Test Steps and Expected Behavior: (check `test/` directory for the .sh test files, see README for what each test script does)

1. **test_part1_caching.sh**

```
(base) lavanika@Lavanikas-MacBook-Pro test % ./test_part1_caching.sh

 test cache miss and fetching from catalog
{"volume":100,"name":"Stock1"}
 repeat to show cache hit (no catalog call)
{"volume":100,"name":"Stock1"}
 trigger cache invalidation, Stock1 removed from cache
Cache invalidated for stock: Stock1
 to verify cache replacement

 querying multiple stocks, cache replacement will be triggered
querying Stock1...
{"volume":100,"name":"Stock1"}querying Stock2...
{"volume":150,"name":"Stock2"}querying Stock3...
{"volume":200,"name":"Stock3"}querying Stock4...
{"volume":250,"name":"Stock4"}%
(base) lavanika@Lavanikas-MacBook-Pro test %
```

frontend.log:

```
2025-05-05 14:44:08 - Starting FrontendServiceApplication using Java
23.0.2 with PID 73622 (/Users/lavanika/Desktop/Spring
2025/677/Lab3/spring25-lab3-lava-nika/src/frontend-service/target/classes
started by lavanika in /Users/lavanika/Desktop/Spring
2025/677/Lab3/spring25-lab3-lava-nika/src/frontend-service)
2025-05-05 14:44:08 - No active profile set, falling back to 1 default
profile: "default"
2025-05-05 14:44:08 - Tomcat initialized with port 7070 (http)
2025-05-05 14:44:08 - Initializing ProtocolHandler ["http-nio-7070"]
2025-05-05 14:44:08 - Starting service [Tomcat]
2025-05-05 14:44:08 - Starting Servlet engine: [Apache Tomcat/10.1.39]
2025-05-05 14:44:08 - Initializing Spring embedded WebApplicationContext
2025-05-05 14:44:08 - Root WebApplicationContext: initialization
completed in 272 ms
2025-05-05 14:44:08 - No replicas configured. Cannot select leader.
2025-05-05 14:44:08 - Starting ProtocolHandler ["http-nio-7070"]
2025-05-05 14:44:08 - Tomcat started on port 7070 (http) with context
path '/'
2025-05-05 14:44:08 - Started FrontendServiceApplication in 0.599 seconds
(process running for 0.716)
2025-05-05 14:44:31 - Initializing Spring DispatcherServlet
'dispatcherServlet'
2025-05-05 14:44:31 - Initializing Servlet 'dispatcherServlet'
```

```
2025-05-05 14:44:31 - Completed initialization in 1 ms
2025-05-05 14:44:31 - Stock lookup request received: Stock1
2025-05-05 14:44:31 - CACHE MISS: Stock1
2025-05-05 14:44:31 - Fetching Stock1 from catalog at
http://localhost:8081
2025-05-05 14:44:31 - Caching result for Stock1
2025-05-05 14:44:31 - Stock lookup request received: Stock1
2025-05-05 14:44:31 - CACHE HIT: Stock1
2025-05-05 14:44:31 - Cache invalidated for Stock1
2025-05-05 14:44:31 - Stock lookup request received: Stock1
2025-05-05 14:44:31 - CACHE MISS: Stock1
2025-05-05 14:44:31 - Fetching Stock1 from catalog at
http://localhost:8081
2025-05-05 14:44:31 - Caching result for Stock1
2025-05-05 14:44:31 - Stock lookup request received: Stock2
2025-05-05 14:44:31 - CACHE MISS: Stock2
2025-05-05 14:44:31 - Fetching Stock2 from catalog at
http://localhost:8081
2025-05-05 14:44:31 - Caching result for Stock2
2025-05-05 14:44:31 - Stock lookup request received: Stock3
2025-05-05 14:44:31 - CACHE MISS: Stock3
2025-05-05 14:44:31 - Fetching Stock3 from catalog at
http://localhost:8081
2025-05-05 14:44:31 - Caching result for Stock3
2025-05-05 14:44:31 - Stock lookup request received: Stock4
2025-05-05 14:44:31 - CACHE MISS: Stock4
2025-05-05 14:44:31 - Fetching Stock4 from catalog at
http://localhost:8081
2025-05-05 14:44:31 - Caching result for Stock4
```

2. **test_frontend.sh**

```
(base) lavanika@Lavanikas-MacBook-Pro test % ./test_frontend.sh
sending order through frontend
{"data":{"name":"Stock1","type":"buy","quantity":10,"number":1}}
 getting stock via frontend, checking for cache hit or miss
{"volume":100,"name":"Stock1"}
 Invalidating stock cache
Cache invalidated for stock: Stock1
 Retrieve that order
{"data":{"name":"Stock1","type":"buy","quantity":10,"number":1}}%
(base) lavanika@Lavanikas-MacBook-Pro test %
```

frontend.log

```
2025-05-05 14:53:57 - Forwarding order to order service: {name=Stock1, type=buy, quantity=10}
2025-05-05 14:53:57 - Received ping from http://localhost:9091 with replicaId 1
2025-05-05 14:53:57 - Received ping from http://localhost:9092 with replicaId 2
2025-05-05 14:53:57 - Received ping from http://localhost:9093 with replicaId 3
2025-05-05 14:53:57 - Leader selected: http://localhost:9093
2025-05-05 14:53:57 - Stock lookup request received: Stock1
2025-05-05 14:53:57 - CACHE MISS: Stock1
2025-05-05 14:53:57 - Fetching Stock1 from catalog at http://localhost:8081
2025-05-05 14:53:57 - Caching result for Stock1
2025-05-05 14:53:57 - Cache invalidated for Stock1
2025-05-05 14:53:57 - Requesting order #1 from order service
```

3. **test_catalog.sh**

```
(base) lavanika@Lavanikas-MacBook-Pro test % ./test_catalog.sh
stock update (buy or sell)
{"message":"Trade successful"}
 test catalog stock retrieval
{"volume":95,"name":"Stock1"}%
(base) lavanika@Lavanikas-MacBook-Pro test %
```

catalog.log

```
2025-05-05 14:44:13 - Tomcat initialized with port 8081 (http)
2025-05-05 14:44:13 - Initializing ProtocolHandler ["http-nio-8081"]
2025-05-05 14:44:13 - Starting service [Tomcat]
2025-05-05 14:44:13 - Starting Servlet engine: [Apache Tomcat/10.1.39]
2025-05-05 14:44:13 - Initializing Spring embedded WebApplicationContext
2025-05-05 14:44:13 - Root WebApplicationContext: initialization completed in 248 ms
2025-05-05 14:44:13 - Loaded stock: Stock1 with volume: 100
2025-05-05 14:44:13 - Loaded stock: Stock2 with volume: 150
2025-05-05 14:44:13 - Loaded stock: Stock3 with volume: 200
2025-05-05 14:44:13 - Loaded stock: Stock4 with volume: 250
2025-05-05 14:44:13 - Starting ProtocolHandler ["http-nio-8081"]
2025-05-05 14:44:13 - Tomcat started on port 8081 (http) with context path '/'
2025-05-05 14:44:13 - Started CatalogServiceApplication in 0.565 seconds (process running for 0.672)
2025-05-05 14:44:31 - Initializing Spring DispatcherServlet 'dispatcherServlet'
2025-05-05 14:44:31 - Initializing Servlet 'dispatcherServlet'
2025-05-05 14:44:31 - Completed initialization in 6 ms
2025-05-05 15:07:35 - BUY: 5 of Stock1; remaining volume= 95
2025-05-05 15:07:35 - Cache invalidation triggered for Stock1
```

4. test_part2_replication.sh

```
(base) lavanika@Lavanikas-MacBook-Pro test % ./test_part2_replication.sh
sending order via frontend
{"data":{"name":"Stock2","type":"buy","quantity":10,"number":1}}
 verify if order exists for all replicas
{"data":{"name":"Stock2","type":"buy","quantity":10,"number":1}}{"data":{"name":"Stock2","type":"buy","quantity":10,"number":1}}{"data":{"name":"Stock2","type":"buy","quantity":10,"number":1}}
:10,"number":1}}
(base) lavanika@Lavanikas-MacBook-Pro test %
```

5. test_part3_leader_failure.sh

```
(base) lavanika@Lavanikas-MacBook-Pro test % ./test_part3_leader_failure.sh
bring down leader replica (at 9093) now (ctrl+c). enter to continue


 sending order again via frontend, it will switch to the next leader
{"data":{"name":"Stock2","type":"sell","quantity":3,"number":1}}
 frontend picks new leader and continues working
(base) lavanika@Lavanikas-MacBook-Pro test %
```

frontend.log:

```
2025-05-05 16:13:29 - Tomcat started on port 7070 (http) with context path '/'
2025-05-05 16:13:29 - Started FrontendServiceApplication in 0.546 seconds (process running for 0.647)
2025-05-05 16:13:52 - Initializing Spring DispatcherServlet 'dispatcherServlet'
2025-05-05 16:13:52 - Initializing Servlet 'dispatcherServlet'
2025-05-05 16:13:52 - Completed initialization in 1 ms
2025-05-05 16:13:52 - Forwarding order to order service: {name=Stock2, type=buy, quantity=10}
2025-05-05 16:13:52 - Received ping from http://localhost:9091 with replicaId 1
2025-05-05 16:13:52 - Received ping from http://localhost:9092 with replicaId 2
2025-05-05 16:13:52 - Received ping from http://localhost:9093 with replicaId 3
2025-05-05 16:13:52 - Leader selected: http://localhost:9093
2025-05-05 16:20:04 - Forwarding order to order service: {name=Stock2, type=sell, quantity=3}
2025-05-05 16:20:04 - current leader http://localhost:9093 is unreachable, re-electing leader
2025-05-05 16:20:04 - Received ping from http://localhost:9091 with replicaId 1
2025-05-05 16:20:04 - Received ping from http://localhost:9092 with replicaId 2
2025-05-05 16:20:04 - Could not reach replica at http://localhost:9093: I/O error on GET request for "http://localhost:9093/orders/ping"
2025-05-05 16:20:04 - Leader selected: http://localhost:9092
```

6. test_part3_restarted_follower_recovery.sh

```
(base) lavanika@Lavanikas-MacBook-Pro test % ./test_part3_restarted_follower_recovery.sh
start only 2 order replicas, leave replica 3 down. enter to continue


 sending order again via frontend, it will go to current leader (replica 2)
{"data":{"name":"Stock2","type":"buy","quantity":50,"number":1}}
 verify order is in replicas 1 and 2, missing in replica 3

 replica 1:
{"data":{"name":"Stock2","type":"buy","quantity":50,"number":1}}
 replica 2:
{"data":{"name":"Stock2","type":"buy","quantity":50,"number":1}}
 replica 3:
curl: (7) Failed to connect to localhost port 9093 after 0 ms: Couldn't connect to server

 start replica 3, it will recover order from current leader (replica 2), enter to continue

{"data":{"name":"Stock2","type":"buy","quantity":50,"number":1}}%
(base) lavanika@Lavanikas-MacBook-Pro test %
```

order.log

```
2025-05-05 16:31:31 - Starting OrderServiceApplication using Java 23.0.2 with PID 96751 (/Users/lavani
2025-05-05 16:31:31 - The following 1 profile is active: "replica3"
2025-05-05 16:31:31 - Tomcat initialized with port 9093 (http)
2025-05-05 16:31:31 - Initializing ProtocolHandler ["http-nio-9093"]
2025-05-05 16:31:31 - Starting service [Tomcat]
2025-05-05 16:31:31 - Starting Servlet engine: [Apache Tomcat/10.1.39]
2025-05-05 16:31:31 - Initializing Spring embedded WebApplicationContext
2025-05-05 16:31:31 - Root WebApplicationContext: initialization completed in 251 ms
2025-05-05 16:31:31 - Order service Replica with ID: 3 has started
2025-05-05 16:31:31 - Replica started with ID: 3
2025-05-05 16:31:31 - Replica unreachable during sync check http://localhost:9093
2025-05-05 16:31:31 - Recovered 1 orders from leader http://localhost:9092
2025-05-05 16:31:31 - Starting ProtocolHandler ["http-nio-9093"]
2025-05-05 16:31:31 - Tomcat started on port 9093 (http) with context path '/'
2025-05-05 16:31:31 - Started OrderServiceApplication in 0.6 seconds (process running for 0.708)
2025-05-05 16:31:35 - Initializing Spring DispatcherServlet 'dispatcherServlet'
2025-05-05 16:31:35 - Initializing Servlet 'dispatcherServlet'
2025-05-05 16:31:35 - Completed initialization in 0 ms
2025-05-05 16:31:35 - Found order #1: {name=Stock2, type=buy, quantity=50, number=1}
```