product:boar, quantity:2, trader:8 at time 2024-12-10 19:43:55.922790
Transaction: message: Available,buyer_id: 1, request_no: 56, product: boar, quantity: 2 at time 2024-12-10 19:44:00.360758
Request: buyer_id:1, request_no:57, product:boar, quantity:3, trader:8 at time 2024-12-10 19:44:03.920338
Transaction: message: Available,buyer_id: 1, request_no: 57, product: boar, quantity: 3 at time 2024-12-10 19:44:05.291339
Request: buyer_id:1, request_no:58, product:boar, quantity:2, trader:7 at time 2024-12-10 19:44:09.895339
Transaction: message: Available,buyer_id: 1, request_no: 58, product: boar, quantity: 2 at time 2024-12-10 19:44:12.049339
Request: buyer_id:1, request_no:59, product:fish, quantity:2, trader:8 at time 2024-12-10 19:44:16.334428
Transaction: message: Available,buyer_id: 1, request_no: 59, product: fish, quantity: 2 at time 2024-12-10 19:44:17.527428
Request: buyer_id:1, request_no:60, product:fish, quantity:2, trader:8 at time 2024-12-10 19:44:22.221429
Transaction: message: Available,buyer_id: 1, request_no: 60, product: fish, quantity: 2 at time 2024-12-10 19:44:24.372428
Request: buyer_id:1, request_no:61, product:salt, quantity:2, trader:8 at time 2024-12-10 19:44:28.628015
Transaction: message: Available,buyer_id: 1, request_no: 61, product: salt, quantity: 2 at time 2024-12-10 19:44:30.075014
Request: buyer_id:1, request_no:62, product:salt, quantity:3, trader:8 at time 2024-12-10 19:44:34.428016
Transaction: message: Available,buyer_id: 1, request_no: 62, product: salt, quantity: 3 at time 2024-12-10 19:44:36.798014
Request: buyer_id:1, request_no:63, product:salt, quantity:3, trader:7 at time 2024-12-10 19:44:41.296015
Transaction: message: Available,buyer_id: 1, request_no: 63, product: salt, quantity: 3 at time 2024-12-10 19:44:42.785015
Request: buyer_id:1, request_no:64, product:boar, quantity:3, trader:8 at time 2024-12-10 19:44:47.159020
Transaction: message: Available,buyer_id: 1, request_no: 64, product: boar, quantity: 3 at time 2024-12-10 19:44:49.721014
Request: buyer_id:1, request_no:65, product:boar, quantity:2, trader:7 at time 2024-12-10 19:44:54.288016
Transaction: message: Available,buyer_id: 1, request_no: 65, product: boar, quantity: 2 at time 2024-12-10 19:44:57.156071
Request: buyer_id:1, request_no:66, product:fish, quantity:3, trader:8 at time 2024-12-10 19:45:00.644071
Transaction: message: Available,buyer_id: 1, request_no: 66, product: fish, quantity: 3 at time 2024-12-10 19:45:04.900072
Request: buyer_id:1, request_no:67, product:salt, quantity:3, trader:8 at time 2024-12-10 19:45:09.390075
Transaction: message: Available,buyer_id: 1, request_no: 67, product: salt, quantity: 3 at time 2024-12-10 19:45:12.362074
Request: buyer_id:1, request_no:68, product:fish, quantity:1, trader:8 at time 2024-12-10 19:45:16.121639
Transaction: message: Available,buyer_id: 1, request_no: 68, product: fish, quantity: 1 at time 2024-12-10 19:45:18.408635
Request: buyer_id:1, request_no:69, product:salt, quantity:2, trader:8 at time 2024-12-10 19:45:23.022636
Transaction: message: Available,buyer_id: 1, request_no: 69, product: salt, quantity: 2 at time 2024-12-10 19:45:24.898637
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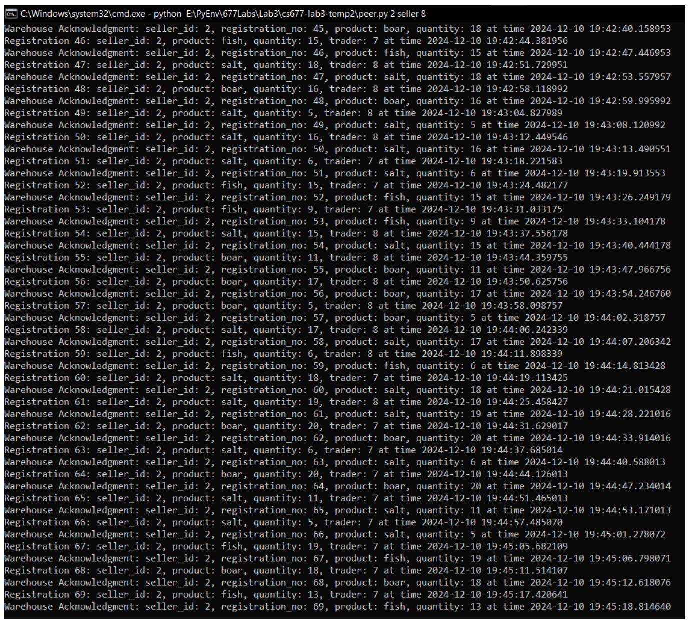

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Warehouse Acknowledgment: seller_id: 2, registration_no: 45, product: boar, quantity: 18 at time 2024-12-10 19:42:40.158953
Registration 46: seller_id: 2, product: fish, quantity: 15, trader: 7 at time 2024-12-10 19:42:44.381956
Warehouse Acknowledgment: seller_id: 2, registration_no: 46, product: fish, quantity: 15 at time 2024-12-10 19:42:47.446953
Registration 47: seller_id: 2, product: salt, quantity: 18, trader: 8 at time 2024-12-10 19:42:51.729951
Warehouse Acknowledgment: seller_id: 2, registration_no: 47, product: salt, quantity: 18 at time 2024-12-10 19:42:53.557957
Registration 48: seller_id: 2, product: boar, quantity: 16, trader: 8 at time 2024-12-10 19:42:58.118992
Warehouse Acknowledgment: seller_id: 2, registration_no: 48, product: boar, quantity: 16 at time 2024-12-10 19:42:59.995992
Registration 49: seller_id: 2, product: salt, quantity: 5, trader: 8 at time 2024-12-10 19:43:04.827989
Warehouse Acknowledgment: seller_id: 2, registration_no: 49, product: salt, quantity: 5 at time 2024-12-10 19:43:08.120992
Registration 50: seller_id: 2, product: salt, quantity: 16, trader: 8 at time 2024-12-10 19:43:12.449546
Warehouse Acknowledgment: seller_id: 2, registration_no: 50, product: salt, quantity: 16 at time 2024-12-10 19:43:13.490551
Registration 51: seller_id: 2, product: salt, quantity: 6, trader: 7 at time 2024-12-10 19:43:18.221583
Warehouse Acknowledgment: seller_id: 2, registration_no: 51, product: salt, quantity: 6 at time 2024-12-10 19:43:19.913553
Registration 52: seller_id: 2, product: fish, quantity: 15, trader: 7 at time 2024-12-10 19:43:24.482177
Warehouse Acknowledgment: seller_id: 2, registration_no: 52, product: fish, quantity: 15 at time 2024-12-10 19:43:26.249179
Registration 53: seller_id: 2, product: fish, quantity: 9, trader: 7 at time 2024-12-10 19:43:31.033175
Warehouse Acknowledgment: seller_id: 2, registration_no: 53, product: fish, quantity: 9 at time 2024-12-10 19:43:33.104178
Registration 54: seller_id: 2, product: salt, quantity: 15, trader: 8 at time 2024-12-10 19:43:37.556178
Warehouse Acknowledgment: seller_id: 2, registration_no: 54, product: salt, quantity: 15 at time 2024-12-10 19:43:40.444178
Registration 55: seller_id: 2, product: boar, quantity: 11, trader: 8 at time 2024-12-10 19:43:44.359755
Warehouse Acknowledgment: seller_id: 2, registration_no: 55, product: boar, quantity: 11 at time 2024-12-10 19:43:47.966756
Registration 56: seller_id: 2, product: boar, quantity: 17, trader: 8 at time 2024-12-10 19:43:50.625756
Warehouse Acknowledgment: seller_id: 2, registration_no: 56, product: boar, quantity: 17 at time 2024-12-10 19:43:54.246760
Registration 57: seller_id: 2, product: boar, quantity: 5, trader: 8 at time 2024-12-10 19:43:58.098757
Warehouse Acknowledgment: seller_id: 2, registration_no: 57, product: boar, quantity: 5 at time 2024-12-10 19:44:02.318757
Registration 58: seller_id: 2, product: salt, quantity: 17, trader: 8 at time 2024-12-10 19:44:06.242339
Warehouse Acknowledgment: seller_id: 2, registration_no: 58, product: salt, quantity: 17 at time 2024-12-10 19:44:07.206342
Registration 59: seller_id: 2, product: fish, quantity: 6, trader: 8 at time 2024-12-10 19:44:11.898339
Warehouse Acknowledgment: seller_id: 2, registration_no: 59, product: fish, quantity: 6 at time 2024-12-10 19:44:14.813428
Registration 60: seller_id: 2, product: salt, quantity: 18, trader: 7 at time 2024-12-10 19:44:19.113425
Warehouse Acknowledgment: seller_id: 2, registration_no: 60, product: salt, quantity: 18 at time 2024-12-10 19:44:21.015428
Registration 61: seller_id: 2, product: salt, quantity: 19, trader: 8 at time 2024-12-10 19:44:25.458427
Warehouse Acknowledgment: seller_id: 2, registration_no: 61, product: salt, quantity: 19 at time 2024-12-10 19:44:28.221016
Registration 62: seller_id: 2, product: boar, quantity: 20, trader: 7 at time 2024-12-10 19:44:31.629017
Warehouse Acknowledgment: seller_id: 2, registration_no: 62, product: boar, quantity: 20 at time 2024-12-10 19:44:33.914016
Registration 63: seller_id: 2, product: salt, quantity: 6, trader: 7 at time 2024-12-10 19:44:37.685014
Warehouse Acknowledgment: seller_id: 2, registration_no: 63, product: salt, quantity: 6 at time 2024-12-10 19:44:40.588013
Registration 64: seller_id: 2, product: boar, quantity: 20, trader: 7 at time 2024-12-10 19:44:44.126013
Warehouse Acknowledgment: seller_id: 2, registration_no: 64, product: boar, quantity: 20 at time 2024-12-10 19:44:47.234014
Registration 65: seller_id: 2, product: salt, quantity: 11, trader: 7 at time 2024-12-10 19:44:51.465013
Warehouse Acknowledgment: seller_id: 2, registration_no: 65, product: salt, quantity: 11 at time 2024-12-10 19:44:53.171013
Registration 66: seller_id: 2, product: salt, quantity: 5, trader: 7 at time 2024-12-10 19:44:57.485070
Warehouse Acknowledgment: seller_id: 2, registration_no: 66, product: salt, quantity: 5 at time 2024-12-10 19:45:01.278072
Registration 67: seller_id: 2, product: fish, quantity: 19, trader: 7 at time 2024-12-10 19:45:05.682109
Warehouse Acknowledgment: seller_id: 2, registration_no: 67, product: fish, quantity: 19 at time 2024-12-10 19:45:06.798071
Registration 68: seller_id: 2, product: boar, quantity: 18, trader: 7 at time 2024-12-10 19:45:11.514107
Warehouse Acknowledgment: seller_id: 2, registration_no: 68, product: boar, quantity: 18 at time 2024-12-10 19:45:12.618076
Registration 69: seller_id: 2, product: fish, quantity: 13, trader: 7 at time 2024-12-10 19:45:17.420641
Warehouse Acknowledgment: seller_id: 2, registration_no: 69, product: fish, quantity: 13 at time 2024-12-10 19:45:18.814640
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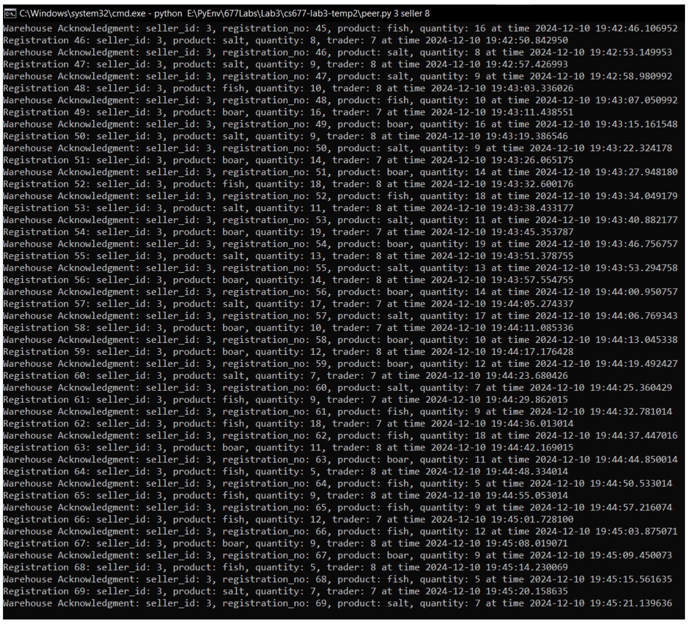
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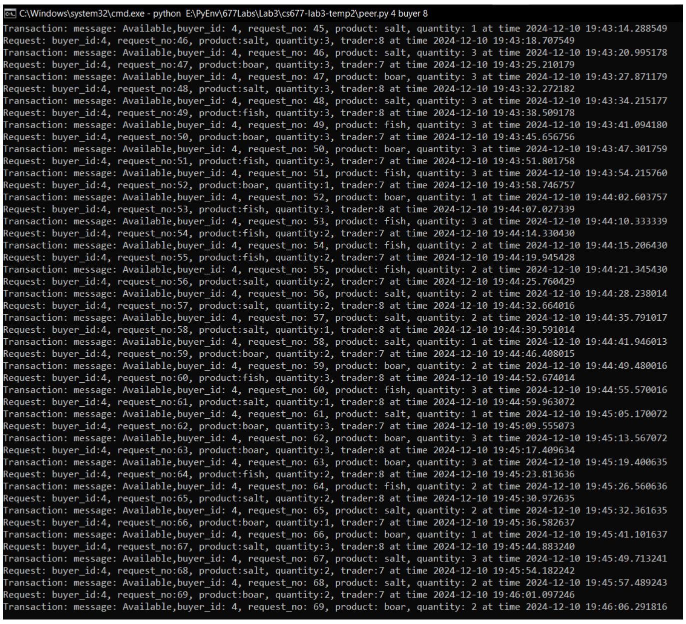
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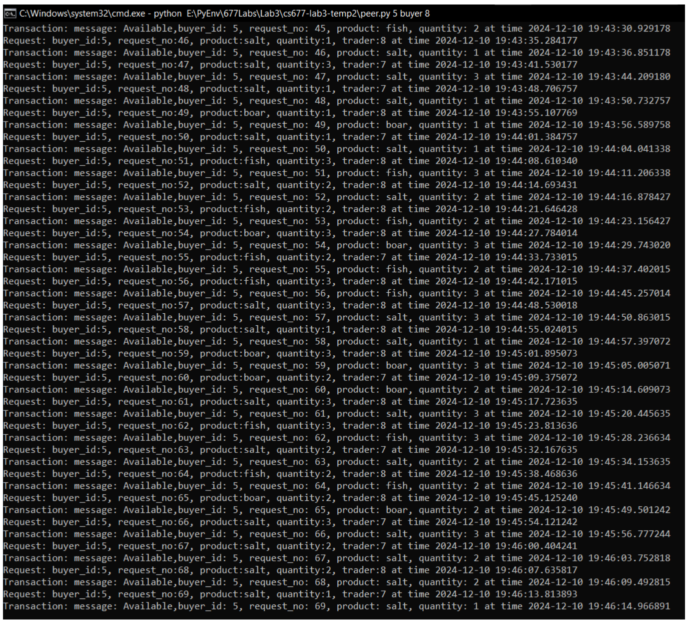
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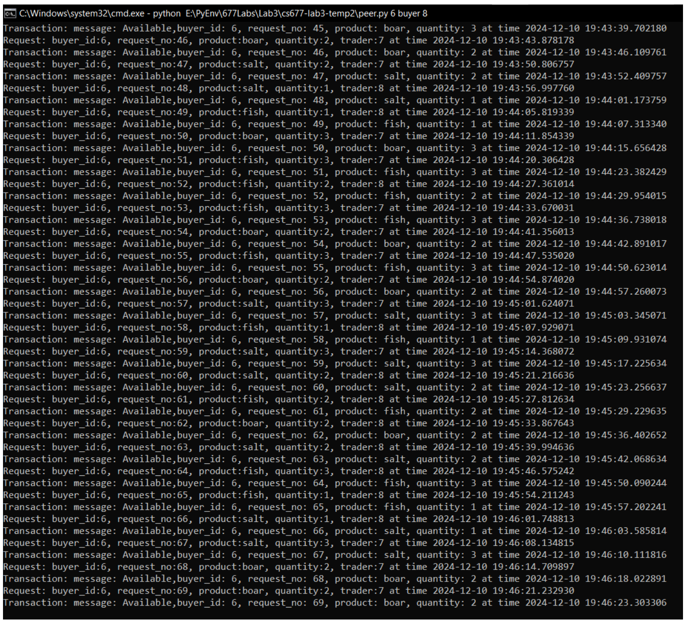
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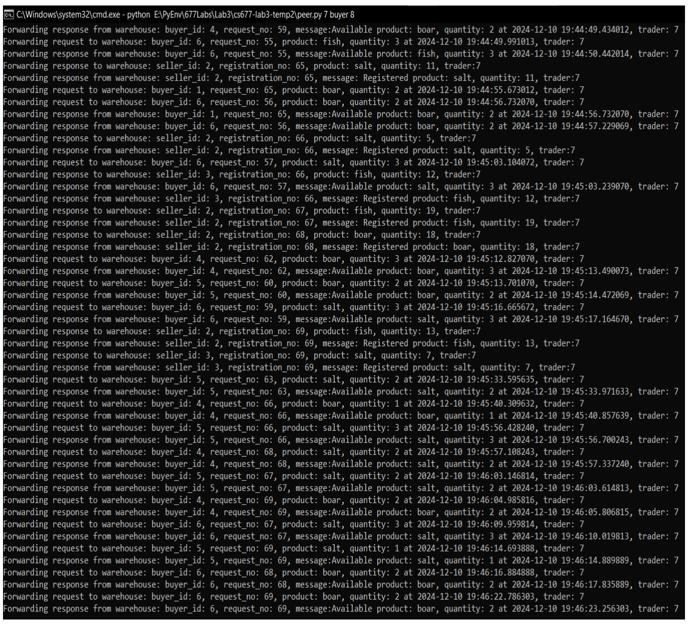
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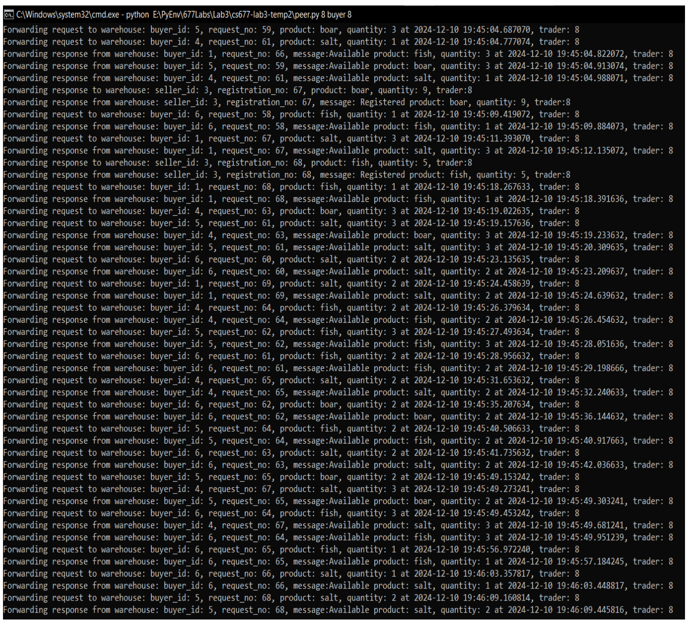
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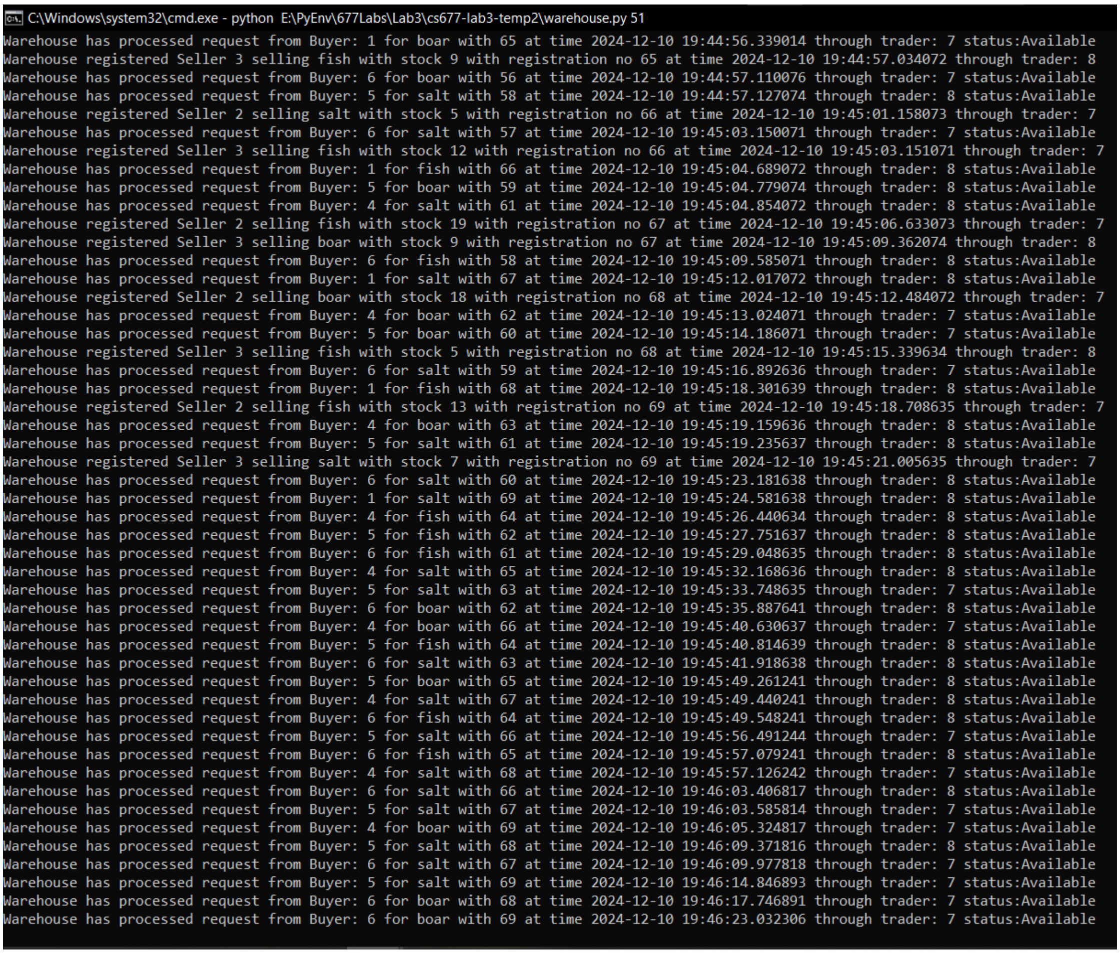

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C:\Windows\system32\cmd.exe - python  E:\PyEnv\677Labs\Lab3\cs677-lab3-temp2\warehouse.py 51
Warehouse has processed request from Buyer: 1 for boar with 65 at time 2024-12-10 19:44:56.339014 through trader: 7 status:Available
Warehouse registered Seller 3 selling fish with stock 9 with registration no 65 at time 2024-12-10 19:44:57.034072 through trader: 8
Warehouse has processed request from Buyer: 6 for boar with 56 at time 2024-12-10 19:44:57.110076 through trader: 7 status:Available
Warehouse has processed request from Buyer: 5 for salt with 58 at time 2024-12-10 19:44:57.127074 through trader: 8 status:Available
Warehouse registered Seller 2 selling salt with stock 5 with registration no 66 at time 2024-12-10 19:45:01.158073 through trader: 7
Warehouse has processed request from Buyer: 6 for salt with 57 at time 2024-12-10 19:45:03.150071 through trader: 7 status:Available
Warehouse registered Seller 3 selling fish with stock 12 with registration no 66 at time 2024-12-10 19:45:03.151071 through trader: 7
Warehouse has processed request from Buyer: 1 for fish with 66 at time 2024-12-10 19:45:04.689072 through trader: 8 status:Available
Warehouse has processed request from Buyer: 5 for boar with 59 at time 2024-12-10 19:45:04.779074 through trader: 8 status:Available
Warehouse has processed request from Buyer: 4 for salt with 61 at time 2024-12-10 19:45:04.854072 through trader: 8 status:Available
Warehouse registered Seller 2 selling fish with stock 19 with registration no 67 at time 2024-12-10 19:45:06.633073 through trader: 7
Warehouse registered Seller 3 selling boar with stock 9 with registration no 67 at time 2024-12-10 19:45:09.362074 through trader: 8
Warehouse has processed request from Buyer: 6 for fish with 58 at time 2024-12-10 19:45:09.585071 through trader: 8 status:Available
Warehouse has processed request from Buyer: 1 for salt with 67 at time 2024-12-10 19:45:12.017072 through trader: 8 status:Available
Warehouse registered Seller 2 selling boar with stock 18 with registration no 68 at time 2024-12-10 19:45:12.484072 through trader: 7
Warehouse has processed request from Buyer: 4 for boar with 62 at time 2024-12-10 19:45:13.024071 through trader: 7 status:Available
Warehouse has processed request from Buyer: 5 for boar with 60 at time 2024-12-10 19:45:14.186071 through trader: 7 status:Available
Warehouse registered Seller 3 selling fish with stock 5 with registration no 68 at time 2024-12-10 19:45:15.339634 through trader: 8
Warehouse has processed request from Buyer: 6 for salt with 59 at time 2024-12-10 19:45:16.892636 through trader: 7 status:Available
Warehouse has processed request from Buyer: 1 for fish with 68 at time 2024-12-10 19:45:18.301639 through trader: 8 status:Available
Warehouse registered Seller 2 selling fish with stock 13 with registration no 69 at time 2024-12-10 19:45:18.708635 through trader: 7
Warehouse has processed request from Buyer: 4 for boar with 63 at time 2024-12-10 19:45:19.159636 through trader: 8 status:Available
Warehouse has processed request from Buyer: 5 for salt with 61 at time 2024-12-10 19:45:19.235637 through trader: 8 status:Available
Warehouse registered Seller 3 selling salt with stock 7 with registration no 69 at time 2024-12-10 19:45:21.005635 through trader: 7
Warehouse has processed request from Buyer: 6 for salt with 60 at time 2024-12-10 19:45:23.181638 through trader: 8 status:Available
Warehouse has processed request from Buyer: 1 for salt with 69 at time 2024-12-10 19:45:24.581638 through trader: 8 status:Available
Warehouse has processed request from Buyer: 4 for fish with 64 at time 2024-12-10 19:45:26.440634 through trader: 8 status:Available
Warehouse has processed request from Buyer: 5 for fish with 62 at time 2024-12-10 19:45:27.751637 through trader: 8 status:Available
Warehouse has processed request from Buyer: 6 for fish with 61 at time 2024-12-10 19:45:29.048635 through trader: 8 status:Available
Warehouse has processed request from Buyer: 4 for salt with 65 at time 2024-12-10 19:45:32.168636 through trader: 8 status:Available
Warehouse has processed request from Buyer: 5 for salt with 63 at time 2024-12-10 19:45:33.748635 through trader: 7 status:Available
Warehouse has processed request from Buyer: 6 for boar with 62 at time 2024-12-10 19:45:35.887641 through trader: 8 status:Available
Warehouse has processed request from Buyer: 4 for boar with 66 at time 2024-12-10 19:45:40.630637 through trader: 7 status:Available
Warehouse has processed request from Buyer: 5 for fish with 64 at time 2024-12-10 19:45:40.814639 through trader: 8 status:Available
Warehouse has processed request from Buyer: 6 for salt with 63 at time 2024-12-10 19:45:41.918638 through trader: 8 status:Available
Warehouse has processed request from Buyer: 5 for boar with 65 at time 2024-12-10 19:45:49.261241 through trader: 8 status:Available
Warehouse has processed request from Buyer: 4 for salt with 67 at time 2024-12-10 19:45:49.440241 through trader: 8 status:Available
Warehouse has processed request from Buyer: 6 for fish with 64 at time 2024-12-10 19:45:49.548241 through trader: 8 status:Available
Warehouse has processed request from Buyer: 5 for salt with 66 at time 2024-12-10 19:45:56.491244 through trader: 7 status:Available
Warehouse has processed request from Buyer: 6 for fish with 65 at time 2024-12-10 19:45:57.079241 through trader: 8 status:Available
Warehouse has processed request from Buyer: 4 for salt with 68 at time 2024-12-10 19:45:57.126242 through trader: 7 status:Available
Warehouse has processed request from Buyer: 6 for salt with 66 at time 2024-12-10 19:46:03.406817 through trader: 8 status:Available
Warehouse has processed request from Buyer: 5 for salt with 67 at time 2024-12-10 19:46:03.585814 through trader: 7 status:Available
Warehouse has processed request from Buyer: 4 for boar with 69 at time 2024-12-10 19:46:05.324817 through trader: 7 status:Available
Warehouse has processed request from Buyer: 5 for salt with 68 at time 2024-12-10 19:46:09.371816 through trader: 8 status:Available
Warehouse has processed request from Buyer: 6 for salt with 67 at time 2024-12-10 19:46:09.977818 through trader: 7 status:Available
Warehouse has processed request from Buyer: 5 for salt with 69 at time 2024-12-10 19:46:14.846893 through trader: 7 status:Available
Warehouse has processed request from Buyer: 6 for boar with 68 at time 2024-12-10 19:46:17.746891 through trader: 7 status:Available
Warehouse has processed request from Buyer: 6 for boar with 69 at time 2024-12-10 19:46:23.032306 through trader: 7 status:Available
```

5.3. Known Issues :

- Traders' caches may become outdated between synchronization intervals, leading to overselling or under-selling in high-demand scenarios.
- The heartbeat protocol may falsely mark a trader as inactive due to minor network delays, leading to unnecessary failovers.
- The use of a single .json file for warehouse storage poses a reliability risk and must be addressed with redundant or distributed storage.
- Lack of proper time ordering in distributed queues can cause some requests to be delayed indefinitely, leading to potential starvation and inefficiencies in request processing.
- Requires a lot of manual configuration to execute and check performance of multiple experiments.

6. EXPERIMENTAL RESULTS AND EVALUATION

6.1. Throughput of the Cache-less and Cache-based Approach :

$$Throughput = \frac{Total\ number\ of\ requests\ processed\ by\ warehouse}{Total\ time\ taken\ (in\ seconds)}$$

Number of Peers = 8   Number of Buyers = 4   Number of Sellers = 2   Buyer : Seller Ratio = 2:1   Number of Traders = 2

	Cache-less Approach	**Cache-based Approach**
Requests Processed = 50*4 = 200	Time Taken : 550.3216 Throughput = 0.36342	Time Taken : 377.4255 Throughput = 0.5299
Requests Processed = 60*4= 240	Time Taken : 652.3600 Throughput = 0.36789	Time Taken : 450.4124 Throughput = 0.53284

Analysis on the system : The throughput of the system in the cache-based approach is higher. According to the definition, this implies that the total time taken for processing is lower in the cache-based approach, making it more efficient.

6.2. Throughput for Buyer : Seller Ratio for Number of Requests Processed :

Number of Traders = 2	Cache-less Approach	Cache-based Approach
Number of Peers = 8 Number of Buyers = 4 Total Number of Requests = 50*4 = 200	Time Taken : 550.3216 Throughput = 0.36342	Time Taken : 377.4255 Throughput = 0.52990
Number of Peers = 6 Number of Buyers = 2 Number of Sellers = 2 Total Number of Requests = 50 * 2 = 100	Time Taken : 531.944465 Throughput = 0.18798	Time Taken : 360.919311 Throughput = 0.2770702

6.3. Rate of Over-Selling for Cache-based Approach :

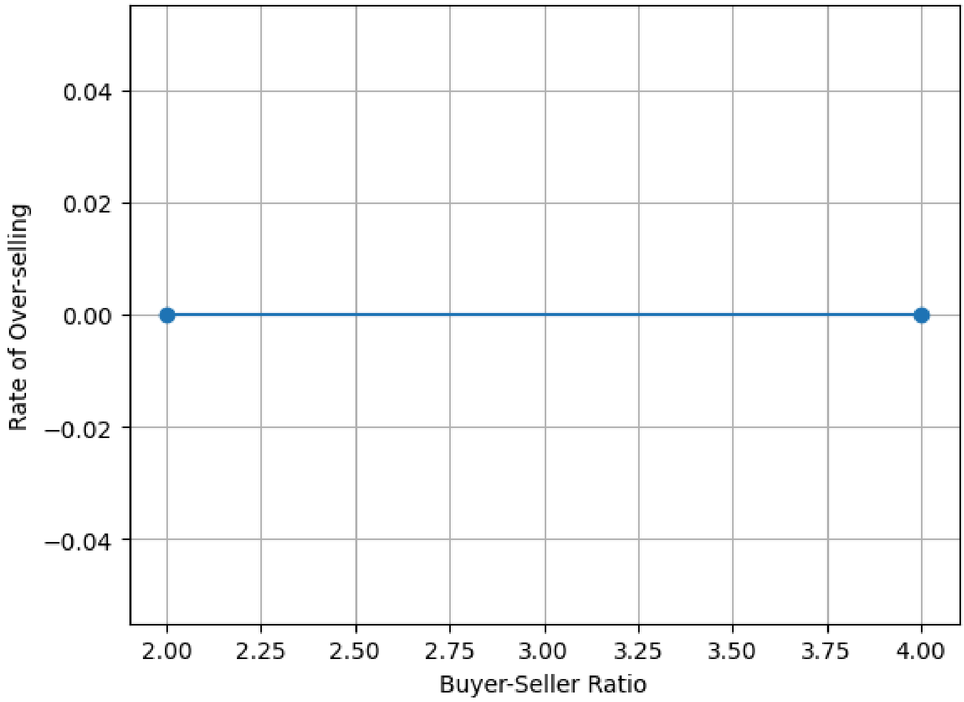
$$Rate\ of\ Overselling\ (\%)\ =\ (\frac{Number\ of\ buy\ requests\ denied\ by\ warehouse}{Total\ number\ of\ buy\ requests})\ *\ 100$$

Number of Peers = 8 Number of Buyers = 4 Number of Sellers = 2 Buyer : Seller Ratio = 2:1 Number of Traders = 2

Total Buy Requests = 50*4 = 200	Buy requests denied = 0 Rate of over-selling (%) = 0
Total Buy Requests = 60*4 = 240	Buy requests denied = 0 Rate of over-selling (%) = 0

6.4. Impact of Buyers-to-Sellers Ratio on Over-Selling Incidence for Total Buy Requests :

In the below plot, we set X axis : Buyer : Seller Ratio and Y axis : Rate of Over-selling (%) :



Analysis on the system : In our multiple runs, we hardly noticed any underselling or overselling. This is likely because requests for each product are maintained in a priority queue, ensuring consistency for each trader even before synchronization. Additionally, since the cache is updated every time a request is forwarded to the warehouse after being processed by the trader with respect to its local cache, the likelihood of stale caches is low.

6.5. Impact of Sellers deposit with Trader for Total Buy Requests :

$N_g = 5$ and $T_g = 3$	Buy requests denied by warehouse = 0 Rate of over-selling (%) = 0
$N_g = 5$ and $T_g = 5$	Buy requests denied by warehouse = 0 Rate of over-selling (%) = 0
$N_g = 3$ and $T_g = 5$	Buy requests denied by warehouse = 1 Rate of under-selling (%) = 1/100

Analysis on the system : In our multiple runs, we hardly noticed any underselling or overselling. This is likely because requests for each product are maintained in a priority queue, ensuring consistency for each trader even before synchronization. Additionally, since the cache is updated every time a request is forwarded to the warehouse after being processed by the trader with respect to its local cache, the likelihood of stale caches is low.

6.6. Impact of Trader on Throughput :

	Number of Traders = 2	**Number of Traders = 1 (Trader failure)**
Requests Processed = 50*4 = 200	Time Taken : 377.4255 Throughput = 0.5299	Time Taken : 1069.899 Throughput = 0.18693
Requests Processed = 60*4 = 240	Time Taken : 450.4124 Throughput = 0.53284	Time Taken : 1437.317 Throughput = 0.16697

Analysis on the system : With 2 traders, throughput is higher as requests are distributed, ensuring faster processing. When one trader fails, throughput decreases as the remaining trader handles all requests, but seamless failover ensures minimal disruption.

7. CONCLUSION

7.1. Additional Research Questions :

- How does the buyers-to-sellers ratio impact the accuracy and reliability of cache-based system?
- What are the trade-offs between cache synchronization frequency and system throughput in reducing overselling?
- What is the optimal balance between synchronization frequency and scalability in distributed cache-based systems to ensure both consistency and performance under high demand?
- How effectively does the heartbeat protocol maintain fault tolerance in distributed trading systems during trader failures?

7.2. Hypothesis About Our System :

The system is designed to maintain high throughput and consistency under dynamic buyer-to-seller ratios by leveraging cache synchronization with Lamport clocks and robust fault tolerance via heartbeat protocols. It is hypothesized to effectively minimize overselling, underselling, and downtime while ensuring accurate inventory updates and seamless failover during trader failures.

7.3. Opinion And Conclusion :

Whether the Gauls should use the cache-less or cache-based approaches ?

The Gauls should prefer the cache-based approach for its higher throughput and reduced latency, provided synchronization intervals are optimized to minimize overselling and underselling. Cache-less, while consistent, introduces significant delays due to warehouse dependency.

Is there an alternatively better cache consistency implementation ?

A quorum-based consistency model or versioning with vector clocks could enhance cache-based implementation by providing stronger consistency while retaining high performance, especially in high-demand scenarios.