An-Najah National University

Faculty of Engineering & Information Technology

Dos-Project - Part 2

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1. Introduction

In this lab, we extend the Bazar.com online bookstore developed in Lab 1 to handle higher workloads and improve performance. The main objective is to apply key distributed systems concepts including replication, caching, and consistency using a microservices-based architecture and RESTful APIs.

2. System Architecture:

The system consists of the following components:

- **Frontend Server**
  - Receives all client requests
  - Implements load balancing using Round Robin
  - Maintains an in-memory cache with LRU eviction
- **Catalog Service**
  - Stores book information (title, price, quantity)
  - Implemented with SQLite
  - Replicated into two instances running on different ports
- **Order Service**
  - Handles purchase requests
  - Replicated into two instances
  - Updates all catalog replicas to maintain consistency

3. Replication

Replication is implemented for both the Catalog Service and the Order Service.

The frontend server distributes incoming requests among replicas using a Round Robin load-balancing strategy.

For write operations (purchases), the Order Service propagates updates to all catalog replicas, ensuring that all copies remain synchronized.

4. Caching

An in-memory cache is implemented inside the frontend server to store responses for read-only requests (/info/:id).

Cache characteristics:

- Used only for read requests
- Limited cache size
- Uses Least Recently Used (LRU) eviction policy
- Significantly reduces response time for repeated requests

5. Cache Consistency

To maintain strong consistency, a server-push invalidation mechanism is used.

When a write operation occurs:

- **The Order Service updates the catalog replicas**
- **The frontend cache is explicitly invalidated for the affected item**
- **The next read request results in a cache miss and fetches updated data**

This mechanism prevents stale data from being served to clients.

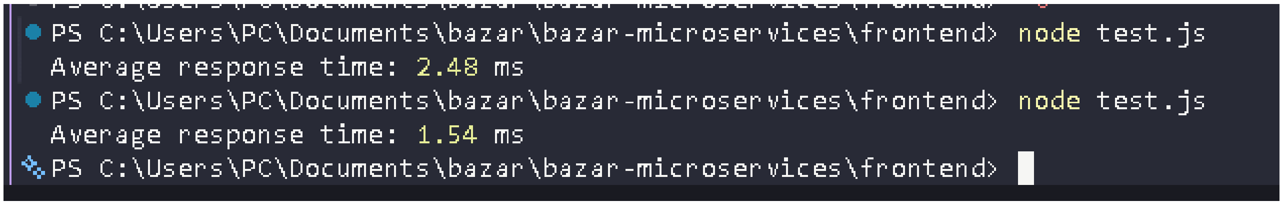
6. Experimental Evaluation

6.1 Response Time Measurement

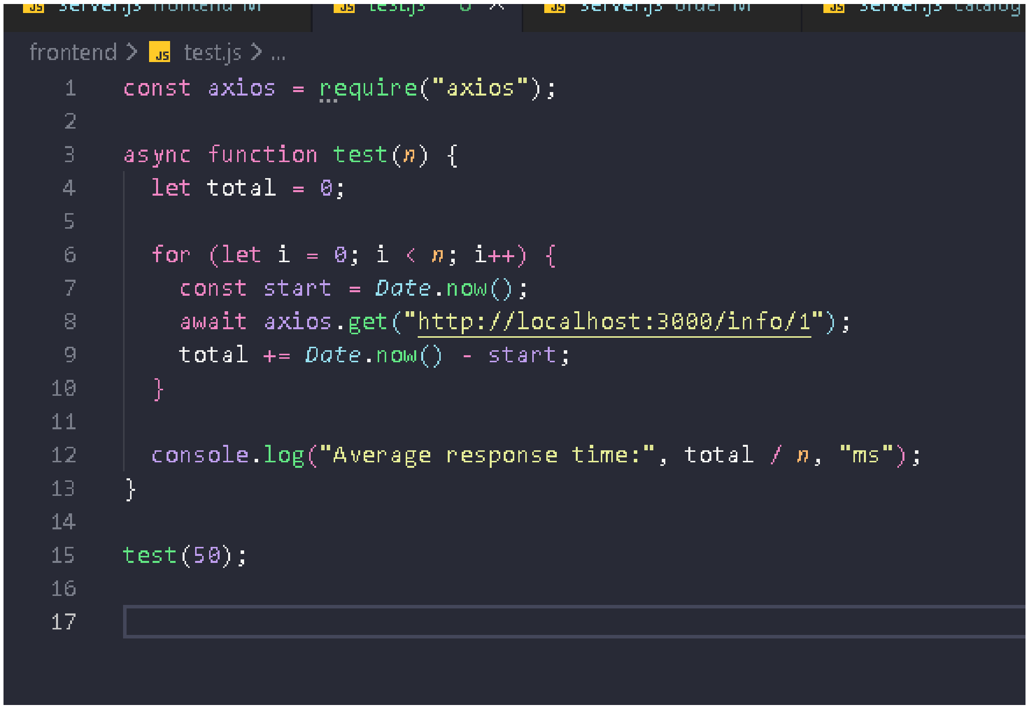
We measured the average response time for /info/:id requests in two scenarios:

We measured the average response time by issuing 50 consecutive /info/:id requests using a Node.js script. The experiment was performed with caching disabled and enabled.

Scenario	Average Response Time
Without Cache	2.48 ms
With Cache	1.54 ms



```
PS C:\Users\PC\Documents\bazar\bazar-microservices\frontend> node test.js
Average response time: 2.48 ms
PS C:\Users\PC\Documents\bazar\bazar-microservices\frontend> node test.js
Average response time: 1.54 ms
PS C:\Users\PC\Documents\bazar\bazar-microservices\frontend>
```



```
const axios = require("axios");

async function test(n) {
  let total = 0;

  for (let i = 0; i < n; i++) {
    const start = Date.now();
    await axios.get("http://localhost:3000/info/1");
    total += Date.now() - start;
  }

  console.log("Average response time:", total / n, "ms");
}

test(50);

```

6.2 Cache Invalidation Experiment

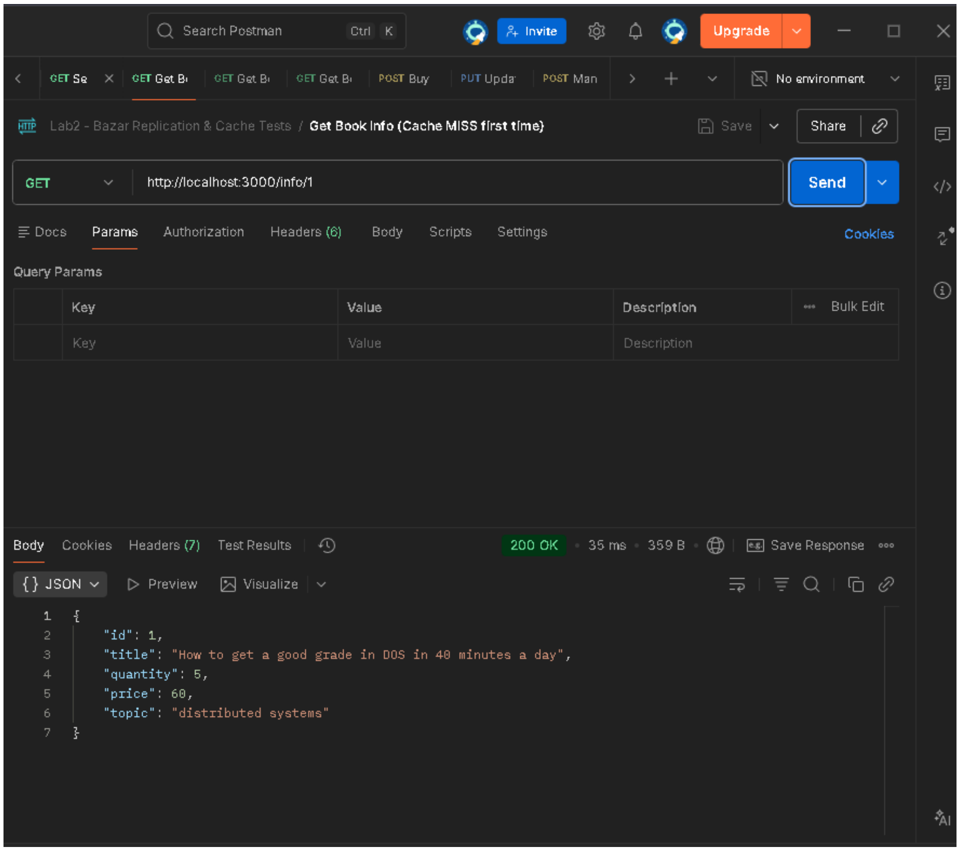
The following experiment was conducted:

1. **Request /info/:id → Cache HIT**
2. **Execute /purchase/:id**
3. **Cache invalidation occurs**
4. **Request /info/:id again → Cache MISS**

Step	Result
Before Purchase	Cache HIT
After Purchase	Cache MISS
Consistency	Maintained

Operation	Time (ms)
Cache Invalidation	**4**
Request after invalidation (MISS)	**3**

- **first request**

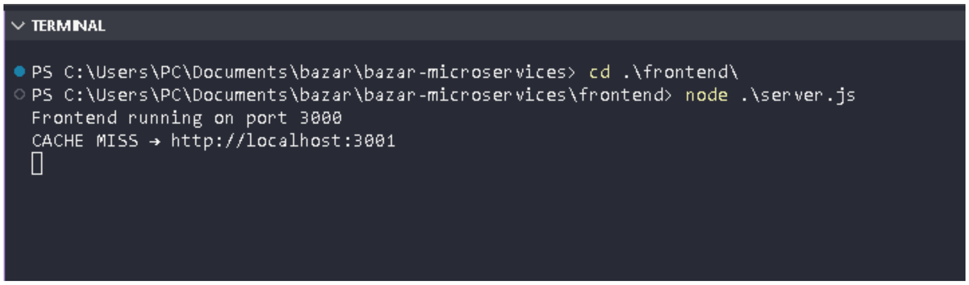


Lab2 - Bazar Replication & Cache Tests / Get Book Info (Cache MISS first time)

GET http://localhost:3000/info/1

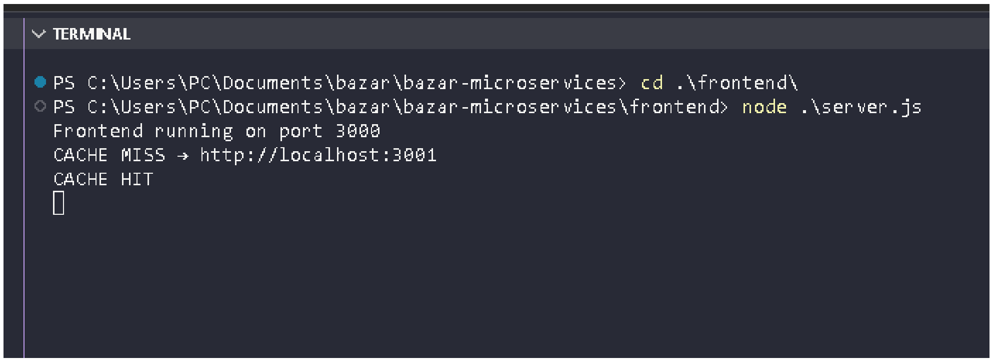
200 OK · 35 ms · 359 B

```
{
    "id": 1,
    "title": "How to get a good grade in DOS in 40 minutes a day",
    "quantity": 5,
    "price": 60,
    "topic": "distributed systems"
}
```



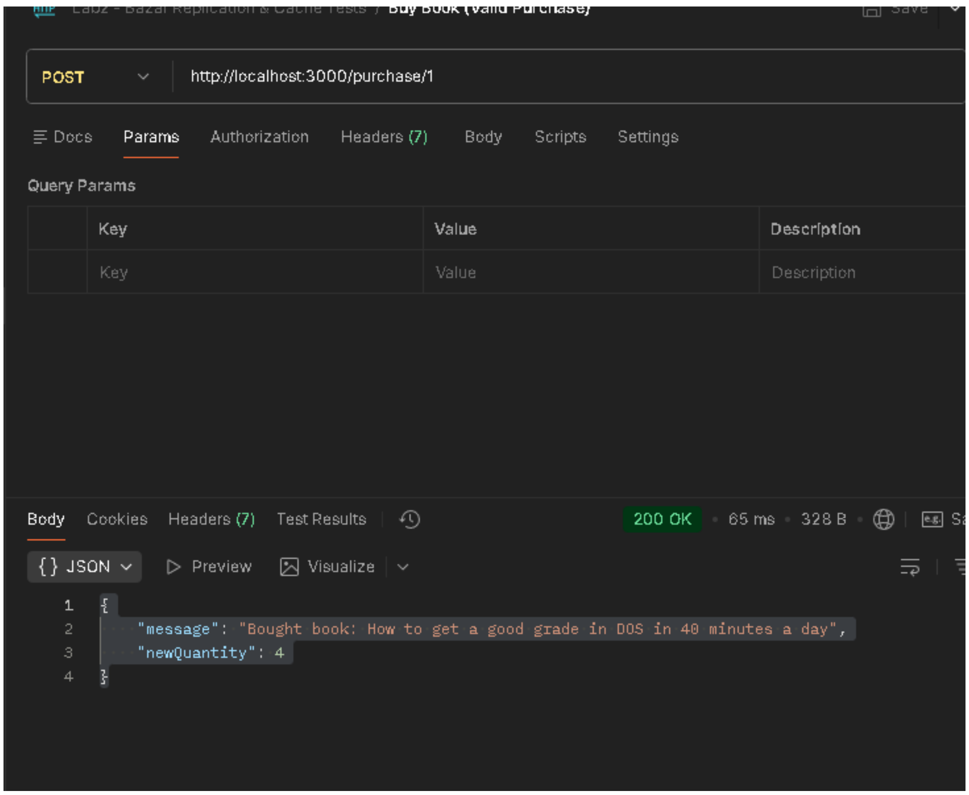
```
PS C:\Users\PC\Documents\bazar\bazar-microservices> cd .\frontend\
PS C:\Users\PC\Documents\bazar\bazar-microservices\frontend> node .\server.js
Frontend running on port 3000
CACHE MISS → http://localhost:3001
```

- **second request** <u>GET http://localhost:3000/info/1</u>



```
PS C:\Users\PC\Documents\bazar\bazar-microservices> cd .\frontend\
PS C:\Users\PC\Documents\bazar\bazar-microservices\frontend> node .\server.js
Frontend running on port 3000
CACHE MISS → http://localhost:3001
CACHE HIT
```

- **third request**



Lab2 - Bazar Replication & Cache Tests / Buy Book (Valid Purchase)

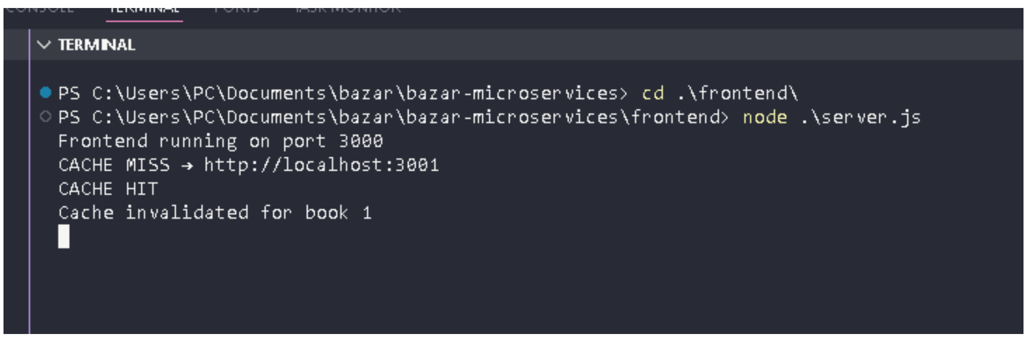
POST http://localhost:3000/purchase/1

Query Params

Key	Value	Description
Key	Value	Description

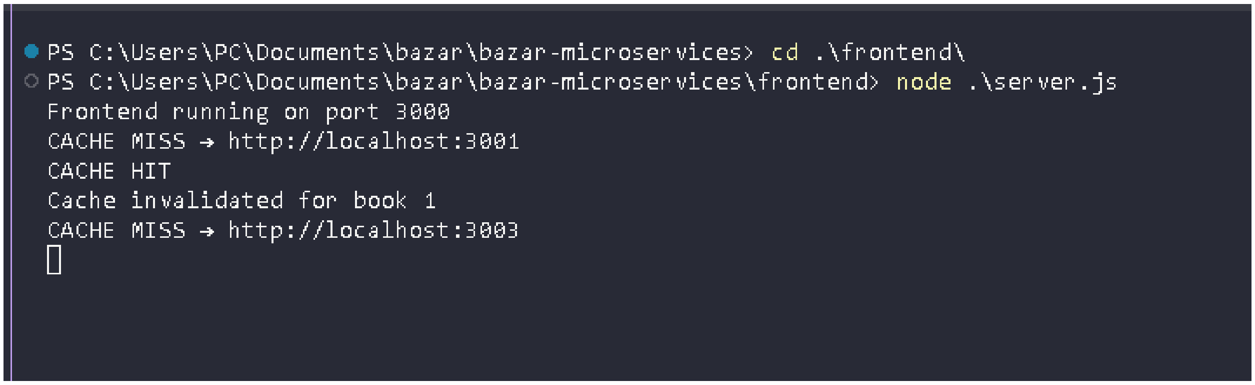
200 OK • 65 ms • 328 B

```
{
    "message": "Bought book: How to get a good grade in DOS in 40 minutes a day",
    "newQuantity": 4
}
```



```
● PS C:\Users\PC\Documents\bazar\bazar-microservices> cd .\frontend\
○ PS C:\Users\PC\Documents\bazar\bazar-microservices\frontend> node .\server.js
  Frontend running on port 3000
  CACHE MISS → http://localhost:3001
  CACHE HIT
  Cache invalidated for book 1
```

- <u>**Fourth request**</u> <u>**GET http://localhost:3000/info/1**</u>



```
● PS C:\Users\PC\Documents\bazar\bazar-microservices> cd .\frontend\
○ PS C:\Users\PC\Documents\bazar\bazar-microservices\frontend> node .\server.js
  Frontend running on port 3000
  CACHE MISS → http://localhost:3001
  CACHE HIT
  Cache invalidated for book 1
  CACHE MISS → http://localhost:3003
```

7. Design Tradeoffs

- **Replication improves availability and scalability**

- **Caching reduces latency but introduces consistency complexity**

- **Strong consistency is achieved at the cost of additional invalidation overhead**

- **SQLite was chosen for simplicity but limits scalability**

8. Possible Improvements

- **Add health checks for replicas**

- **Use adaptive load balancing (e.g., least-loaded)**

- **Dockerize all services**

- **Replace SQLite with a distributed database**

9. How to Run the System

Start Catalog replicas:

- **node server.js**
- **$env:PORT=3003; node server.js**

Start Order replicas:

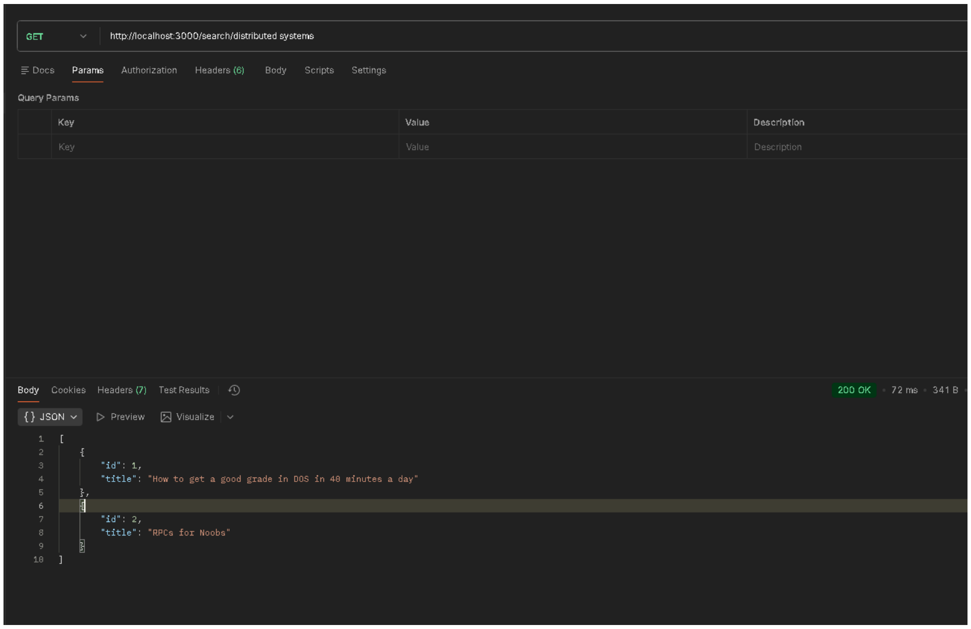
- **node server.js**
- **$env:PORT=3004; node server.js**

Start Frontend server:

- **node server.js**

10.result :

- http://localhost:3000/search/distributed systems

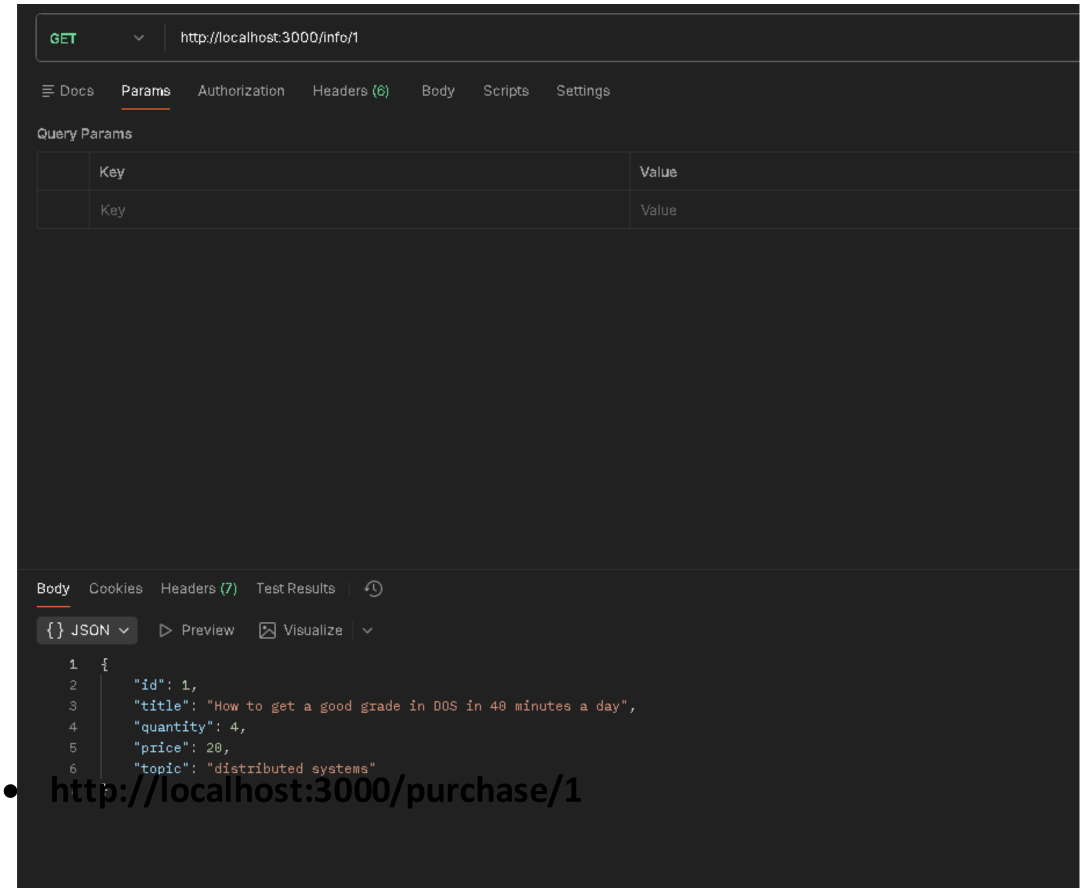


http://localhost:3000/search/distributed systems

200 OK • 72 ms • 341 B

```
[
    {
        "id": 1,
        "title": "How to get a good grade in DOS in 40 minutes a day"
    },
    {
        "id": 2,
        "title": "RPCs for Noobs"
    }
]
```

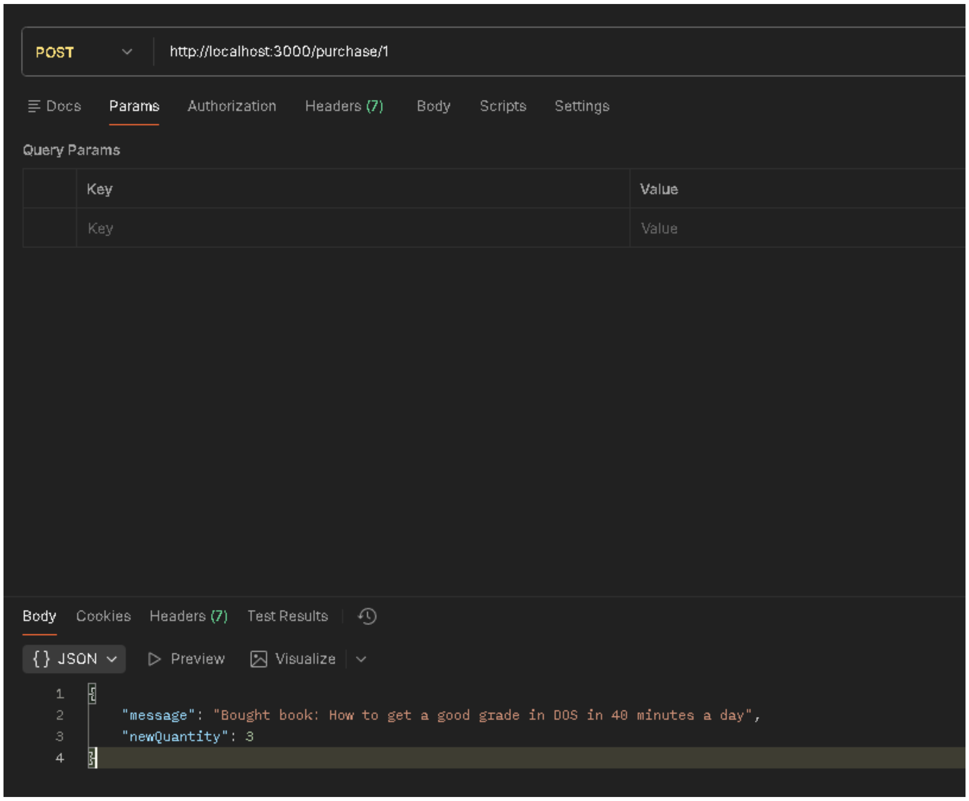
- http://localhost:3000/info/1



http://localhost:3000/info/1

```
{
    "id": 1,
    "title": "How to get a good grade in DOS in 40 minutes a day",
    "quantity": 4,
    "price": 20,
    "topic": "distributed systems"
```

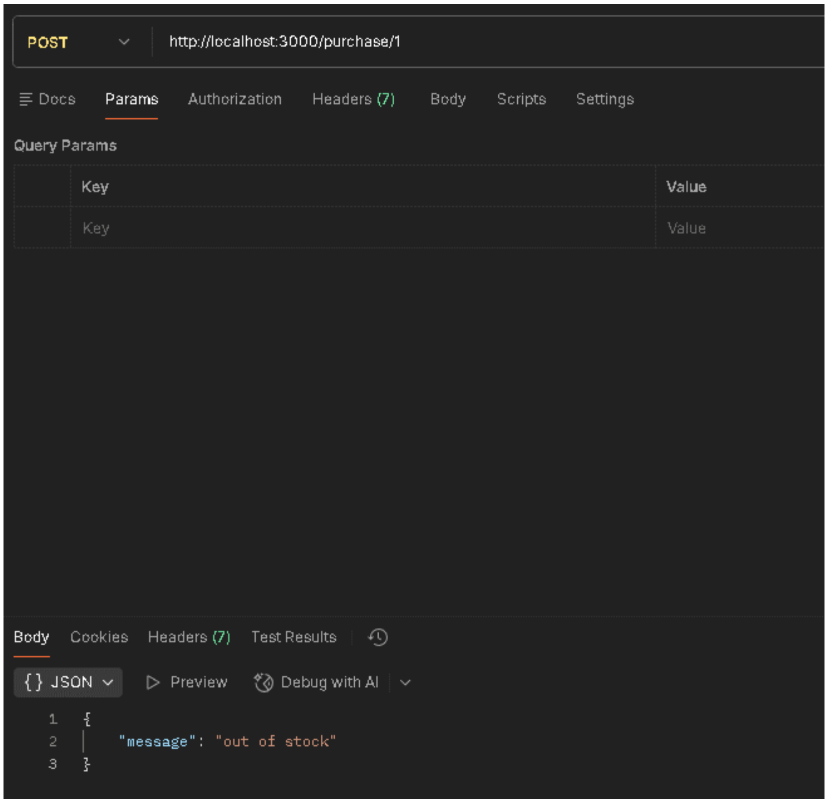
- http://localhost:3000/purchase/1



POST http://localhost:3000/purchase/1

```
{
    "message": "Bought book: How to get a good grade in DOS in 40 minutes a day",
    "newQuantity": 3
}
```

- http://localhost:3000/purchase/1 **when the out of stock**



POST http://localhost:3000/purchase/1

```
{
    "message": "out of stock"
}
```

11. Conclusion

This lab demonstrates how replication, caching, and consistency mechanisms can be combined to build a scalable and efficient distributed system. The experimental results confirm improved performance while maintaining correct system behavior.